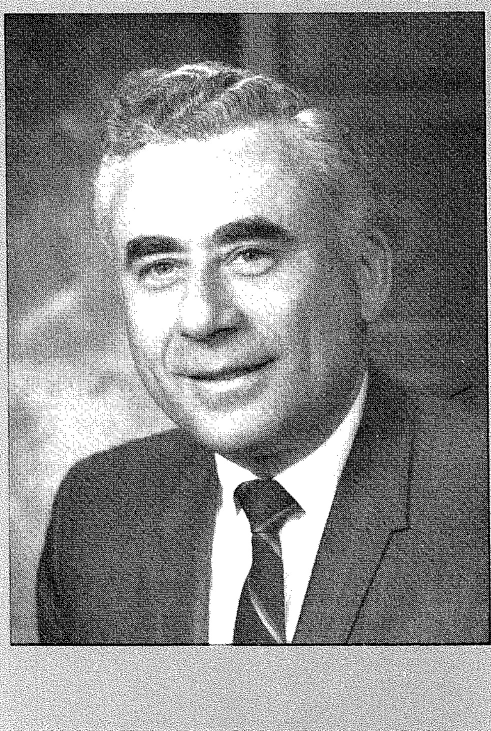
Professionalism

The papers presented in this issue exemplify the wide range of technical activities under way at RCA on the west coast: navigation and communications systems for general aviation; striped-filter color cameras for industrial application; color alphanumeric and graphic displays to support the peripheral requirements of our computer systems; RF signal detection in dense environments required in military applications. In total, these activities attest to the breadth and depth of the professionalism of our RCA engineers.

Inventiveness by itself is not complete professionalism. The additional ingredients necessary are the integration of technology with the real needs and requirements of our customers at a cost he can afford. Technology—the recognition of needs and requirements for products and systems—and cost cannot be separated when measuring total engineering capability. The ability to integrate these elements can be the difference between the amateur and the true professional engineer.

It is satisfying to see this being accomplished by RCA engineers on the west coast as documented by the papers in this issue.



Sidney Sternberg
Division Vice President and
General Manager
Electromagnetic and Aviation
Systems Division
Van Nuys, California

Our cover
. . . graphically symbolizes the broad range of technical activities underway at RCA's West Coast facilities. A relief map of the Western United States provides the background for the artist's sketches that represent the various product lines described in this issue. **Cover concept and design:** Andy Whiting.

Vol 15 | No 6
Apr | May
1970

RCA Engineer

A technical journal published by
RCA Corporate Engineering Services 2-8,
Camden, N.J.

RCA Engineer articles are indexed annually in the April-May Issue and in the "Index to RCA Technical Papers."

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

Contents

editorial input

RCA out west

This is the first issue of the *RCA Engineer* devoted primarily to papers written by engineers at RCA's California locations — Van Nuys, Los Angeles, and Burbank. Readers who have had prior contact with these activities will probably not be surprised by the level of engineering competence displayed in these pages; but, unless that contact was very extensive, they cannot help being impressed by the wide range of products and services covered. To the majority of our readers, however, this issue will be a revelation.

Although a few papers had been published in the *RCA Engineer* during the rapid growth years of the west coast groups, many of these activities were somewhat of a mystery, and in fact, many will remain mysterious because of security restrictions in certain areas. Nevertheless, from the standpoint of opening new channels of communications, we are glad to see that all is no longer quiet on the western front. This blossoming of publication activity, hopefully, will engender yet a higher level of professional commitment on the part of west coast engineers to continue to communicate their ideas. This issue demonstrates three major benefits of publishing: increased professional prestige for the authors, wider exposure for products and services both inside and outside RCA, and increased awareness on the part of management regarding the accomplishments of its engineers.

This burgeoning of publications activity did not happen overnight; nor is the present issue solely a result of editorial prodding and cajoling. Two ingredients—sincere management interest and thorough follow-up by Editorial Representatives—were vital to the success of this effort, first planned over two year ago. Yes, plans that were revised and updated every two months until the present fruition.

But this type of planning is not unique to the present issue. The foundation for each *RCA Engineer* is laid at least two years in advance through meetings between division Editorial Representatives, local engineering management, and the editoral staff. At that embryo stage, we attempt to decide which areas of technology will be appropriate and timely two years hence. Naturally, such early plans provide only a skeletal thematic framework; in subsequent bi-monthly meetings, new topics—from all areas of RCA—are added to support the basic theme; authors and tentative paper titles are included; and the plans are repeatedly updated and revised—to achieve timeliness, topical coverage, and reader interest.

To reiterate, each issue of your journal requires a generous amount of local management support and consistent and thorough follow-up by Editorial Representatives. Issues are now being planned for 1972, but in such long-range planning, there is enough flexibility to cover new papers, new topics, or entirely new issues. If you would like to participate in the planning cycle, contact your Editorial Representative (listed in the inside back cover of each issue); the information and ideas he brings to your magazine depend upon the participation and planning of groups he represents.

Future issues

The next issue, the fifteenth anniversary of the *RCA Engineer,* will contain representative papers from most areas of RCA. Some of the topics to be covered are:

Holographic research and applications

Airborne data automation

Selection of small computers

Design automation

Color TV camera design

Survivability

Undersea testing

Waveguide limiter design

Recording studio equipment design

Discussions of the following themes are planned for future issues:

RCA engineering on the West Coast

Linear integrated circuits

Consumer electronics

RCA engineering in New York

Computers: next generation

Mathematics in engineering

Advanced Technology Laboratories

The Engineer and the Corporation

The changing role of the electronic engineer

R. H. Aires

The computer, the transistor, and the integrated circuit have produced revolutionary changes in engineering. Circuits are no longer designed by specialists, who have all the available component type numbers in their memories. Today, engineers use computer-aided design techniques to combine entire groups of functional circuitry for sophisticated applications. This paper reminisces on some of the design methods of past decades, highlights some of the innovations that have caused those methods to change, and extrapolates today's methods into the future.

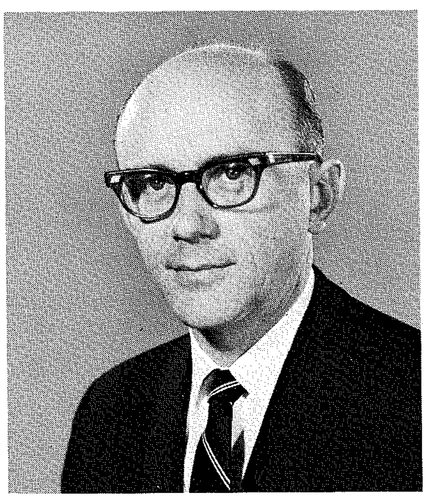
NOT TOO MANY YEARS AGO, an electrical engineer could catalog, in his head, nearly all the available components needed to fulfill most requirements. For example, to design a power-supply circuit, he had the option of using a type 80 or a type 83. The type 83 automatically spelled quality, first because of the exotic blue glow, and second because with a voltage drop of only 15 volts (independent of current) it required a choke input. These tubes required a separate 5-volt rectifier filament winding, and the differences between supplies consisted primarily in the quality of regulation and ripple reduction required. Some engineers with unlimited budgets used two chokes. Those who chose the blue-glow tubes often used a "swinging" choke. I am not sure whether it was a value engineer or the car radio that caused the need for a rectifier with a 6-volt filament and an indirectly heated cathode like the type 84, which eliminated the need for a separate filament winding. Gas rectifiers such as the OZ4 with ionically heated cathodes could be used for more efficient power supplies. Although the OZ4 was part of the vocabulary, it was not widely used except in car radios, perhaps because it required no filament power—a thought that staggered the confidence of all those who knew that a rectifier should really have a filament.

For power output tubes, there were several choices. Initially, troides such as the 45 and 2A3 were the main source of quality audio power. To obtain more efficiency, pentodes such as the 41 and 42 (later to be called 6K6 and 6F6) were used even though they had slightly more distortion. In a short time, the beam power tubes such as the 6V6, 6L6, and 807's dominated. For amplification, there were triodes such as the 6F5 ($\mu=100$) and the 6J5 ($\mu=20$), the 6J7 sharp-cutoff pentode, the 6K7 remote cutoff pentode, the 6L7 dual control grid tube for use as a frequency converter or for dual control applications, and the 6H6 twin diode detector. With characteristics of these devices well-known, any circuit could be designed from audio amplifiers (Fig. 1) to shortwave sets (to 20 MHz).

Of course, I have over-simplified somewhat, since there were already equivalents of these tubes with different pin arrangements. Cost conscious engineers had already found that a radio could be built without a filament transformer by using higher voltage filaments (25Z6 and 25L6 for example). There were even a few tubes with 117V filaments which were ideal for the experimeter and for one-tube phonographs.

Although I have indicated that an individual engineer could design with most of the component information in his head, the tendency was to specialize in audio, IF, RF, or power-supply circuits. This approach continued when the

Reprint RE-15-6-17
Final manuscript received November 7, 1969



R. H. Aires, Chief Engineer
Engineering Department
Electromagnetic and Aviation Systems Division
Van Nuys, California
received the BSEE from Cornell University in 1950, and the MSEE from the University of Pennsylvania in 1959. Under Mr. Aires since 1965, the EASD Engineering Department (with a staff or 425, including 175 engineers) has placed heavy emphasis on the development and utilization of custom integrated circuits and LSI technology in its product lines, stressed acquisition of new young engineers to the staff and undertaken in-house and other technical courses to keep the engineers technically updated. EASD's patent submissions per engineer are among the highest for RCA operating divisions. Company-sponsored programs and technique contracts are carefully selected to complement and augment the quality and innovativeness which characterize EASD's design, development, and production programs. From 1963 to 1965, Mr. Aires was responsible for the formation and management of RCA's Defense Microelectronics activity. As manager of DME, he also served as a primary consultant at the corporate level for planning microelectronic programs for DEP and other RCA activities. He has personally contributed to RCA's accomplishments in the field of high-speed monolithic digital circuits and high-performance monolithic analog circuits, which were developed to fulfill critical performance requirements in a large variety of military electronic equipment. From 1959 to 1963, Mr. Aires was Staff Engineer reporting to the Chief Defense Engineer, responsible for management of the DEP's IR&D program. The scope of work ranged from basic physics through advanced studies of military and space systems. From 1958 to 1959 he was Manager, TIROS Electrical Design—his direct contributions including development of state-of-the-art circuitry to achieve small size and minimum power dissipation with maximum reliability, utilizing solid-state devices. From 1954 to 1958, as Leader and Manager, he supervised the development of antenna control systems and power supplies for airborne fire-control systems. Before joining RCA, Mr. Aires worked for the Philco Corporation where he was engaged in the development of very precise deflection and high voltage circuitry for a single-gun color tube. Several patents were issued for these developments. Mr. Aires is a member of Eta Kappa Nu, a Senior Member of the IEEE, and past Chairman and member of the Executive Committee of the San Fernando Valley Section. He is a Director of the San Fernando Valley Engineers' Council, and was Chairman of Engineer's Week Committee for the San Fernando Valley in 1967.

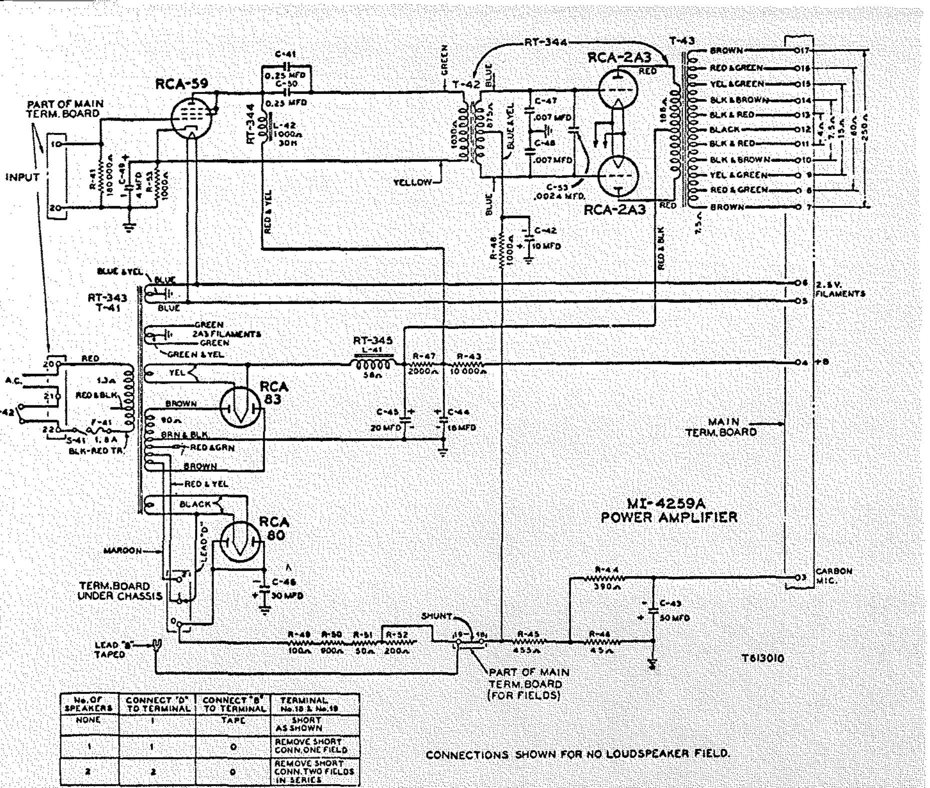


Fig. 1—Power amplifier schematic using RCA80, 83, and 2A3 tubes. The amplifier was part of the RCA Photogphone Theater Sound System of the 1930's.

scope suddenly widened into radar and TV. By the way, tubes improved slightly, but most of the progress was made by making them much smaller and by putting more than one type in single envelope, expanding the number of types until very few engineers could keep the information on all the types in his head.

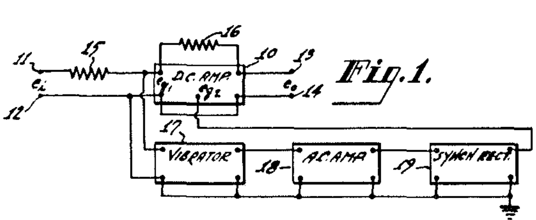
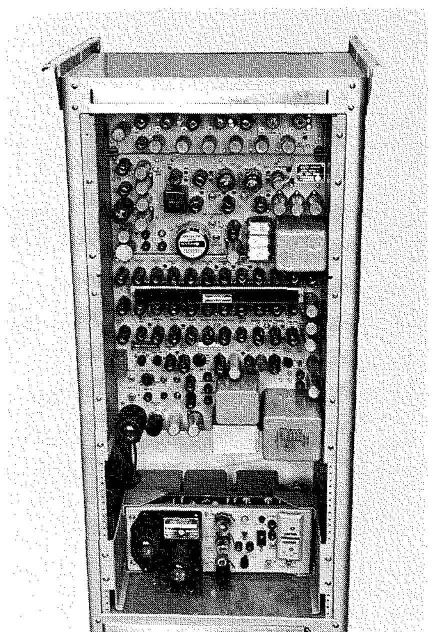
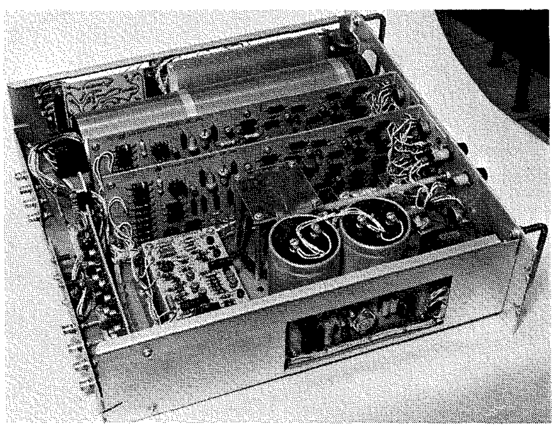


Fig. 2—Block diagram of E. A. Goldberg's patent for stabilized DC amplifier—a big assist for analog computers.





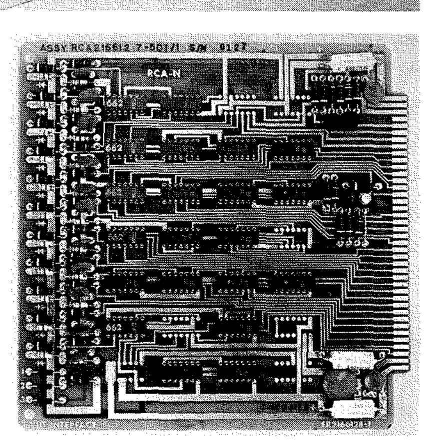


Fig. 3—Comparison of a closed-circuit TV generator using tubes (top left) with the solid-state monoscope circuitry used in the 6050 Video Terminal (top right). Bottom right is one of several integrated-circuit logic boards used in new data terminal for CSD to generate information for alphanumeric displays.

Enter the computer (Fig. 2)

A revolution occurred when the analog computer was invented: the same device could now be used for many purposes. Some engineers began to think of a new level of blocks such as the amplifier, the integrator, and the multiplier. The theory of control systems became important everywhere and EE undergraduate courses began to include servomechanisms. The real explosion came when people began to talk about digits, binary numbers, and digital logic. Large groups of engineers began to build general-purpose digital computers, and other words entered our vocabulary such as software and programming.

Reliability and solid-state devices (Fig. 3)

Just when it appeared that the reliability of existing components would be the major limitation in the size of a system that could work for more than an hour, solid-state devices became a reality. The preceding sentence implies that reliability engineers and solid state engineers were already at work in their specialities developing, among other things, several more languages. New words such as MTBF, beta, emitter, base and collector crept into the language of the electrical engineer. And thousands of transistor type numbers entered the catalogs.

New thoughts on old subjects

Communication engineers had also come up with new theories on how to improve the ability to find the signal in noise utilizing statistics. The tube engineers didn't give up either; they invented magnetrons, TWT's, BWO's, klystrons and other high frequency devices. Although CRT's were important elements during the second world war, many improvements have been made including the addition of color, storage, and multiple guns.

Integrated circuitry—the major revolution (Fig. 4)

During the past decade, the most revolutionary component to appear was the integrated circuit. More new terms came into the language: dual gates, quad fours, flipflops, hex inverters, and many more. A battle for acceptance developed between DTL, T^2L, ECL, RTL and several more types of logic families. Linear circuits had a harder time getting started but OP AMPS of all types appeared and the differential amplifier in almost any form became the answer to any amplification requirement. Within the last few years another race has developed. This time it is related more to silicon processing techniques than to types of circuitry and includes MOS vs. bipolar, P-MOS vs. C-MOS, MOS vs. SOS, and even high-threshold vs. low-threshold P-MOS.

Today's engineer (Figs. 5 and 6)

By this time, I hope I have convinced you that no engineer can keep all of these details in his head. In fact you can't find all the data needed in several books. What is the answer to the question of specialists? In Van Nuys we have a total of 160 engineers, including the leaders and managers. If we had specialists in the way it was done in the 1940's we would not have enough engineers to cover all the specialities required. Does this mean that by definition we have generalists? Perhaps it is possible that the definition of a design engineer is changing. Except for a small percentage of electronic engineering that use component specialists, most design engineers today work with less circuit detail, but cover a much greater number of functions than was possible ten years ago.

I believe we are in a transition period where the engineer will once again be able to keep most of what he needs to know in his head; that is, very fundamental ideas. The computer will keep all the details at his fingertips. The communications expert who previously used pages of calculations to finally arrive at the proper combination of elements for a Tchebysheff filter need only tell the computer what fundamental conditions he would like to meet, and the detailed circuit parameters will come back to him with not only a schematic but a detailed list of parts with breakdowns for purchasing and released drawings for the factory.

The future

Can you visualize that only one or two engineers will design and test a new computer main frame in a few months? I believe we are almost there now. There are automated design programs in existence that contain, in memory, very large portions of logic such as shift registers, adders, coders and decoders which can automatically generate a large amount of logic on a single silicon chip after entering only gross logic diagrams. Other programs exist which can generate the wiring layout to combine these complex elements onto a printed-circuit board. Backplanes or automated wire wrap programs can now be automatically generated to interconnect the printed-circuit boards by additional computer programs (Fig. 7). In a few more years, new programs will create the inputs that are now required to produce integrated circuits, boards, and backplanes. In other words, only a fundamental statement of the kind of computer main frame is to be designed will be necessary. All future subdecisions will be made automatically; best of all, the computer will print-out all the documentation required.

If I am creating the impression that we are going to put ourselves out of a job it is because I haven't continued to stress the amount of engineering that will be required to build the machines and create the programs that are going to do all these wonderful things. I do believe that more engineers will return to thinking in terms of fundamental requirements with less thought given to detailed arrangements. After all, not too many engineers in the '40's worried about how each electron got from the cathode to the plate. Why then should we worry about how a multiplication is accomplished in a computer as long as it happens reliably.

For the division controllers reading this—who by the way have received most of the advantages of the computer so far—get ready to re-program the financial-accounting programs because when all this happens there will be only a few engineers left who can charge DL. All the rest of the operation will be on overhead. Can you imagine the result when one engineer can create enough in one hour to cause an expenditure of $100,000 of automated design and production to occur by pushing a button. The overhead rate will approach infinity unless you reprogram.


Fig. 4—Ruby being cut for custom integrated circuit designed by EASD engineers.

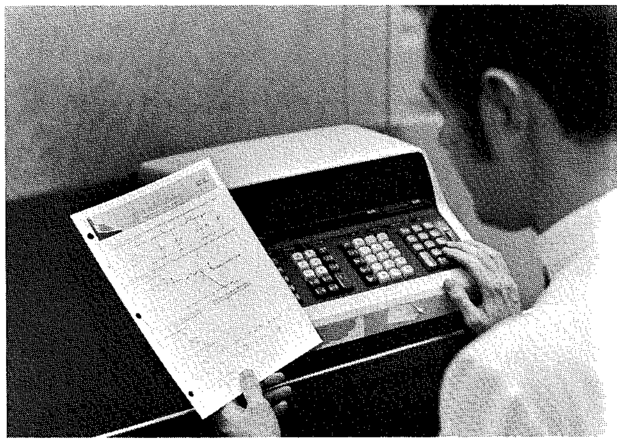


Fig. 5—L. W. Poppen using Hewlett-Packard calculator to design Tchebysheff filter circuit.


Fig. 6—Don Clock using a data terminal for computer-assisted design.

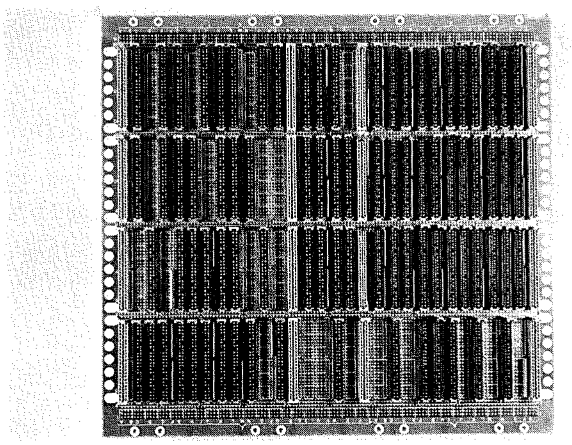


Fig. 7—Backplane that was designed by a computer for the 4101C computer.

College recruiting and RCA

M. C. Kidd

How can RCA provide itself with a continuous thrust of new methods, creativity, and enthusiasm? One way is through college recruiting. In a dynamic, competitive business such as electronics, college recruiting is vital to a company's long range growth and stability. The requisite skill levels and balance of working groups can be maintained only by a continual addition of capable people. Most big companies find it in their best interest to hire as many people directly from the colleges as practical. The recruiting, however, is competitive. At Ohio State, where I recruit, 650 companies compete for the hundred or so electrical engineers in a graduating class. The outstanding graduates get as many offers as they desire, so recruiting must be given sufficient priority to get results.

It goes without saying that everyone wants the top people. When you meet the exceptional individual, you must offer him a real opportunity to win his interest. The challenge is to convince him that he should come to RCA where his interests and abilities can be immediately useful. The recruiter's awareness of the wide range of activity going on in the various organizations and operating divisions can make a big difference. Since we are looking both for specific skills and long range potential, the more diverse the experience of the recruiter, the more he can relate to the interests of the prospective employee and inform him where he would best be able to contribute.

The difference between college recruiting and recruiting for your own group is quite significant. If you are a circuit design leader, it is very tempting to give a little circuit quiz to each man you interview. This, I believe, is inappropriate unless the candidate expresses specific interest or claims special knowledge in circuit design. The students will also get smarter as the day goes on if you ask the same questions.

Many of today's graduates are aware that they must match their academic capabilities with the type of work they will have the opportunity to do. Research demands much more analytical skill than design, development, or manufacturing. The practical and personal skills will be more important in manufacturing operations. While maturity may be substituted somewhat for technical ability, the proper balance will make the difference in one's ultimate success. There are many alternatives for the young graduate in RCA in addition to design engineering. It is important now to describe the total range of opportunity that RCA offers. Since each job is usually so individualized, imagination is needed to create a hypothetical situation that is realistic.

We have two jobs to do when we recruit: evaluate the candidate and convince him that RCA is a good company. I believe that we should try to do both at the same time. Possibly the best way to do this is to help him in any way possible. I have given advice to a number of people which had nothing to do with their future at RCA and their response made me realize that we have a unique opportunity to give guidance because of our understanding of the industry and its requirements. Many professors don't have this background and cannot help the students that frequently need guidance in moving into industry. Also, whether we want to be or not, we are each Mr. RCA and the company benefits or suffers by our image.

I feel that college recruiting is a most challenging and stimulating job, since each individual is completely unique with different abilities, experience, and interests. Because of this, each interview will vary completely with the person interviewed. It would seem that most graduates from a good college can be very useful in RCA if they are in the right job. Fortunately, the engineering rotational program allows those potentially universal engineers to look around and find a home with some selection possible. A great many of the young men that I interview are not the top students and in general are not spectacular when I talk to them. The recruiting decision becomes more difficult with them, since I have seen a number of young engineers who did not impress me at first later turn into outstanding engineers. How do you know in advance that a graduate will follow a job through to completion overcoming all obstacles without giving up? This is a very valuable characteristic and it isn't necessarily related to grades. This kind of man may not try hard to impress you and may only answer your questions without volunteering any information. You cannot afford to miss this type of person, and

Marshall C. Kidd, Administrator
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received the BChE and BEE from Ohio State University in 1944 and 1948 respectively. After experience with the Bakelite Corporation as a Chemical Engineer and employment with the Allen B. Du-Mont Labs where he did circuit work on projection television, he joined the RCA Home Instruments Advanced Development group. His work included development of a loud speaker transient measuring equipment, transistor television and automatic control circuits. Basic patents were obtained on avalanche circuits from work with transistor video amplifiers. In 1958, he transferred to the Electronic Data Processing Advanced Development group, where he helped develop the TRACE system which resulted in the Vee Det detector for vehicle detection. As a leader in the Industrial Computer Systems Department of EDP, he had responsibility for the development of the RCA 110 Computer in which his group received the David Sarnoff Team Award. The computer was later used as the Saturn Checkout Computer by EASD. At ASD, in Burlington, Massachusetts, he performed studies on self-test and application of integrated circuits to Automatic Test Equipment. In the circuit design of the LM ATCA and DECA, his group used the first analog integrated circuits on the Apollo program. The ASD Hybrid Microelectronics facility was set up and operated under his direction in its initial phase. In his current assignment, he is responsible for the ASD IR&D program. Mr. Kidd is the author of a number of technical papers on transistor circuits instrumentation techniques and microelectronics. He holds twelve U.S. Patents, is a Senior Member in the IEEE, and a member of the EIA Microelectronics group.

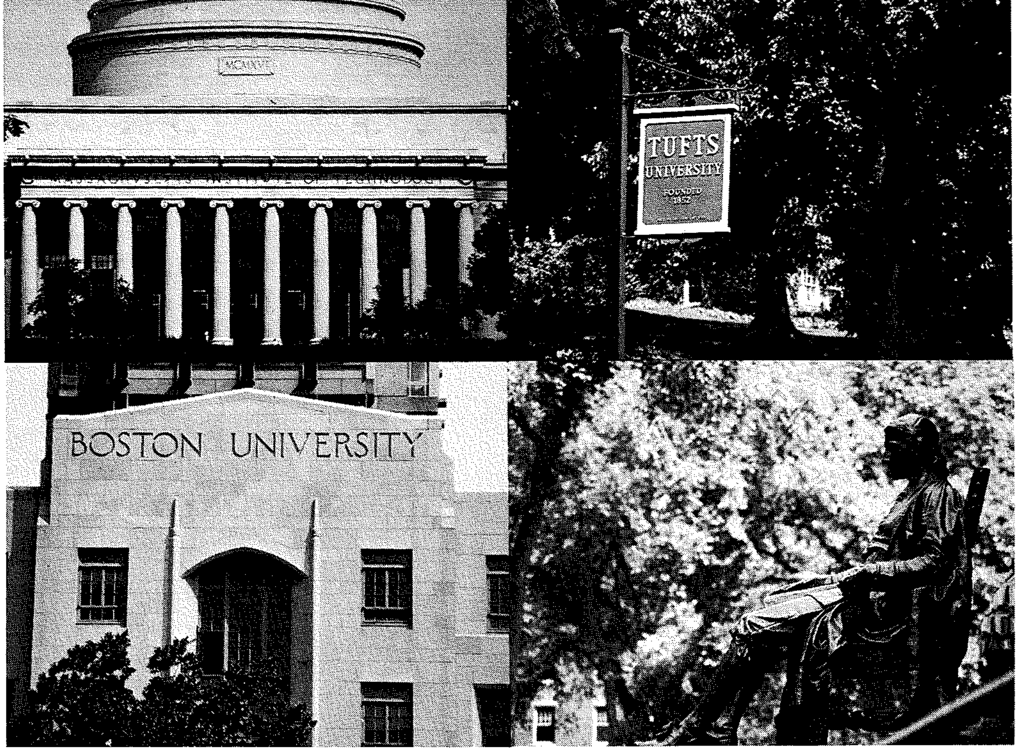
Reprint RE-15-6-24
Final manuscript received May 23, 1969.

every effort should be made to identify him because RCA needs him.

While RCA needs brilliant people for many jobs, one should beware of the brilliant but inflexible person, who impresses everyone he talks to and is so superior to the previous individuals that if you make an elimination because of limited requirements, you may make a serious mistake. This type is limited by his inflexibility. He cannot always adjust to the practical requirements of the job. His perspective is distorted and his demands are frequently unreasonable. He may give the impression of being discriminated against or persecuted in some subtle way. He is usually articulate, but he will often indicate his problem to you if you are alert and perceptive. It is very hard to generalize here, but the presence of negative traits should be observed.

Since the person interviewed is trying to make a good impression on you, or should be, anything observed that is truly negative such as arrogance and bad manners will most likely worsen on the job when his guard is down. People that are really difficult to get along with have to compensate with some special ability to be as productive as the more personable though less talented individuals. Usually, however, it is possible to find extremely capable people that do get along reasonably well with most others on the job. Getting along means being able to take orders and follow through on an assignment with support from others when necessary. I remember a brilliant PhD who would prove after some time on each problem he was given that it was the wrong problem to solve and at least philosophically he would be right. Unfortunately, while being one of the world's great critics, he was not very creative in producing useful ideas and concepts. Because of his intelligence, he was quite a challenge to his management and to each of the companies that he had worked for before he joined RCA. Fortunately, the brilliant person usually lines up his objectives with those of the company and this becomes a major factor in his success.

I often think that if young Tom Edison or Henry Ford were to ask for an interview and somehow got on the schedule, they wouldn't make the grade. Our requirements tend to be rigid. If a student is not in at least the upper half of his class, we don't want to take a chance on him for most assignments. This, I believe, is unfortunate but it is not easy to do anything about. Thirty minutes is not much time to determine such important things as drive, ambition, creativity, stability, integrity, and most important of all, will he be really productive on the job. Past performance is still the best way to predict the future. Grades are important but so is the amount of work done to offset expenses during college and the maturity developed from each job, both technically and personally. Students who have worked on any difficult job are ahead of those that will have to learn how to handle their first challenges at RCA. The co-op student is easily a year ahead of the typical non co-op student when he starts. One of my friends who had seen many trainees go through his department frequently referred to "late bloomers." It may take a year or two and even longer for some engineers to become sufficiently self-motivated to be able to apply their intelligence and creativity to the problems at hand and make contributions beyond those of merely following direction. It would be quite an achievement to predict this characteristic in the initial interview.



The engineering graduate is technically well trained today, particularly compared to 20 years ago. He has invariably worked with computers to solve his problems and most often will have a knowledge of solid-state physics that will make microelectronics more easily understood. He is more sophisticated and knowledgeable about industry since we have been living in a highly technological society for some time now. He may still not know what he wants to do and this should not be held against him because once he gets on the job he probably won't work on exactly what he likes best.

College recruiting is critical to our future. It requires a high degree of perception and intuition combined with experience. If you are asked to recruit, the fact that it is difficult for you to get away makes you more valuable as a recruiter. If you are technically involved in a current program, you will be able to relate more closely to the technical graduate. It is important that the barriers be broken between school and industry in the most effective way. This can be helped by having graduates return to their alma maters on a regular basis so that continuity can be maintained. Your best recruiting help can come from a friendly professor or placement officer. Sufficient time should be planned for you to talk with them and understand what they consider important for their graduates. Feedback is important as well since bad experiences of graduates in any step of the recruiting process must be corrected wherever possible. The pipelines between students rivals RCA's most sophisticated communication systems. In recruiting, as in anything else that RCA does, the results are directly related to our skill and effort.

Electromagnetic and Aviation Systems Division—a profile

R. J. Ellis

One of RCA's major Divisions, Electromagnetic and Aviation Systems is a primary supplier of electronic warfare equipment, intelligence data systems, intrusion—ordance systems, and aviation equipment. Applying modern engineering methods (e.g., computer-aided design and microminiaturization) EASD has established a solid reputation for technical excellence, cost consciousness, and schedule performance with its commercial and military customers. This Division profile looks briefly into EASD's background, describes the product lines, and provides an insight into the engineering organization that supports these product lines. It serves as a brief introduction to the other papers in this issue, which deal with some of EASD's products and services in more detail. For a closer look at the underlying engineering philosophy, the reader should refer to the paper by R. H. Aires in thjs issue.

IN THE FALL OF 1950, the Los Angeles Plant of the RCA Victor Division received a contract from the United States Navy to develop an Airborne Weather Radar, the AN/APS-42. This was the modest beginning of what was later to become the Electromagnetic and Aviation Systems Division, which comprises plants in Van Nuys, California (Fig. 1), West Los Angeles (Fig. 2), and in Huntsville, Alabama (Fig. 3). Sidney Sternberg, Division Vice President and General Manager, has his headquarters in Van Nuys. An integral part of this operation is the Aviation Equipment Department in West Los Angeles with Joseph R. Shirley as Division Vice President.

From 1950 to 1958 the fledgling Los Angeles Plant expanded its technological manufacturing base from the APS-42 Airborne Weather Radar to AN/APN-70 Airborne LORAN, to AN/AIC-10 Aircraft Intercommunications Equipment, and to Electronic Countermeasures Systems. In 1957 and 1958 two events resulted in the establishment of a full-fledged DEP division in Van Nuys.

In 1958, Missile and Surface Radar Division in Moorestown, N.J. was fully loaded with the BMEWS program and a new major contract for the Atlas Checkout Equipment. Since most of the early Atlas engineering development and integration work was to be done at the Vandenberg Air Force Base, California, space would be needed to accommodate engineers from M&SR. Concurrently, a company survey indicated the advisability of forming a DEP Division on the West Coast; the decision was made to build a new plant at 8500 Balboa Blvd., Van Nuys, California.

The Atlas design engineers from Moorestown moved temporarily into the Los Angeles plant while the new Van Nuys facility was being built. In September 1959 the Van Nuys plant was opened for business, under the name of West Coast Missile and Surface Radar.

The Division's employment mushroomed during the early years of its existence as the Atlas program went into production. The technological base expanded into computers, displays, and electronic warfare equipment. As the Atlas program began to phase out, the Division was successful in capturing another large contract for computerized checkout for the Saturn Launch Vehicle used in the Apollo program. Additional technical competence in displays and mass-memories was developed and several electronic warfare production contracts were won and fulfilled. A new facility was constructed in Huntsville, Alabama, to house the Saturn field engineering and logistics work.

In the latter half of the 1960's the division entered the ordnance field, manufacturing various fuzes and arming devices for the Vietnam war effort. Airlines message switching systems were also successfully delivered. Mass memories and drums were developed and manufactured for the RCA commercial market. Early in 1968, a major contract was received from the Navy for a transportable electronic warfare system, the AN/SLQ-19 Countermeasure set (Fig. 4). This was a QRC (quick-reaction contract) program with the first system to be delivered in only 13 weeks. The Division received a commendation from the Navy for schedule performance on this contract.

More recently, new products such as intrusion-sensors are being developed. Military aviation products, such as airborne integrated data systems, and several types of military drum memories are now in development and production. The Aviation Equipment Department's technology and manufacturing base has further expanded in the general aviation and the airline markets into the advanced weather radars, transponders, distance measuring equipment, and communication and navigation equipment.

The products

The equipment and systems which EASD currently designs, manufac-

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received his education as a business administration major at Columbia University and as an English major at Syracuse University. He studied electronics through the Capital Radio Engineering Institute. He is presently studying law for a LLB. Mr. Ellis has had more than twenty years experience in all areas of integrated logistic support. Those areas include technical publications, provisioning, training, field support, data management, documentation control, and reproduction, and supply support. His present responsibilities include preparation and production of technical publications, proposals, brochures, presentations, reports, and all similar documentation. He also is responsible for all reproduction services including microfilm, drawing vault files, and drawing distribution. Mr. Ellis is Deputy Chairman of the Technical Publications Section of the American Ordnance Association.

Reprint RE-15-6-18
Final manuscript received January 14, 1970.

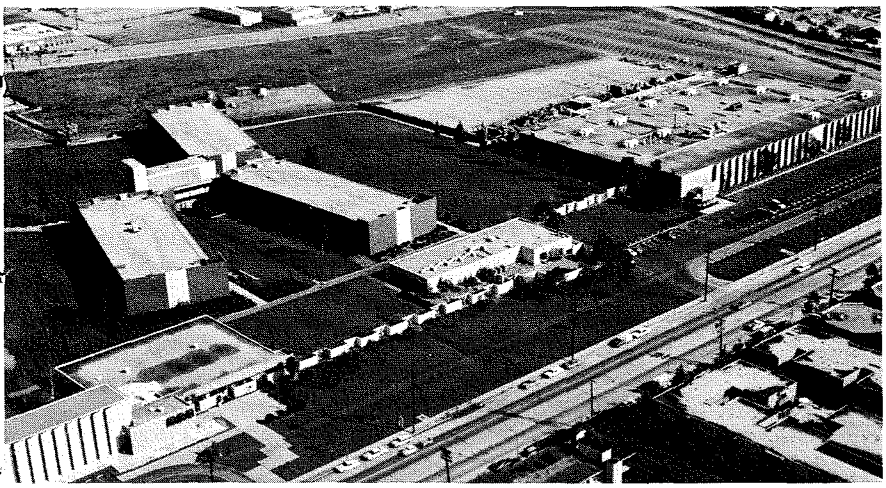


Fig. 1—Aerial view of the EASD Van Nuys facility at 8500 Balboa Blvd.

Fig. 2—Aviation Equipment Department, West Los Angeles.

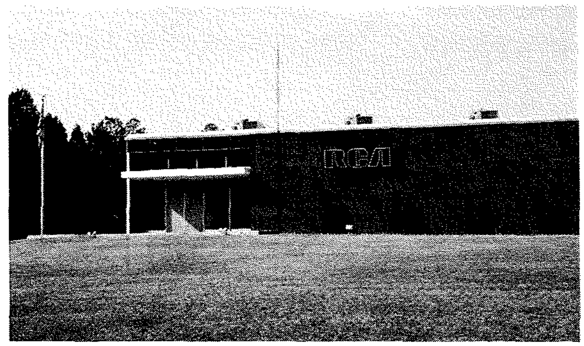


Fig. 3—EASD, Huntsville, Alabama.

Fig. 4—Mr. Sternberg (at left) briefing Mr. Sarnoff and Mr. Watts on the AN/SLQ-19 Countermeasures Set. Program Manager Jackson is at the right.

tures, and markets are divided into five major product lines:

1) Electronic warfare systems,
2) Intelligence data systems,
3) Military aviation products,
4) Intrusion—ordnance systems, and
5) Aviation equipment.

Electronic warfare systems

The major strength of the Division in recent years has been electronic warfare (EW); Fig. 5 illustrates, in summary form, the nature of the equipment and technology that supports the EW product line. The function of most of EASD's electronic warfare equipment is to detect and locate the threat, and then immediately to analyze, display, and record vital information for the command and control decision. EASD has been a major EW supplier to the Navy with primary emphasis upon electronic countermeasures to confuse and/or deceive the threat. Typical EASD electronic warfare equipments for the Navy are: deception repeaters, jammers, traveling-wave-tube oscillators, high-power amplifiers, and automatic control equipment. Complete threat reactive systems were delivered to the Navy on a quick-reaction basis in the form of the SLQ-19 Countermeasure System. A new multiple-target electronic warfare system for installations, such as tanks or jeeps, is under development now for the Army (Fig. 5). Airborne decoys for ship protection are also being developed under contracts to the military. EASD has also designed and proposed the ship electronic warfare system for the new DD963 destroyers soon to be built.

Intelligence data systems

The intelligence data systems (IDS) product line is directed toward the man-machine relationship in the computer and peripheral equipment field. EASD has been a prime supplier of computer peripherals to the Computer Systems Division. Recent efforts have been to expand this capability to serve the military. Major equipments are alphanumeric displays; random-access mass memories (Fig. 6); drum memories (Fig. 7); and central processors. Several complete computer systems have been developed including a switching system for airline use and a communications and checkout system for the Saturn launch vehicles. Under a present system contract, EASD is developing operational support equipment for the Mariner Mars '71 program (Fig. 8). In the last two years, EASD has brought into development and production a new drum memory system. Drum memories are under contract for the Army (Tacfire) and the Navy (NADC). The largest single program potential is in the S-3A ASW aircraft now under contract to Sanders Corp. Airborne displays have been delivered to the Air Force and are being evaluated.

Military aviation products and systems

Military aviation products and systems (MAPS) is a relatively new product line at EASD. The knowledge, experience, and products of the Aviation Equipment Department, added to the EASD capability for systems design and integration, provide the basis for combining transportation/housekeeping avionic equipment into integrated avionics systems. To date, distance measuring equipment has been delivered to the Army, and signal adapters that are part of an airborne

Fig. 5—Multiple-target electronic warfare system.

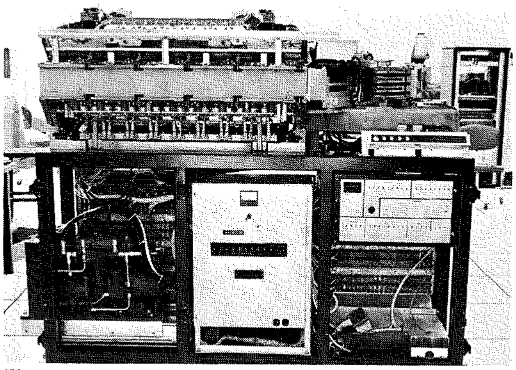


Fig. 6—70/568 random-access mass memory.

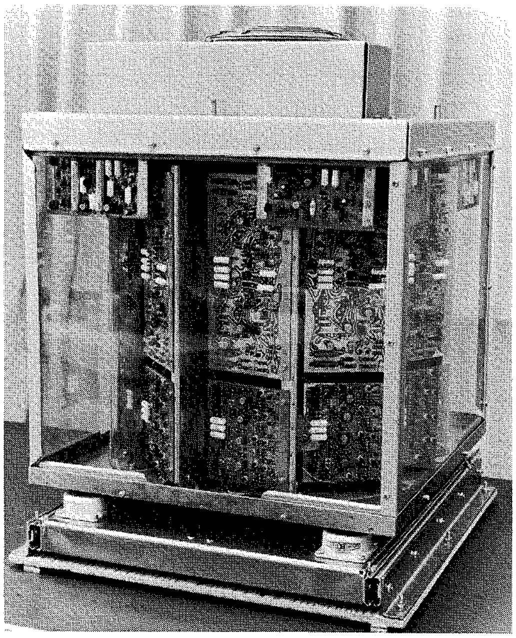


Fig. 7—Spectra 70/567 drum memory.

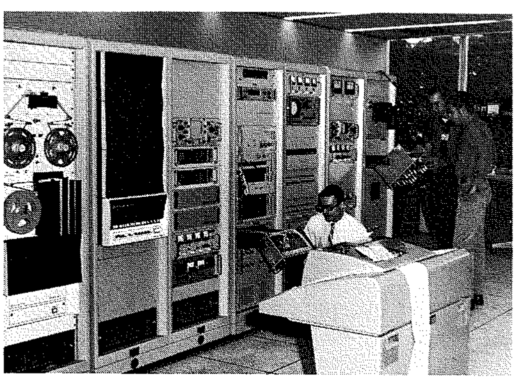


Fig. 8—Mariner Mars '71 equipment checkout laboratory.

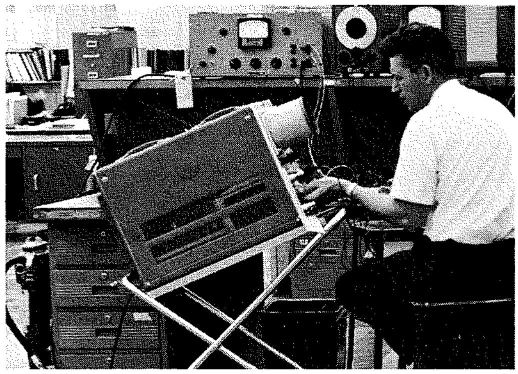


Fig. 10—S. Franklin verifying a design in the fuze laboratory.


Fig. 11—Hybrid microelectronics laboratory.

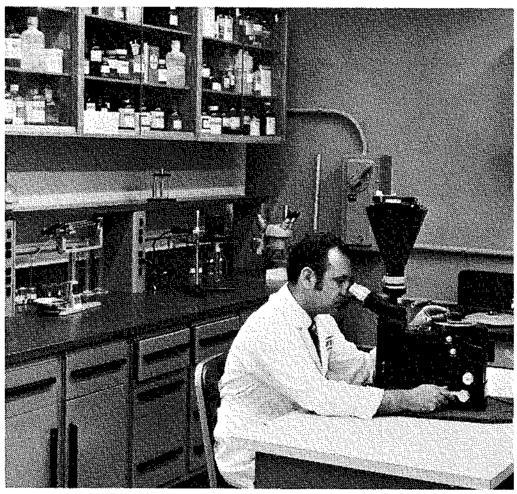


Fig. 12—Hal Rocheleau in the chemical and metallurgical laboratory.

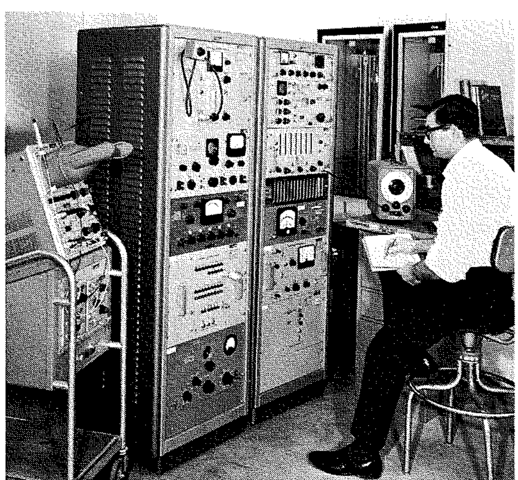


Fig. 13—Test equipment laboratory.

integrated data system are being developed for the Army.

Intrusion—ordnance systems

Intrusion—ordnance systems are divided into three significant products: 1) intrusion-sensing devices; 2) intrusion systems; and 3) fuze devices for height-of-burst control of bombs, missiles, rockets, and motar and artillery shells.

Intrusion-sensing devices have become more important lately because of the evasive "hit-and-run" tactics of the Vietcong and North Vietnamese. Past intrusion sensors used an electronic beam cutting across roadways and paths; however, this was easily discernable. Modern intrusion sensing devices are primarily seismic accelerometers that sense ground waves due to earth vibrations. They detect the movement of personnel or vehicles and transmit the warning signals to a diagnostic receiving station. EASD is one of the top companies in the development of intrusion devices. Currently under development are both seismic and microphonic intrusion devices for the Army.

The development of intrusion systems has been greatly emphasized by the requirements of Vietnam operations. Various designs and applications of intrusion systems are currently being investigated by EASD.

RCA's experience in producing fuzes dates back to World War II. With the escalation of the Vietnam conflict, the demand for fuze devices increased. and EASD was designated as the division to pursue this development and production. Motar fuzes have been delivered to the army in large quantities. EASD also has been successful in high-volume production of fuzes for air-to-ground rockets for the Navy.

Aviation equipment

Aviation equipment for commercial and general aviation is the responsibility of the Aviation Equipment Department. These equipments include distance measuring equipment, weather radars, transponders, navigation/communication receivers and transmitters, and airborne integrated data systems. Most of these equipments are described in some detail in several related papers in this issue.

RCA is a leader in the commercial aircraft equipment market—domestic and international. For example, RCA weather radar is used on fifty percent of the world's commercial airlines and in over sixty percent of the general aviation applications.

Engineering organization

Fig. 9 shows the engineering organization; Table I shows the functional design activities of the various groups, arranged according to product line and technical competence.

Table I—Technical contributions of the design engineering groups.

EW systems and technology
- *Systems and equipment*
  - Equipment development
  - Power conversion systems
  - Systems integration
  - Mechanical development
- *Systems and techniques*
  - Intercept techniques
  - ECM techniques

MAPS and ordnance systems engineering
- *Ordnance systems*
  - Ordnance equipment
  - Ordnance development
- *MAPS systems*
  - MAPS development
  - MAPS mechanical engineering

Advanced EW systems

Displays and peripheral systems engineering
- *Displays and peripheral systems design*
  - Commercial peripheral products
  - System programming
  - Commercial display products
  - Military system design
- *Displays and peripheral systems programs*
  - NASA programs

Mass memories and computer systems engineering
- *Computer systems engineering*
  - Programming
  - Automation systems
  - Command & control systems
  - Military product design
- *S-3A Program and advanced peripheral technology*
  - Advanced mechanical development
  - Subsystem development
  - Advanced mass memory development
  - S-3A coordination
  - Advanced peripheral techniques

Staff engineers

The Engineering Activity at EASD's Aviation Equipment Department operates as a separate entity that reports to the Division Vice President of Aviation Equipment Department.

Modern engineering requires many tools to achieve reliable and maintainable products. Such tools include computer-aided design, coordinatographs, scientific calculators, and modern laboratories. Figs. 10 through 13 show some of the laboratories and other equipment used at EASD as tools for the engineers.

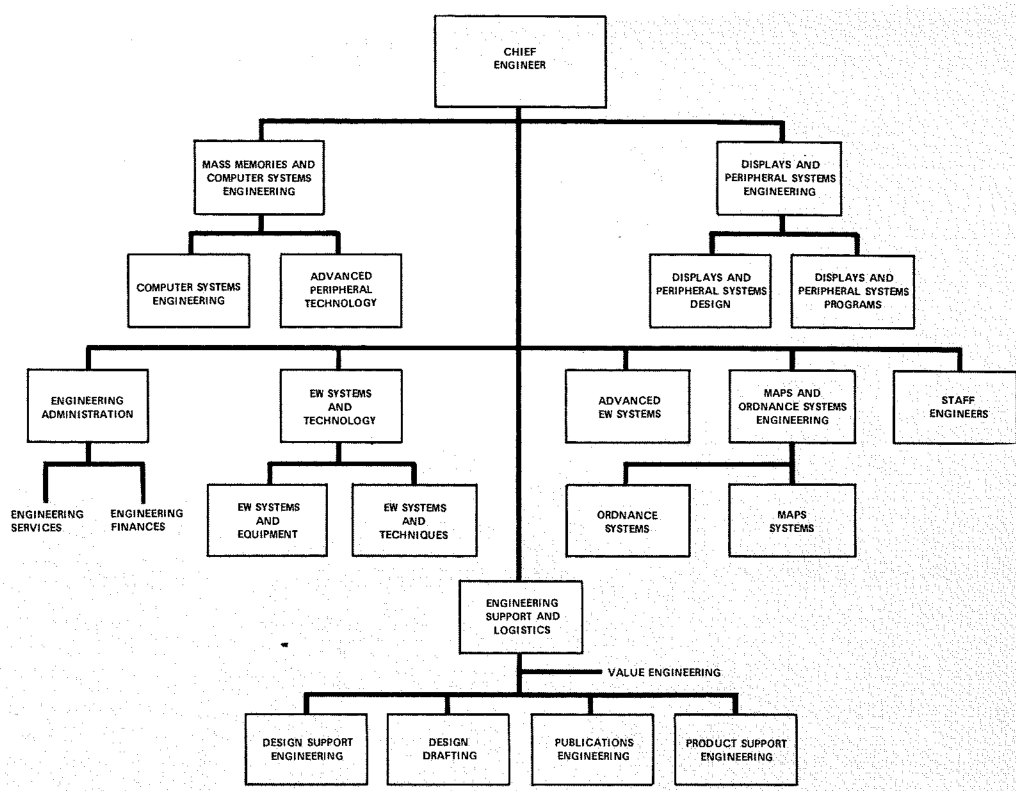


Fig. 9—Engineering organization.

Research and development

Engineering is currently investigating techniques and advanced hardware for each of EASD's product lines.

Research in electronic warfare includes:

1) Lightweight, low-volume, high-efficiency traveling-wave-tube supplies;
2) Advanced threat detection, identification, and processing;
3) Detecting low-level signals of unknown characteristics embedded in a noise environment; and
4) Reduced-size frequency memory.

Advanced hardware development for EW includes:

1) A solid-state modulator for high-power traveling-wave-tube amplifiers;
2) Electronically alterable digital PRP filter/trackers utilizing content-addressable memories; and
3) An amplitude comparison direction-finding system.

Present research in intelligence data systems includes:

1) The development of data-base management and inter-operator communication systems; and
2) Display keyboards.

Advanced hardware development for the IDS product line includes:

1) Advanced graphic display terminals;
2) Improved existing recording technology on drum and disks systems; and
3) A stand-alone, TV-oriented, alphanumeric display using cost-effective LSI logic exclusively.

Military Aviation Products and Systems are currently engaged in the definition and design of VLF navigation receiver front ends and digital phase comparators for a navigation receiver. Another program is devoted to the definition and specification of LSI processing for aircraft communication and navigation functions associated with flight management processors.

Investigations in Ordnance include:

1) Improved packaging and heat transfer techniques to survive gun environments;
2) Increased detection and sensitivity of seismic sensors; and
3) Minimized seismic sensor power requirements.

A satellite of DEP Advanced Technology Laboratories was opened at EASD in January 1970. This joint venture will perform research that is vital to EASD's growth plans.

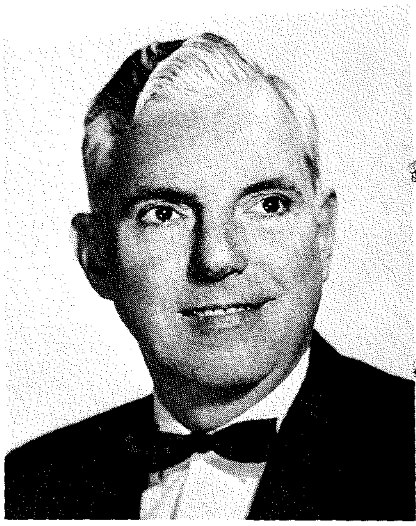
The Future

Much of the present engineering work at EASD foreshadows several future trends. EASD Engineers will rely more on automation through computer-aided design with greater emphasis on microminiaturization to improve reliability, reduce weight and size, and ease maintainability problems. As always, the accent will be on the development of system concepts and hardware in each product line.

VHF communication and navigation systems for general aviation

R. P. Crow

Already the major world supplier of airborne weather radar, RCA now produces the most commonly used types of avionic equipment, as well as air-traffic-control transponders and distance-measuring equipment both for airlines and general aviation. Leading the way in avionics integration, RCA has applied integrated circuit technology, advanced component miniaturization, and new materials to the integration of aircraft avionics systems.



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received the BSEE from Purdue University in 1943. He was an Air Force fighter pilot during World War II, and was in the active reserves for several years thereafter. Mr. Crow has more than 20 years of experience in the navigation/communications field. His background includes 12 years at Motorola, where he headed the first group responsible for solid-state equipment design work and was involved in the development of several new product lines in the communications and industrial control fields. Later he was Chief Engineer of the Motorola Aviation Electronics facility in California. He has been associated with RCA since 1961. He is currently responsible for the design of navigation and communications equipment. Mr. Crow has 16 patents to his credit.

THE BASIC UNITS IN RCA's new navigation and communication equipment line are shown in Fig. 1. They are

1) The AVN-210 Integrated VHF Navigation System,
2) The AVC-110 VHF Communications Transceiver,
3) The AVI-201 RMI/Converter, and
4) The AVA-310 Audio System.

Those familiar with avionic equipment can see that this new line represents a high degree of avionic systems integration and that there are many advantages. Originally designed for the general-aviation market, all units have received Federal Aviation Agency TSO requirements for commercial aviation. A TSO (Technical Standard Order) is generally equivalent to a government specification for commercial aviation equipment.

AVN-210 navigation system

The AVN-210—described in detail by Masse in this issue—combines all the indicators, controls, and circuits necessary for complete VOR/localizer, glideslope, and marker-beacon functions. It also serves as the control head for a remote distance-measuring equipment, including the self-test function. The AVN-210 is the basic model of a series including the AVN-211, AVN-212, AVN-214, and AVN-215. The latter models, while similar in appearance to the AVN-210, lack one or more of the basic capabilities of the AVN-210.

AVC-110 transceiver

The AVC-110—described in detail by Volmerange in this issue—includes the normal functions of control head, transmitter, and receiver of a 360-channel airborne communications system operating in the 118- to 136-MHz band. All frequencies for both the transmitter and the receiver are derived from a divide-by-N digital frequency synthesizer. The 20-watt transmitter includes protective circuits which reduce the transmitter supply voltage under adverse temperature or antenna-VSWR conditions.

AVI-200 series RMI/converters

The AVI-200 RMI (radio magnetic indicator)/converter is a companion to the AVN-210 navigation system; in fact, the AVN-210 output drives the AVI-200 automatic VOR converter. As with the AVN-210 and AVC-110, the AVI-200 is also packaged in a 3-in. ATI (Air Transport Indicator) case. It extends 8½ in. behind the instrument panel.

The RMI series provides all traditional RMI functions; namely, the slaved gyro compass card and dual needles for indicating automatic VOR or ADF (automatic direction finder) compass bearings with respect to aircraft heading. At least one automatic VOR converter (two for the AVI-202 model) is included in the unit. Input switching enables various combinations of ADF and VOR readouts to be obtained. In addition, the AVI-201 provides selected heading information to the automatic pilot.

AVA-310 audio system

The AVA-310 audio system is used in conjunction with all of the aircraft navigation and communication equipment. It provides the means for switching the various communications or navigation equipment audio outputs either to earphone or loudspeaker channels. Separate amplifiers are used for these two audio channels. The amplifiers include compressing circuitry which tends to equalize the amplifier output over wide-ranging input levels. Filtering enables selection of voice or identification Morse code tones. Auxiliary inputs and outputs, along with electronic switching, provide the versatility of passenger entertainment, intercommunication, announcements, etc.

Advantages of system integration

The RCA approach has been to pro vide high performance and quality in instrument-panel-mounted avionics Although a number of panel-mounted equipments have been available fo years, they have all been in th low-cost category intended for non instrument-flying single-engine ai

Reprint RE-15-6-1
Final manuscript received October 28, 1969.

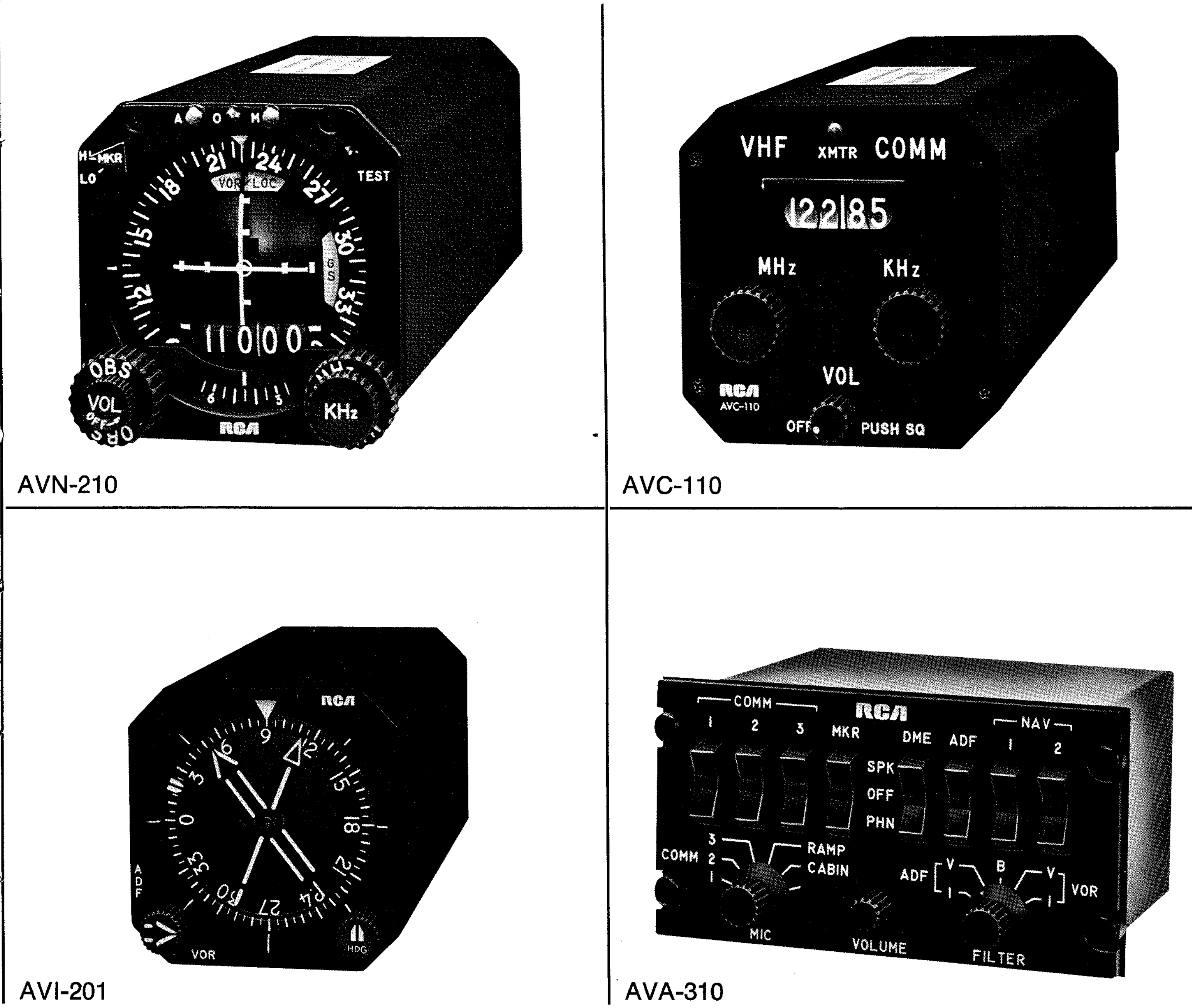


Fig. 1—The navigation and communication line of equipment produced by the Aviation Equipment Department of EASD.

craft. Even the equipment that is most competitive with RCA's new line is all remotely mounted and controlled, and only the indicators and/or control heads are panel-mounted. For example, Fig. 2 shows a group of modern remotely mounted equipments along with their associated control heads and indicators. The equipment equivalently performs functions identical to those of RCA's single-package AVN-210 navigation system. The advantages of integrating the several avionics functions in a single package are as follows:

1) Considerable weight reduction; aside from the weight saving of miniaturization, a savings in weight of two or more remote packages and associated aircraft wiring is substantial. In the case of the navigation system, the weight saving in an AVN-210 installation is typically 20 to 25 pounds.

2) Reduction of cockpit workload; integration eliminates potential pilot confusion resulting from multiple control heads and separate indicators.

3) Substantial space savings; elimination of separate control heads and indicators relieves instrument-panel congestion and conserves room in the aircraft.

4) Notable improvement in system reliability. Studies and field reports show that system reliability improves with: a) a reduction in the number of system components, brought about by circuit integration and elimination both of remote control circuitry and of multiple components, such as power supplies; b) a considerable reduction in wiring and interconnections; c) lower operating temperatures as a result of the low power demands of some miniaturized circuit forms; d) the use of monolithic integrated circuits which, on a circuit function-per-function basis, are more reliable than discrete components; and e) an idealized environment, such as the cockpit.

5) Reduction of system costs; although many miniature components are relatively expensive, initial equipment costs

are lower because most redundant components are eliminated and packaging costs are reduced.

6) Low current drain; a safety factor derives from the possibility that power for the equipment could be supplied from an emergency battery in the event of an aircraft power failure.

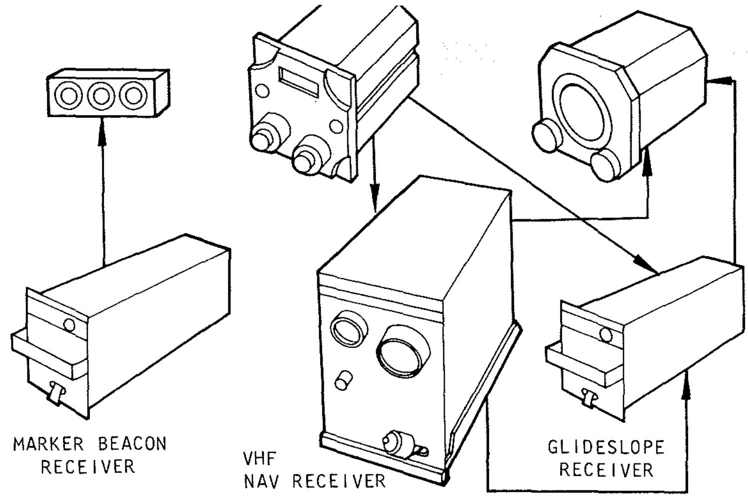


Fig. 2—Typical navigation system with traditional remotely-mounted black boxes before the introduction of the AVN-210.

General design aspects

The availability of competitively priced monolithic integrated circuits has been a major factor in the design of RCA's integrated avionics. Numerous single-function integrated circuits are used, and in the frequency synthesizer of the AVC-110 transceiver medium-scale integration techniques were applied. Use of small, stable ceramic capacitors has greatly improved circuit function densities. Although multilayer printed-circuit boards offer packaging advantages, consideration of cost and reliability dictates the use of double-sided printed-circuit boards with plated-through holes. An eyelet-type of device called a griplet is used in most holes to attain the added reliability of redundant connections from one side of the printed-circuit board to the other. Redundant paths on both sides of the boards serve the same purpose. With these approaches, intermittent connections are virtually nonexistent.

Maintenance costs throughout the life of avionic equipment has historically been more than twice the original equipment cost. Notwithstanding reliability improvement, serviceability is an important design factor. In the integrated navigation and communication equipments, the majority of the components are located on printed-circuit boards. In a typical case, the boards are mounted along the surfaces of the unit so that all of the board components are readily accessible for test or replacement.

In general, each printed-circuit board consists of a complete sub-system. For example, the marker-beacon receiver of the AVN-210 is a complete subsystem entirely mounted on a single board. Isolating a subsystem to a single board minimizes the number of external leads and makes subsystem testing less complex.

Since each unit operates directly from 14- or 28-volt aircraft power supplies, without wiring changes, there is no need for several models to fit all aircraft types. Performance is essentially constant from approximately 11.5 to 32 VDC. Each unit contains some form of DC regulator set typically to 9.5 volts. Where a low average current drain is required, such as the 300 mA drawn by the AVN-210, a series-type regulator is used. The communications transmitter, however, requires approximately 13 VDC for full output; also currents in the order of 5 amperes are drawn. Hence a series DC regulator would be inefficient and would produce a serious dissipation problem. Thus, in this particular instance, a switching-type regulator is used.

Power supply design is of particular importance, especially where a single supply is used by two or more subsystems, as in the case of the AVN-210. Careful attention must be paid to circuit design, component ratings, and quality to achieve an adequate MTBF for the system. Subsystems must be isolated with respect to the power supply so that one cannot adversely affect another.

With increasing avionic complexity, the pilot must have an effective means of monitoring the equipment operation. The AVN-210 contains a simple, but effective, self-test for each function. The AVC-110 enables the pilot to monitor both receiver and transmitter operations and to observe whether transmitter protective circuits have decreased communications range under adverse conditions.

Emergency provisions in the AVA-310 audio system enhance system reliability for all navigation-and-communication audio aboard the aircraft. Interconnections allow earphone operation for the units in the event of a total electronic failure; that is, failure of both amplifiers and/or the power supply.

Digital circuits, with recent advances in components, offer size advantages in areas that heretofore have strictly followed analog approaches. Traditionally, VOR converters handling 30-Hz signals have usually contained bulky components, but the AVN-210 VOR converter is considerably smaller thanks to active filters and digital circuit techniques.

With the exception of the audio system, each unit is mounted in the aircraft instrument panel by means of a standard instrument clamp. It enables one man, unaided, to remove the unit from either the front or rear of the panel merely by loosening two front panel screws.

Main connectors in each unit are of the PT type, but size and keying differences prevent misconnecting them. Antenna connectors are keyed in the same manner for the same reason.

Market potential

RCA's new aviation nav/com line is the start of a trend based on a solid technical foundation. Quality and performance heretofore found only in remotely mounted equipments are now available in panel-mounted equipment with the attendant advantages of smaller size, lighter weight, and lower equipment and installation costs. Together with operational advantages and high reliability, these are attractive factors in a market that ranges from light twin-engine aircraft to the business jet. There appears to be a natural fit in the growing community-airline market. Some of the smaller military aircraft also offer a potential market.

The AVN-210—an integrated aircraft navigation system

M. Masse

The AVN-210 VHF Navigation System combines several previously separate navigational functions in one compact instrument package. To accomplish this, some unconventional circuit and packaging techniques were used. This paper first introduces the reader to some aircraft navigational concepts and then describes the electrical design and packaging techniques used to achieve this unique, integrated unit. Some of the problems encountered, and their solutions, are also discussed.

THERE ARE TWO BASIC commonly used aircraft navigational aids:

1) A VOR receiver and converter for en-route navigation. VOR is an abbreviation for VHF omnidirectional range (also known as "omnirange").
2) An instrument landing system (ILS) which by means of localizer, glideslope, and marker-beacon functions provides the pilot with course, descent, and range information on final approach.

The AVN-210 Navigation System provides the pilot with all necesary radio instrumentation for both VOR and ILS flight.

VOR receiver and converter

The VOR receiver operates in the 108- to 118-MHz frequency band with a ground transmitter power of 200 watts. Because of the modulation process at the VOR ground station, the VOR converter will be able to recognize a phase difference between two 30-Hz signals transmitted—a reference-phase signal and a variable-phase signal. This phase relationship will depend on the azimuth of the airplane relative to the ground station and magnetic north. For example, the VOR receiver of an airplane located on a magnetic north azimuth from the VOR station receives a signal in which the variable and reference 30-Hz audio are exactly in phase. At an easterly azimuth, the variable phase lags the reference phase by 90° and so on. The purpose of the VOR converter is to recognize the phase difference between the variable and reference signals, and to process the information for display to the pilot on a course indicator.

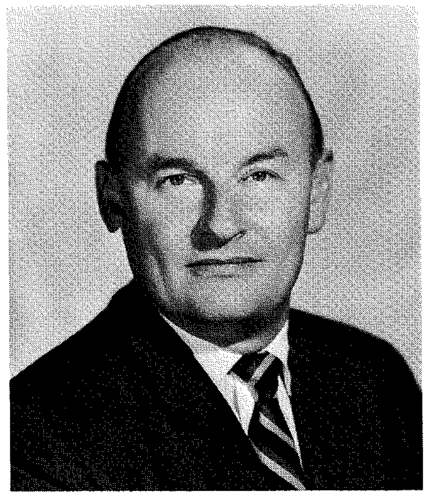
Reprint RE-15-6-2
Final manuscript received October 28, 1969.

Localizer receiver and converter

At the airport site, an RF signal is radiated along the runway. The signal is modulated at 90 Hz along the left side of the runway and at 150 Hz along the right side. The radiation patterns of the two modulations are of equal field intensity along the centerline of the runway. When the navigation receiver is tuned to a localizer frequency, the detector sees a composite signal of 90 and 150 Hz. [In the RCA AVN-210 system, this receiver is the same as that used for VOR.] The respective amplitudes of the 90- and 150-Hz components, as seen by the receiver, depend upon the angular displacement of the airplane from the centerline of the runway. In the localizer converter, the 90- and 150-Hz components are isolated, rectified, and differentially compared (see Fig. 1). The amplitude difference, displayed by the right-left meter, indicates to the pilot the lateral displacement of the airplane with respect to the runway center.

Glideslope receiver and converter

From the glideslope antenna array at the airport, a horizontally polarized RF beam is radiated at a vertical angle of from 2½° to 3° (see Fig. 1). The upper side of the beam is modulated at 90 Hz; the lower side is 150 Hz. At the center of the beam, the 90- and 150-Hz components are of equal field intensity. An aircraft following the center of the beam descends toward the runway at an angle equal to that of the radiated beam. The glideslope receiver and converter receives the signal and transforms it to a visual display representing the vertical displacement of the airplane from the center of the beam.



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received the BSEE from the Advanced Industrial Studies School *(Hautes Etudes Industrielles)* of the University of Lille, France, in 1948. He joined the RCA Aviation Equipment Department in 1964, and participated in the design of the AVQ-75 DME and the AVN-210 VHF Integrated Navigation System. During prior job tenure with Lear and then Motorola, Mr. Masse worked on VOR/Localizer and Glideslope receivers, marker-beacon receivers, automatic direction finders, and automatic VOR. Prior to this he was employed by Canadair Ltd where he worked on the F86 and T33 electrical and electronic simulators. Mr. Masse has been awarded one patent since joining RCA.

Marker-beacon receiver and light amplifiers

Two 75-MHz transmitters, called the outer and middle markers, are normally part of an airport's ILS installation. Each transmitter radiates a fan or dumbbell-shaped pattern. The outer marker is typically located from four to seven miles from the approach end of the runway, and within 250 feet of the extended centerline of the runway. The carrier is amplitude-modulated at 400 Hz and keyed to produce successive dashes. The middle marker is typically located 3500 ±250 feet from the runway and within 50 feet of the centerline extended. The carrier is amplitude-modulated at 1300 Hz and keyed to produce alternate dots and dashes.

As the airplane on an ILS approach passes over the outer marker, a blue lamp lights in accordance with the 400-Hz modulation. During passage over the middle marker, with the 1300-Hz modulation, an amber lamp lights. Since the location of the middle marker is relatively fixed, and the distance from the runway of the outer marker is published on approach plates, the pilot has a distinct indication of his position. Passage over the marker is emphasized by the keyed tone audible through the aircraft audio system.

The 75-MHz carrier of the airway markers is amplitude-modulated at 3000 Hz. The airway markers are located on prominent airways or holding points. They are used for navigation location references. The Morse Code identification keying indicates the direction of the marker from the associated VOR station with respect to magnetic north.

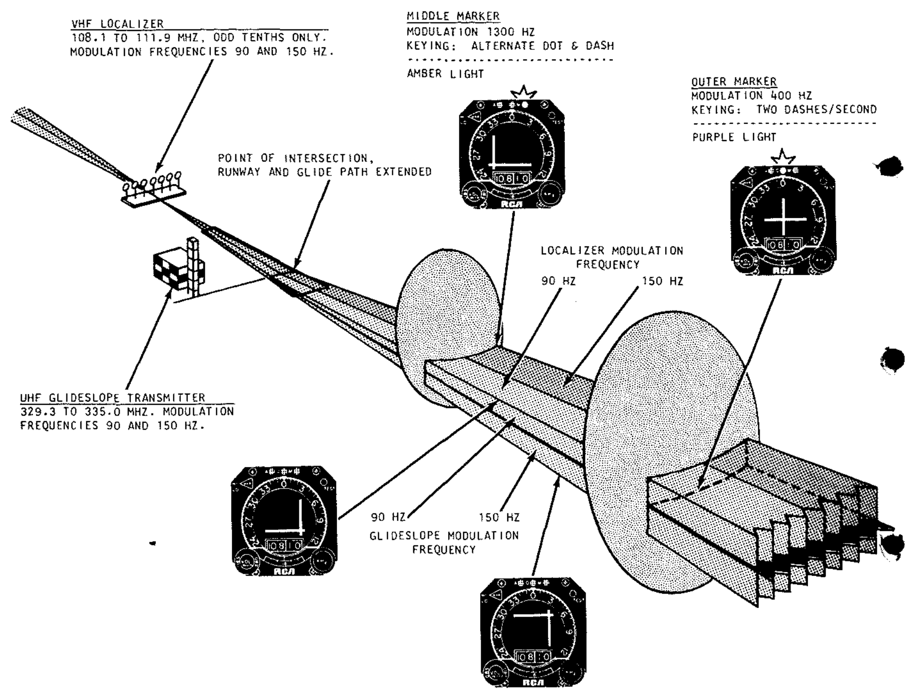


Fig. 1—Instrument landing system.

System concept

Until recently, equipping an airplane for VOR-ILS flight required installation of a number of distinct units of various dimensions and weights; the functions of these units were typically as shown by the separate blocks in Fig. 2. Moreover, for commercial flight under instrument flight rules (IFR), two navigation receivers and indicators are required by Federal Aviation Administration regulation. With the advent of semiconductor components, various combinations of the functions shown in Fig. 2 began to take place. Examples of such combinations are the frequency selector and VOR/localizer receiver, VOR/localizer converter and indicator, or the VOR/localizer receiver and converters. Integrated circuits have made possible the AVN-210 Integrated Navigation System, which combines all of the VOR-ILS functions shown in Fig. 2 into a single 3-x3-x10½-in. package that can be installed in the standard instrument panel hole normally provided for the indicator only.

The AVN-210 navigation system concept, as illustrated in the block diagram of Fig. 3, adheres closely to what has been the industry practice for a number of years. However, the concentration of all functions into a single black box of greatly reduced size (available at competitive prices, and offering equal performance) makes the ensemble unique. Approaches and techniques were judiciously chosen throughout the design stage to maintain compatibility between cost, size and required performance. In fact, the applicable FAA TSO requirements had to be met, or exceeded, over both standard and extreme environmental conditions. [TSO is technical standard order, an environmental and operational specification based on minimum performance standards. Issued by the FAA, the TSO may be subdivided into categories of location or conditions. TSO approval is required for all equipment used by the airlines.]

The electrical portion of the navigation unit may be divided into four main sections:

1) The navigation receiver,
2) The VOR and localizer converters,
3) The glideslope receiver and converter, and
4) The marker-beacon receiver and light amplifiers.

The navigation receiver

The navigation receiver, also commonly known as the VOR/localizer receiver, is designed to retain the integrity of information received at the antenna since it must be transformed both to a visual display for the pilot and to a command to the automatic pilot. The receiver must therefore be optimal throughout the applicable range of RF input signal level with respect to: immunity to cross-modulation, IF bandpass characteristics, and audio phase and amplitude distortion.

The VOR/localizer receiver is of the well-known double-superheterodyne configuration. The received frequencies, ranging from 108 to 117.95 MHz in 200 discrete channels, are spaced in 50-kHz increments. A bank of 10 crystals, individually selected by means of the MHz knob, initiates a local oscillator signal ranging from 76.025 to 85.025 MHz in 1-MHz steps. This signal is fed to the first mixer for a resultant first IF at a frequency sliding from 31,975 to 32,925 MHz which, in turn, is fed to the second mixer. A bank of 20 crystals, ranging from 44.705 to 45.655 MHz in 50-kHz steps (selected by means of the KHz knob), constitutes the source of the second local oscillator signal for a resultant 12.73-MHz second intermediate frequency.

The RF and IF gain averages 122 dB which, together with the automatic gain control (AGC), provides usable navigation information throughout an RF-signal-input range of from 1.5 to 50,000 antenna-generated microvolts. Selective use of dual-gate field-effect transistors and integrated cascode-connected IF amplifiers provide state-of-the-art capabilities in the optimization of cross-modulation and AGC characteristics, and holds distortion to a minimum. The AGC filtering, important to the integrity of the audio-modulation phase, is achieved by an adaptive filter. The filter provides adequate 30-Hz attenuation, but does not greatly penalize AGC recovery time in the event of large variations in the amplitude of the RF input signal. The required IF bandpass is provided with optimum volume efficiency by a crystal filter that maintains a 6-dB bandwidth greater than ±21 kHz and a 60-dB bandwidth of less than ±60 kHz.

The receiver board also embodies the audio (speech) amplifier capable of delivering up to 100 mW of audio signal into a standard 600-ohm load. The audio output is adjustable by manual volume control knob.

VOR and localizer converters

The VOR signal conveyed from the receiver detector to the VOR converter consists of a 9960-Hz subcarrier, frequency-modulated at 30 Hz; this is the reference-phase signal. A 30-Hz fixed-frequency audio signal, the variable phase signal, is also fed to the VOR converter. With the aid of an FM detector, the 9960-Hz subcarrier is converted to 30 Hz, which then becomes the 30-Hz reference phase. The modulating process at the VOR ground station results in a definite phase relationship between the 30-Hz reference and variable signals for any given azimuth of the airplane relative to the ground station and magnetic north. The converter discriminates the phase difference between the two signals and processes this information for display.

Because of space restrictions, the most common design approach that makes use of bulky inductors and transformers was avoided. Maximum utilization of integrated circuits was achieved by use of

Operational amplifier active filter techniques.
Operational amplifier zero-crossover detector networks to transform the sinewaves into square waves without degradation of phase information.
Quad gates as phase discriminators, level sensors, and disable circuits.

In the localizer converter, to conserve space, highly stable active bandpass filters were used for frequency selection instead of the more common LC filters. The right-left deviation-meter amplifier (an integrated circuit) is common both to the VOR and localizer functions. The right-left information requires smoothing to be usable in an autopilot system. In a typical non-AVN-210 installation, smoothing is effected by paralleling the deviation meter and additional loads by large values of capacitors (typically larger than 5000 μF) located outside of the system black boxes. The AVN-210 achieves the damping at the high-impedance input of the deviation meter amplifier, allowing for internally mounted low-value capacitors, and thus reducing installation complexity and cost.

Glideslope receiver and converter

In addition to performance requirements, which are nearly identical to those of the VOR/localizer receiver, the glideslope receiver must offer an extremely flat AGC characteristic and be capable of handling large percentages of modulation.

The receiver is of the double-conversion type with an RF and IF gain of approximately 95 dB. A bank of 20 crystals ranging from 88.767 to 90.667 MHz provides the primary frequency selection of the first oscillator. Coupling of the selected crystal to the oscillator is effected through an MHz/KHz wafer-switch combination to ensure proper pairing with the localizer frequencies. The first oscillator frequency is tripled and mixed with the incoming signal varying from 329.3 to 335.0 MHz to obtain a 63-MHz first IF. A single-crystal oscillator at 51.6875 MHz provides an injection signal to the second mixer for a second intermediate frequency of 11.310 MHz. State-of-the-art devices, such as double-gate field-effect transistors and integrated IF amplifiers, are used where they offer advantages in performance, size, and cost. Bandpass requirements are efficiently met with the use of a multiple-section crystal filter.

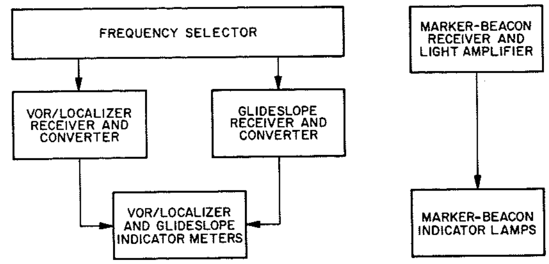


Fig. 2—Grouping by black box of airborne VOR/ILS receiver functions before RCA's AVN-210 system.

The converter is identical to that described for the localizer except for minor differences in bandpass and gain characteristics.

Marker beacon receiver and light amplifier

The AVN-210 marker receiver can operate in either high- or low-sensitivity modes. A switch enables the pilot to make the selection. One dual-gate field-effect transistor and two cascode-connected integrated RF amplifiers provide the 45-dB gain required in the high-sensitivity mode. For all practical purposes, receiver selectivity is determined by the input crystal filter. The audio and AGC amplifiers are integrated circuits. The three audio bandpass filters are low-*Q* series-tuned circuits. They provide the necessary selectivity so that one lamp only can light for any incoming marker signal. The audio (tone) amplifier can deliver up to 75 mW to a standard load of 600 ohms.

Self-test

The self-test function is provided for the entire AVN-210 by a 30-Hz square waveform generated by a simple free-running multivibrator that is excited when the self-test pushbutton is pressed. The square wave is fed concurrently to the VOR/localizer converter, the glideslope converter, and the marker-beacon light amplifier.

If a VOR frequency is selected, depressing the self-test pushbutton activates the VOR circuit, and a 60°-*from* bearing is displayed on the indicator. The three marker lamps light. If an ILS frequency is selected, and the self-test pushbutton is depressed, the third and fifth harmonics present in

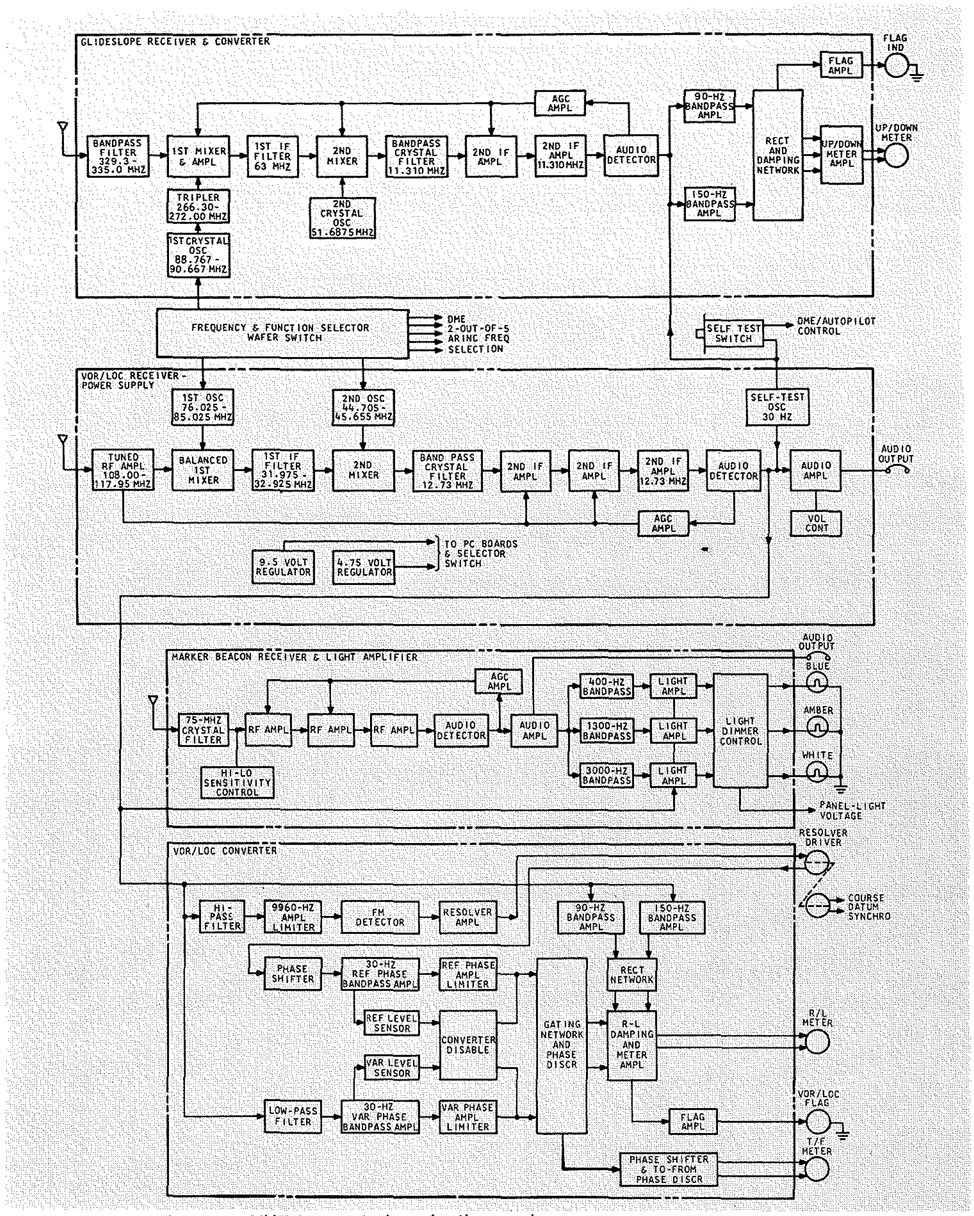


Fig. 3—AVN-210 VHF integrated navigation system.

the 30-Hz square wave pass through the 90- and 150-Hz filters, causing the right-left needle to deflect to the right (90 Hz dominant) and the glideslope needle to deflect downward. The three marker lamps also light. The appropriate warning flags are deflected from view, and the remote DME self-test function is actuated for both the VOR and ILS channels. Such a simple system provides the user with an operational test only. There is no specified accuracy verification by means of self-test; however, for a given unit, subsequent reproducibility of the indications given by the self-test signal generates confidence that the systems are operating accurately. Furthermore, Federal Aviation Regulation Part 91.25 specifies that an externally generated signal be used for checking the accuracy of VOR receivers prior to IFR flight.

Power requirements

The current drain of the system averages 300 mA from a voltage source of 11.5 to 32 VDC. Conventional series regulators provide the 9.5 and 4.75 VDC required for the solid-state circuits.

Physical aspects

Fig. 4 is a photograph of the AVN-210 without its dust cover. The omnirange bearing selector (OBS) card, graduated through 360° in 5° increments, appears on the dial face. It is geared to the OBS selector knob, and enables the operator to select any desired VOR bearing. The following are located within the inner circular area of the bearing angle selector ring:

- The cross pointer needles; the vertical and horizontal needles that indicate, respectively, left-right and up-down deviations from localizer and glideslope approach.
- The to/from (T/F) indicator, located in the window above the horizontal needle, indicates in VOR operation whether the selected course bearing is from the aircraft *to* the station or *from* the station to the aircraft.
- The VOR/LOC and GS warning flags, which drop out of sight whenever a usable signal is present and the equipment is operating properly.
- The display of the selected VOR/localizer receiver frequency.

The casting on the outer periphery of the bearing dial provides support for

1) Three marker-beacon lamps, identified A (airways), O (outer), and M (middle);
2) The marker-beacon HI/LO sensitivity selector switch;
3) The self-test pushbutton switch;
4) The OBS selector knob coaxial to the volume control knob; and
5) The coaxial MHz and KHz frequency-selector knobs.

The enclosed portion of the unit, located behind the instrument dial face, contains:

- The five sensitive DC meter movements that actuate the deviation needles, the T/F indicator, and the warning flags.
- The gearing arrangement necessary to actuate the resolver coupled to the OBS card, and the wafer switches coupled to the frequency selector knobs.

Four printed-circuit cards are mounted in the rear section. Concentrated on these cards are the circuits and components that perform the functions of the VOR/localizer receiver and power supply (top), the VOR/localizer converters (left side), the glideslope receiver and converter (bottom), and the marker-beacon receiver and light amplifiers (right side). In Fig. 4, one of the boards is swung out to show the switch assembly. Sandwiched along the center shaft, the successive wafer switches provide crystal selection for the desired channel, VOR or localizer and glideslope function. They also provide the necessary logic for selecting the frequency for the remotely mounted distance-measuring equipment (DME). The main connector, three antenna jacks, and the power elements of the voltage regulator are mounted on the rear plate. Although compact, the unit is easily serviceable as both side boards swing out, making all internal elements and wiring accessible. All printed circuit boards can be removed from the frame in a few minutes.

Problem areas

Several of the problems normally anticipated in the design and development of a new product proved to be of greater than usual complexity, primarily because of the multiplicity of functions within a small package. The most significant problems were

Receiver spurious responses and oscillator beats,
Power supply and distribution, and
Component-size limitation.

Receiver spurious responses and oscillator beats

Although precautions are taken in printed-circuit layout and in the location of critical-function elements, high-density packaging, such as that of the AVN-210, leaves little freedom to provide isolation between the various sections of a receiver, or even between two or more receivers within the system.

Complete shielding of the oscillators, mixers, and RF sections of the VOR/localizer and glideslope receivers of the AVN-210 is neither practical nor desirable as it would impair serviceability and increase the cost of the equipment.

A three-step procedure was followed to avoid undesirable spurious responses and to preclude oscillator beats that could be generated by the presence of four live oscillators in a limited space:

1) Oscillators and mixers were mounted on separate "baby" printed-circuit boards and boxed into RF-shielded enclosures. This provided sufficient isolation.
2) Separate ground returns from crystal decks to oscillator-mixer assemblies were used to prevent disturbances that would be created by ground loops between receiver sections and between individual receivers.
3) Field-effect transistors, rather than their bipolar counterparts, were used for their ability to provide oscillator signals with lower high-order harmonic content.

Power supply and distribution

Common power sources, in the form of DC-voltage regulators, are used for the entire AVN-210 system. Internally created ripple would cause inaccuracies in the displayed navigation information; for instance:

A 30-Hz ripple originating at the VOR converter could add to the modulation of the RF signal present at the low-level stages of the VOR receiver. This would probably result in a phase shift of the incoming signal and a display of false information by the right-left needle and possibly by the T/F indicator.
A 90- or 150-Hz ripple originating at the localizer converter could add to the 90- or 150-Hz modulation of the RF signal present at the low-level stages of the glideslope receiver. If the modulation depth characteristics of the incoming signals were thus altered, the glide-slope needle would deviate erroneously.

To prevent such inaccuracies, the power sources are designed to offer a very low source impedance to the loads (0.01 ohm) while interconnecting wires and protective-fuse resistances are kept to a minimum, thus avoiding the use of large-size elements necessary for low-frequency (30, 90, and 150 Hz) decoupling. Also, signal paths, power, and ground distribution within a single board are carefully laid out to avoid interstage interference, especially in the presence of adverse environmental conditions.

Component-size limitation

The cost and size definitions of the AVN-210 package demanded a minimum number of the smallest size components. Integrated circuits provided an immediate answer for the "active" part of the circuit. Keeping in mind that low frequencies (30, 90, and 150 Hz) carry the navigation intelligence, one sees that the inductor and capacitor elements offered more of a challenge. Active RC filters are used wherever there are low-frequency discrimination requirements, and high-impedance circuits allow use of small capacitors of relatively low value.

Reliability

To achieve the high degree of reliability most essential to a navigation and approach-aid system, special attention was paid to:

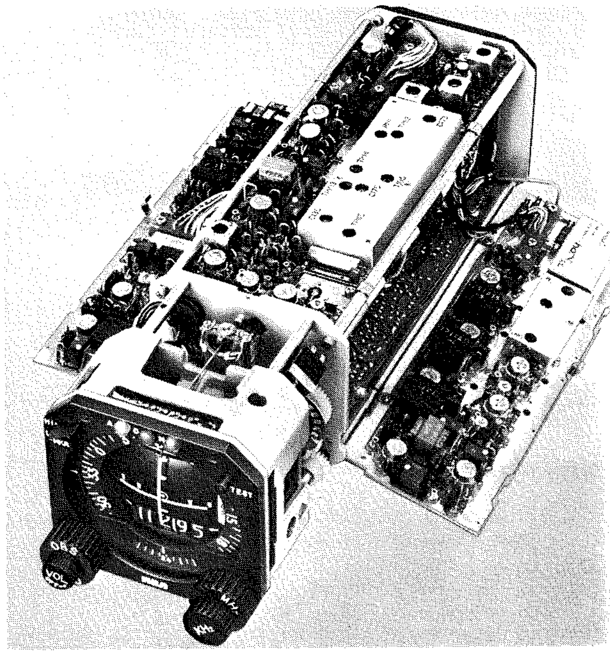


Fig. 4—All AVN-210 subsystems are accessible for servicing.

Reducing the number of components in minimizing circuit complexity.
Reducing eventual component failure through careful evaluation of electrical, mechanical, and thermal stresses.
Reducing the quantity of interconnecting wiring by optimizing the packaging functional distribution.
Eliminating eventual intermittencies by use of redundant circuit paths, plated-through holes, and feed-through griplets, where practical.

Although the AVN-210 contains all of the elements necessary to perform the functions generally provided by several discrete equipments, it is calculated that a minimum mean-time-between-failure (MTBF) of 1500 hours should be obtained by the AVN-210 series. While there is not enough data available at this time to confirm this engineering evaluation, available information is favorable.

Conclusion

The AVN-210 series offers a new concept of an airborne navigation system; it embodies some unconventional circuit techniques for optimum use of miniature components, such as integrated circuits, monolithic ceramic capacitors, and multiple solid-state devices. It represents a first step toward an overdue miniaturization of aircraft navigation equipments. The low power consumption, light weight, ease of installation, and competitive cost should be attractive features to most avionic users.

The AVC-110—a compact airborne communication transceiver

H. Volmerange

The AVC-110 VHF Communications Transceiver utilizes all solid-state circuitry with extensive use of integrated circuits and medium-scale integration. In fact, the only mechanical devices are the operating controls and the associated channel-selector switch. At the heart of the unit is a digital frequency synthesizer which provides the precise RF signals utilized by both the receiver and transmitter. The combination of reliable solid-state components, advanced but proven circuit techniques, and reliability-oriented design approaches, have given the AVC-110 a calculated mean-time-between-failure (MTBF) of more than 1500 hours.

FOR THE PAST SEVERAL DECADES, many manufacturers, including RCA, have contributed design fundamentals to airborne communications equipment which is virtually an indispensable part of the avionics package of an airplane. In more recent years, refinements, rather than fundamentals, have preoccupied designers, but with the AVC-110 VHF Communications Transceiver, entirely contained in one package for instrument-panel mounting, a substantial forward step is achieved. In company with formidable competitors, the AVC-110 provides 360 channels with 50-kHz spacing in the 118.00- to 135.95-MHz frequency band. It has 20 watts of transmitter output power for a rated 200-nautical-mile range, and weighs only 4.8 pounds instead of 10, 15, or even 20 pounds, characteristic of competitive remotely controlled units. Notwithstanding its small size (approximately 3.2 x 3.2 x 10 inches), the AVC-110 ranks among the best since it qualifies for the Federal Aviation Agency TSO (technical standard order), a set of performance and environmental tests comparable to those of military specifications.

The unit consists of five principal subassemblies, most of which can be readily identified in the block diagram (Fig. 1). These are

1) Control head
2) Frequency synthesizer
3) Receiver
4) Transmitter (including modulator)
5) Power supply

Reprint RE-15-6-3
Final manuscript received January 16, 1970.

Note that the relative simplicity of the system is made possible by the digital frequency synthesizer.

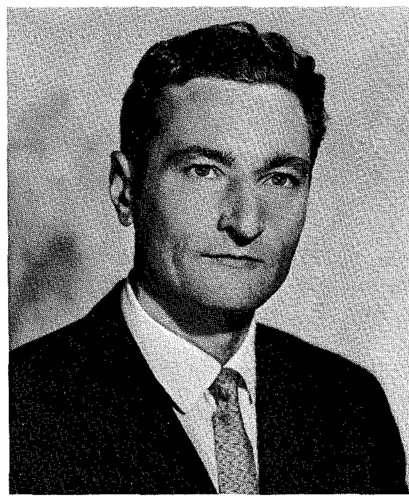
The AVC-110 without the protective dust cover is shown in Fig. 2. Ease of factory production and serviceability are not sacrificed to compactness, as may be noted in the photograph.

The control head is contained in approximately the front two inches of the AVC-110. It consists of the various control knobs, gearing, frequency readout, and transmitter monitoring lamp. The rear portion of this assembly includes the wafer switches necessary for selection of the desired channel frequency. The selector switch also provides voltages for electronic tuning of the receiver RF section.

The frequency synthesizer is mounted on the right side of the unit in a shielded enclosure. The receiver consists of a printed-circuit board assembly and, as can be seen in Fig. 2, is mounted on the top of the unit. The transmitter and modulator assembly is mounted on the finned heat sink and becomes the left-side structural member of the unit. Lastly, the power supplies are mounted on the central chassis and rear plate assembly.

Transmitter/modulator

The transmitter/modulator susbsystem consists of a VHF power amplifier and an amplitude modulator. The VHF part of the transmitter consists of four wideband stages of amplification which provide more than a 20-W output from a 20-mW input. The first



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received the BS from the University of Paris, France, in 1947, and graduated in electrical engineering from the *Conservatoire National des Arts et Metiers*, Paris, in 1951. In France, Mr. Volmerange evaluated airborne communication and navigation electronic equipment for the French air ministry. He came to the United States in 1957, and engaged in advanced development of semiconductor high-speed logic at the Philco Corporation. In 1958, Mr. Volmerange joined the Radiation Instrument Development Laboratory where he designed digital circuits. From 1960 to 1964, with Standard Kollsman Industries, he participated in VHF and UHF research and development programs associated with television receivers. In 1964, he joined Motorola Semiconductors as a senior applications engineer, and he worked in Phoenix, Ariz.. and in Geneva, Switzerland. Mr. Volmerange joined the RCA Aviation Equipment Department in 1967 where he has been instrumental in the development and design of the airborne AVC-110 VHF Communication Transceiver. A member of the IEEE, Mr. Volmerange has been granted one patent and has two patent applications in process.

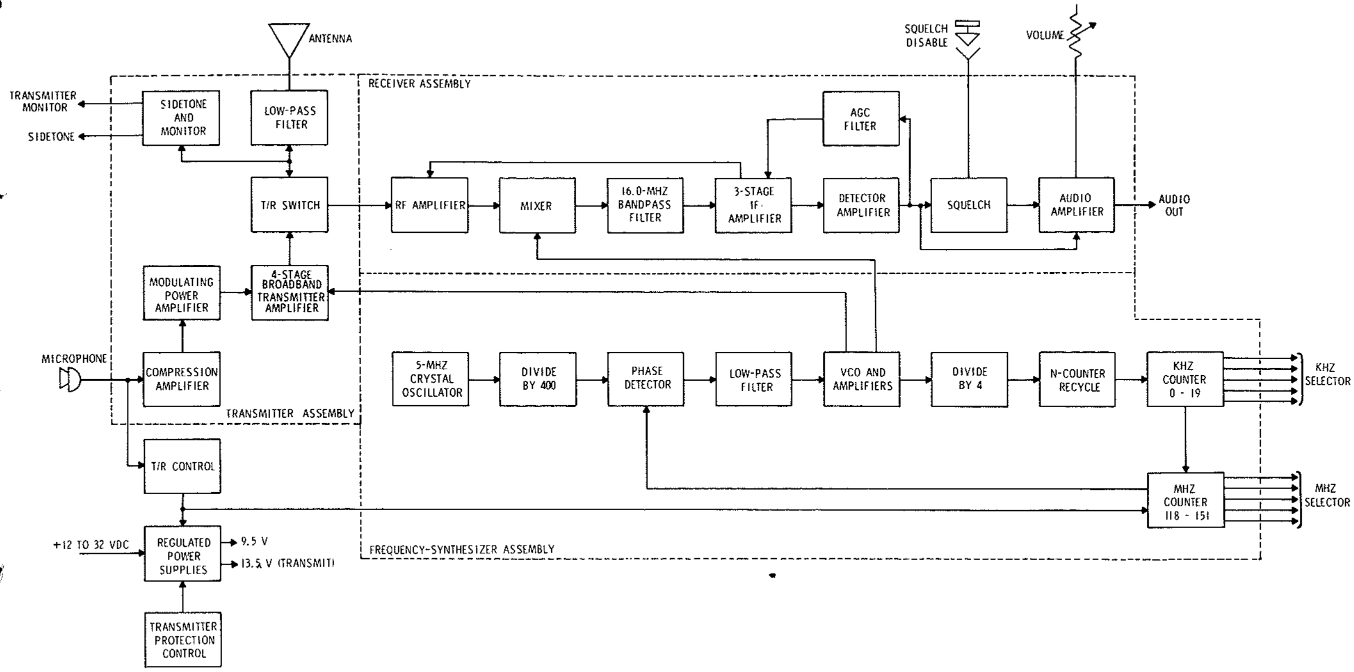


Fig. 1—AVC-110 VHF Communication Transceiver; the heart of this unit is the digital frequency synthesizer which provides precise RF signals for both transmitter and receiver.

two stages operate in class-AB to provide higher gain at a power level where efficiency is not paramount. The last two stages operate in class-C. The collector efficiency of the final stage is 60% and the overall amplifier efficiency is 40%. The final stage is a single package consisting of two dual chips of multiple-emitter transistors with matching diffused emitter resistors. The VHF output of the transmitter passes through a low-pass filter which rejects VHF and UHF harmonics generated in the non-linear power stages. Other circuits related to the VHF output are the sidetone, the VHF TR switch, and the reflected power detector.

Amplitude modulation in transistorized RF power amplifiers is of the collector type and must be applied to several stages to overcome both the loss of power gain at modulation peaks and the feedthrough of drive power to the output at modulation troughs. In the AVC-110, stages 2, 3, and 4 are modulated. Stage 2 receives only the modulation peaks; stages 3 and 4 receive full modulation.

An RCA integrated circuit is used to boost the microphone output to a power level that properly drives the final 15-W push-pull stages driving the modulation transformer.

In a communication system, it is desirable to maximize speech comprehension. This is accomplished by a high index of modulation. The modulator contains a compressor circuit (an AGC at audio frequencies). The output level remains essentially independent of the loudness of the operator's voice. The compressor, while maintaining a relative high modulation level, also prevents overmodulation and has a range of more than 30 dB.

At the heart of the solid-state transmit/receive switch are two PIN diodes. One is used in series with the transmitter output; the other is in shunt with the receiver input at the center of a broad series-tuned circuit. Both are held in a low-impedance conduction mode by current from the transmitter power supply. A fraction of a dB insertion loss to the respective ports is provided, while some 40-dB transmitter-receiver isolation is achieved.

Receiver

The receiver is a single-conversion type. It has a full RF and IF gain of more than 130 dB and has a sensitivity (6 dB signal + noise/noise) of better than one microvolt. It includes a squelch system which maintains a relatively constant threshold over a wide range of input noise.

Receiver front end

The receiver front end consists of two RCA dual-gate MOSFET's used as an RF amplifier and as a mixer. These devices, chosen for their almost perfect square-law characteristics, reduce the effects of cross modulation and spurious mixing products to a minimum—impossible to achieve with bipolar transistors or even with many tubes. Their cascode configuration reduces the feedback capacitance to a point where neutralization is not necessary at high-gain levels. Front-end selectivity is provided by three tuned circuits and a tracking image-rejection trap. Tuning is achieved by varactors whose tuning voltage is provided by a resistance divider controlled by the MHz frequency selector.

Local oscillator and IF amplifier

Local-oscillator voltage is fed to the mixer by the frequency synthesizer at a frequency 16 MHz higher than the received frequency. The IF first passes through an eight-pole crystal filter (6 dB bandwidth greater than ±14kHz, 60 dB bandwidth less than ±30KHz) matched to avoid in-band ripple. The IF amplifier consists of three wideband stages using high-gain RCA integrated circuits in cascode configuration. Conventional detection and audio amplification through a squelchable RCA integrated circuit completes the receiver chain. An interesting feature of the AGC amplifier is that two of the IF integrated-circuit stages are used in sequence as DC

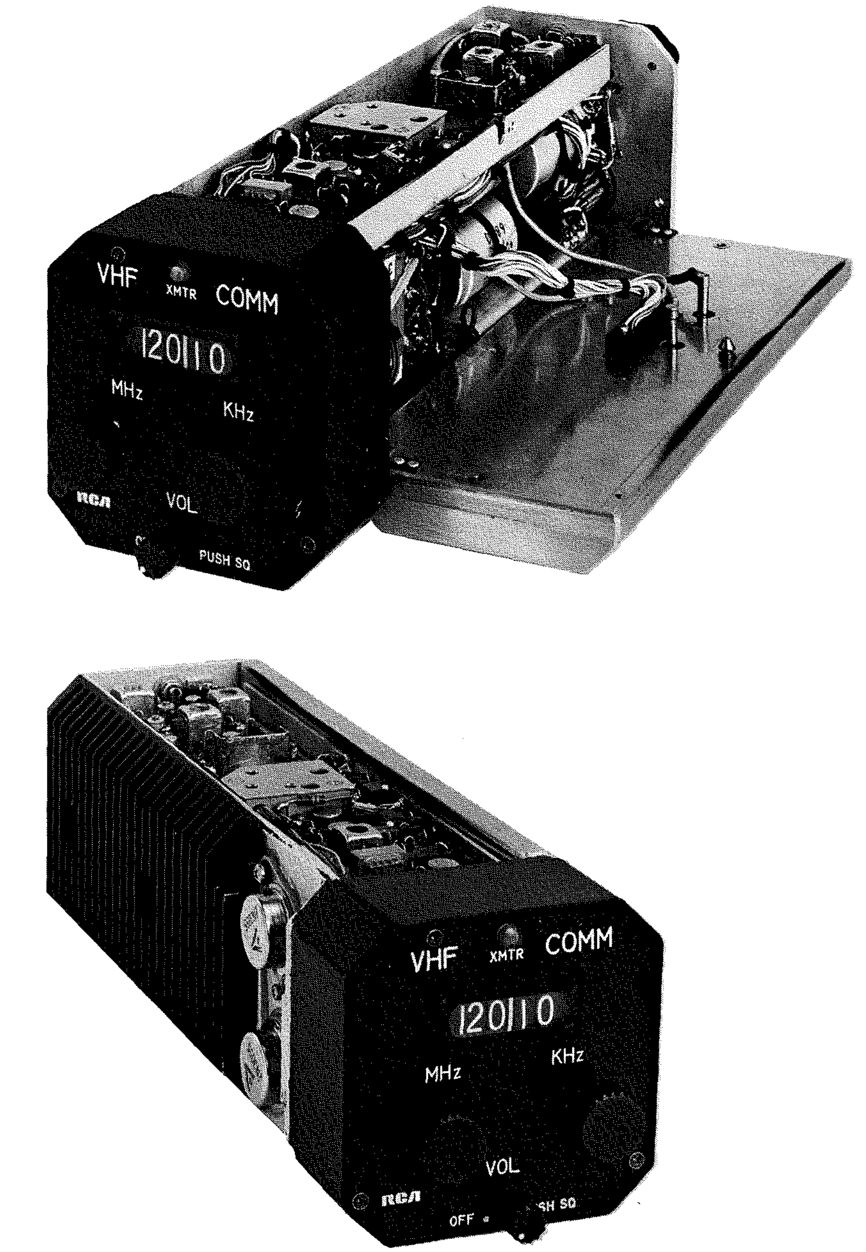


Fig. 2—The AVC-110 transceiver package weighs only 4.8 lbs., is 3x3x10 inches in size, yet delivers 20W of transmitter power for a rated 200-n mi. range.

differential amplifiers to control their own IF gain and to provide the voltage gain necessary for the delayed AGC action in the RF amplifier.

Squelch

Simple squelches mute the receiver audio output as long as the RF input signal is too weak to activate the AGC. This type of squelch presents adjustment difficulties as it opens on high noise levels at the antenna. A balanced squelch is used in the AVC-110. It operates on noise outside of the 3-kHz speech band. Noise quieting as well as the detected rise in the carrier voltage (upon reception of a desired RF signal) cause the squelch to open.

Digital frequency synthesizer

With crowding of the spectrum, tolerances of ±0.005% are placed on transmitting frequencies. These tolerances can only be met by the use of crystal oscillators. For the AVC-110, with 360 channels, multiple mixing of 30 to 40 crystal frequencies would be required to generate transmitter and local oscillator frequencies. This solution would create both reliability and spurious frequency problems.

The availability of digital integrated circuits makes the digital frequency synthesizer a practicality. It requires only one reference crystal oscillator to generate any number of discrete frequencies through the use of a voltage-controlled oscillator (VCO) and a programmable counter. Use of a phase-locked loop ensures an exact output frequency.

The 5-MHz frequency chosen for the crystal oscillator presents the best compromise among size, frequency tolerance, and crystal cost. The 5-MHz reference is divided by 400 in a digital divider using three stages of MSI integrated circuits. The 12.5 kHz thus obtained determines the reference phase, and it is used to trigger an 80-μs ramp with an amplitude that includes all voltages necessary to the tuning of the voltage controlled oscillator (VCO) in the design range. The VCO is a varactor-tuned oscillator covering the frequency range 118.00 to 135.95 MHz plus 16.00 MHz necessary to the transmitter and receiver local oscillator. The VCO is followed by three stages of wideband amplifiers insuring distribution of proper drives to the transmitter, the local oscillator, and the programmable counter. Owing to speed limitations of digital circuits, a 4-to-1 frequency divider is placed between the VCO and programmable counter. The latter, usually called an N-counter, is programmed to count a number of pulses equal to one-fourth the ratio of the desired VHF frequency to the reference 12.5 kHz and deliver an output pulse each time it has counted the programmed number of pulses. The N-counter output pulse closes the MOSFET switch of the "sample-and-hold" phase detector for about 0.5μs. As the MOSFET switch closes, it charges the integrating filter to the ramp voltage of that instant.

If the VCO is exactly at the desired frequency, the counting cycle of the N-counter will last exactly 80 μs, and the successive N-counter output pulses will occur at exactly the same phase of the ramp. The voltage appearing on the integrating filter, and on the VCO varactor, is constant, thus holding a constant output frequency. If, for any reason, the vco frequency deviates, the time required to count the programmed number of pulses will no longer be 80μ. In such a case, the N-counter output pulse will appear at a different phase of the ramp, and the varactor bias voltage will then be modified to bring the vco back to the desired frequency.

There are several design approaches to the circuitry of a digital frequency synthesizer. Considerations such as frequency coverage, environment, and available power supply determine whether the synthesizer will use a high- or low-speed N-counter, one or several vco's, coarse tuning by application of a bias to the vco varactor, auxiliary phase loops, frequency mixing or multiplying, etc. The AVC-110 with a high sampling rate and a straightforward approach has a high-performance wideband phase loop. The high sampling rate is made possible by the use of high-speed emitter-coupled logic for the kHz-setting part of the N-counter. The MHz-setting part of the N-counter uses slower medium-scale integrated circuitry. The resetting after each counting cycle is time-staggered and makes use of a small auxiliary counter to overcome critical propagation delays.

Due to the nature of the N-counter, a digital frequency synthesizer is a sampled system. In this sampling lie most of the limitations and drawbacks of the synthesizer. The first limitation is on the phase-loop gain. If the phase-loop were to run continuously, the gain could theoretically be infinite without affecting stability. Sampling introduces a delay in the correction of phase errors and limits stability versus gain of the phase loop. Since the output of the N-counter closes the sampling switch for about 0.5μs each 80μs, an updating of the varactor bias occurs at a 12.5-kHz rate and introduces frequency modulation inherent to the system. Another undesirable effect of sampling is the switching transients that take place at a 12.5-kHz rate as the reference ramp and the N-counter are reset to start. These switching transients can generate a spectrum of harmonics extending into the VHF band. The harmonics modulate the vco both in frequency and amplitude and create spurious outputs or responses. Care in design, including filtering of power supply leads, limiting of digital circuit bandwidth, and judicious printed-circuit-board layout (especially with regard to ground returns), was required to keep spurious outputs 80 dB or more below the carrier level.

Power supplies

A prerequisite is that the AVC-110 be capable of operating on primary aircraft power supplies of 27.5 or 13.75 VDC without wiring changes. Three regulated power supplies are used in the AVC-110. The current drawn for both the frequency synthesizer and the receiver is less than 0.5 ampere at 9.5 volts, obtained with worst-case voltage conditions in a low 13.75-VDC supply. A conventional series regulator handles this current and serves as a reference for the other two.

To cover the varactor tuning range in the synthesizer and the receiver, more than 9.5 volts is needed. A regulated low-current DC/DC converter steps up the 9.5 volts to 25 volts. It operates at a high chopping rate, 125 kHz, from the synthesizer, and regulates on a principle of variable duty cycle.

The transmitter-modulator subsystem draws a high current, although normally for short transmission periods; yet, the heat dissipation of the small AVC-110 package is limited. For this reason, a high-efficiency switching regulator is used to supply this subsystem. The nominal output voltage of 13.5 VDC is reduced when the protection circuits (described in subsequent paragraphs) modify the reference voltage. The separate transmitter-modulator power supply is ON during transmission only. In turn it controls the solid-state transmit-receive (TR) switch which directs transmitter output to the antenna or directs the receive signal from the antenna to the receiver.

Protection and controls circuits

Protection and feedback control of operation is used throughout the AVC-110 in several unique ways. In transistorized RF power amplifiers, the output stage is usually critical since it is used to the fullest of its capabilities. Excessive transmitter duty (exceeding normal requirements by several times) can overheat the output transistor. A high VSWR in the antenna and/or antenna coaxial cable reflects changes of impedance to the collector of the output transistor and can cause excessive voltage or current peaks. Either situation can have destructive effects, but is prevented in the AVC-110 by control circuitry which reduces the supply voltage. A reflected-power detector (directional coupler) located in the VHF output line and a heat-sink-mounted thermostat are used as sensors for this control circuit. In conditions of reduced supply voltage to the VHF power amplifier, the modulator compressor adjusts automatically to a reduced modulation output to prevent overmodulation. In this way a minimum of communication power (about one quarter of normal, depending on conditions) is transmitted while the output transistor remains at conservative levels of operation. The operator monitors transmitter operation by both aural and visual means. A portion of the detected output signal supplies a transmitter monitor lamp and an audio sidetone. Both the brightness of the lamp and the level of audio sidetone are proportional to the VHF output power.

Another protection circuit is associated with the frequency synthesizer. It keeps the transmitter-modulator power supply off whenever the frequency synthesizer is not locked on frequency—as during the few milliseconds it takes to change channels or in the event the synthesizer should fail to lock on.

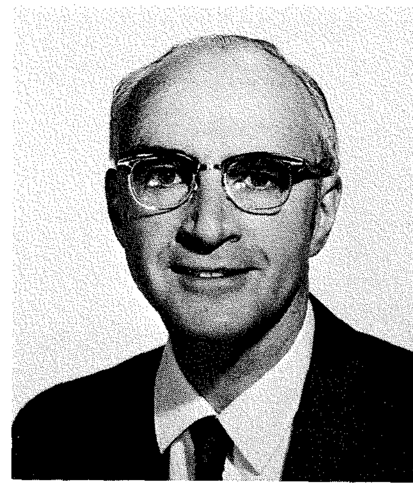
Conclusion

Compact, reliable, self-protected, and self-monitoring, the AVC-110 is in harmony with present aircraft-instrument design philosophy, as evidenced by the growing market it enjoys. Embodying advanced techniques and components, the AVC-110 reflects the present period of rapid technological progress. As improved, more complex and/or less costly integrated circuits, medium-scale integration, and large-scale integration become available, they can be incorporated to offer further advantages in reliability, size, and weight savings.

The AVQ-30—a new airline weather radar

J. H. Pratt

Weather radar has become an indispensable part of the electronic equipment carried by commercial aircraft. It has proved itself in increasing safety and comfort by reducing the incidence of turbulence, and it has resulted in cost savings by reducing detours and holdings, and by reducing damage to aircraft from lightning, hail, and turbulence. It is expected that the new generation of radars described in this paper will further extend this usefulness, will operate with greater reliability, and will require less operator skill.



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graduated from the General Engineering Course of RCA Institute in 1938 and has studied at McGill University, Montreal. He joined RCA Victor Ltd., Montreal in 1939 where he completed various assignments in the fields of ground equipment for air navigational systems, high-power airborne communications transmitters, and radar. Transferring to the newly-formed West Coast Division in 1951, he has worked on airborne radar, airborne LORAN receivers, air traffic control transponders, and distance measuring equipment, specializing mainly in the design of UHF transmitters and receivers. Mr. Pratt is a Senior Member of the IEEE and holds five U.S. Patents.

THE AVQ-30 is the latest in the line of airborne weather radars produced by the RCA Aviation Equipment Department for commercial airlines and general aviation. It is available in two versions: the AVQ-30X operating at X-band (9345 MHz), and the AVQ-30C operating at C-band (5400 MHz). Each radar consists of four basic units: Receiver-Transmitter (RT), Indicator, Antenna, and Control Panel. The equipment is designed to be installed with either single or duplicate Receiver-Transmitters. In both single and dual installations either one or two Indicators may be used. The equipment for one type of dual installation, with the exception of the control panel, is shown in Fig. 1. A special Antenna is available for dual installations in which most of the electromechanical parts are in duplicates. This increases the degree of redundancy considerably and improves the operational reliability. The Indicator may be modified by the addition of a module to display information in television form from external sources as well as the primary radar returns.

The principal specifications for the two radars are listed in Table I.

Background of weather radar

RCA has been active in the field of airborne weather radar for over 16 years. It was in June 1953 that United Air Lines, in conjunction with RCA, began flight tests of an experimental 5.5 cm (C-band) weather radar. This was the beginning of the wholesale commitment of the air transport industry to the use of weather radar as an aid to safety and comfort. It led to the development of the AVQ-10 C-band Weather Radar which has been the most widely accepted radar for airline use.

The decision of most airlines to buy C-band radar in the 1950's was based upon studies which showed that, among the available wavelengths, 5.5 cm gave the best compromise between maximum range and resolution on the one hand, and ability to penetrate rain to show distant storms on the other. However, since the original airline requirements were issued, operational requirements have changed. We have gone from the relatively slow, low-flying piston-engine aircraft to the high-speed, high-flying turbojet. At their high en-route altitudes, jets encounter less thunderstorms. Because of their greater speed, they cannot take the chance of encountering turbulence which is involved in penetrating stormy areas. This has tended to shift emphasis from penetration to avoidance, and has created the requirement for greater maximum radar range. In 1962, the Airlines Aeronautical Engineering Committee started work on a new characteristic to describe a radar suited to the jet age, and (hopefully) to the supersonic transport. This resulted in ARINC Characteristic No. 564-1. This new characteristic tightened requirements on antenna stabilization accuracy, reduced the number of major units from five to four by eliminating the synchronizer unit, and added provisions for dual installations. It includes an objective *performance index* which can be used to estimate the range performance of a particular radar under both "avoidance" and "penetration" conditions. It was to fill these requirements for a new airborne weather radar that the AVQ-30 was designed.

Performance index formula

The performance index formula was originally developed by a subcommittee of EUROCAE, the European Airlines Electronic Engineering Committee and is an example of the international cooperation that exists in the airline industry. The formula is based upon the standard radar equation. It is essentially a measure of the range at which a spherical storm of three nautical miles diameter, precipitating at 50 mm/hour, can be seen on the radar indicator with a certain probability of detection and a certain false-alarm rate. The performance index, PI, in dB, is,

$$\text{PI} = P + 2G + 2T + I - \text{NF} - B_f + K \quad (1)$$

where

P = transmitter peak power in dB above 1 watt
G = antenna gain in dB
T = 10 log (pulse length in microseconds)
I = display integration factor given by

$$3 \log \left(\frac{\text{ant. horiz. beam width}}{\text{ant. horiz. scan angle}} \times \text{PRF} \right)$$

Reprint RE-15-6-4
Final manuscript received January 3, 1970.

NF = receiver noise figure in dB

B_f = receiver bandwidth factor given by $B_f=0$ for $B \lesssim 1.5/\tau$; $B_f=5 \log (B\tau/1.5)$ for $B>1.5$; where B = receiver 3-dB bandwidth in MHz and τ = transmitter pulse length in μs

K = frequency function as tabulated below:

Frequency band	*Penetration*	*K factor avoidance*	*SST cruise*
C	0 dB	+3 dB	+1.5 dB
X	−6 dB	+6 dB	+1.0 dB

The relationship between performance index and maximum range, in nautical miles, is given by,

$$R = \log^{-1} (\text{PI} - 20)/40 \qquad (2)$$

The performance index will be recognized as being related to the effective power returned to the receiver as given by the standard radar equation.

The square-law effect of pulse length may appear to be incorrect, but it comes about because Eq. 1 accounts for the fact that weather targets consist of a large number of randomly-distributed scatters. The effective target cross-sectional area is proportional to the number of scatters illuminated, and this is proportional to pulse length. Optimum receiver bandwidth is inversely proportional to pulse length. This puts a second pulse length factor in Eq. 1 because the bandwidth factor B_f takes into account only the deviation from optimum pulse length. In other words, the second T takes the place of the bandwidth, B, in the denominator of the usual radar equation. The factor K is intended to take into account the difference in both the reflectivity and attenuation of rain at C and X bands. Based upon frequency alone, X band should be 4.8 dB better than C band. A difference of 3 dB appears under "avoidance" because some allowance was made for attenuation even under "avoidance" conditions. It is obvious that the K factor can account for the differences in attenuation at X and C band only in a special case. For this reason, the performance index cannot be used to compare the performance of radars operating in different bands, but it does serve as a convenient measure of the relative performance of different radars operating in the same band.

AVQ-30 system design

During the design of the AVQ-30 Weather Radar system, four important factors were kept in mind:

1) The need to meet the requirements of ARINC Characteristic 564-1 as regards performance index, physical characteristics, stabilization accuracy, and compatibility with standard aircraft wiring.

2) The need to meet FAA Technical Standard Order requirements for performance under specified environmental conditions.

3) The need to meet airline requirements for a high degree of operational reliability as measured by the probability of completing an operating day with an operational radar.

4) The need to meet airline requirements for major unit reliability as defined by mean time between confirmed removals.

These factors are all interrelated to some extent. Striving for the utmost in performance may tend to reduce reliability if insufficient margins are allowed for degradation. Operational reliability is improved by using redundancy, but the added parts result in reduced mean-time-between failures. The relative weight given to the various factors in the design must be largely a matter of judgment based upon experience.

Since most airlines had indicated a need for a maximum range capability of 300 nm, it was desirable to attain a performance index of about 119 dB.

Table I—AVQ-30 performance specifications.

	AVQ-30X	*AVQ-30C*
Primary power	115V, 380 to 420 Hz, single phase	
Single installation	600 VA	700 VA
Dual installation (with one RT operating and the other warmed up and ready for instant operation)	750 VA	850 VA
Transmitter characteristics		
Frequency	9345 ±30 MHz	5400 ±30 MHz
Power output		
Magnetron	65 kW	75 kW
Receiver-transmitter	60 kW	65 kW
Pulse length	6 μs	6 μs
Pulse repetition frequency	200 pps	200 pps
Receiver characteristics		
Noise figure (max)	8.1 dB	8.2 dB
Bandwidth	500 kHz	500 kHz
Sensitivity control	Automatic and manual	
Automatic frequency control	Maintains sensitivity within 1 dB for all transmitter frequency changes	
Sensitivity time control	Gain increases as the second power of range within ±3 dB out to the point where a 3-nautical-mile (nm) target fills the antenna beam. Adjustable for different antenna reflector sizes. Rain attenuation compensation available.	
Antenna characteristics		
Beam shape		
Pencil Beam	2.9°	5.2°
	Antenna pattern characteristics maintained at all tilt angles and stabilization excursions.	
Mapping beam	Follows the law $G=G_o \csc^2 \theta \cos \theta$ within 3 dB for depression angles θ between 2° and 20° (AVQ-30X only), where G stands for Antenna gain.	
Minor lobes	Approximately 24 dB below the main lobe	
Scan angle	180°	180°
Scan rate	45°/second	45°/second
Stabilization system	Split-axis mount (axis sequence: roll, azimuth, pitch)	
Stabilization range:		
Roll	±40°	±40°
Manual tilt (calibrated in 1° increments)	±14°	±14°
Pitch	±20°	±20°
Combined pitch and tilt:	±25°	±25°
Stabilization accuracy:	Within ±0.5° of selected tilt angle for all combinations of roll, pitch, and tilt up to ±20° at roll and pitch rates up to 20° per second (does not include gyro signal and geometric errors).	
Display characteristics		
Range display:	Full-scale ranges of 30, 100, and 300 nm, with 25-nm range marks on the 30- and 100-nm ranges, and 50-nm marks on the 300-nm range. Other range scales available up to 360-nm. Left-right offset permits full range display at extremes of scan.	
Display accuracy		
Range:	Within 5% of target range or 1 nm, whichever is the greater.	
Azimuth angle:	Within ±2° with zero pitch and roll signals. (Does not include radome aberration and Antenna mounting errors.)	
Display brightness	Storage-tube indicator with adjustable filter for brightness control.	
Contour display	Single contour level with adequate adjustment range to cover all proposed contour criteria.	

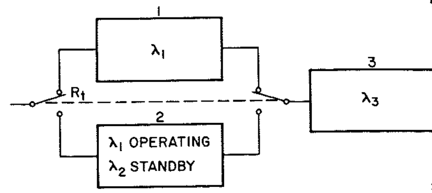


Fig. 2—Operational reliability model.

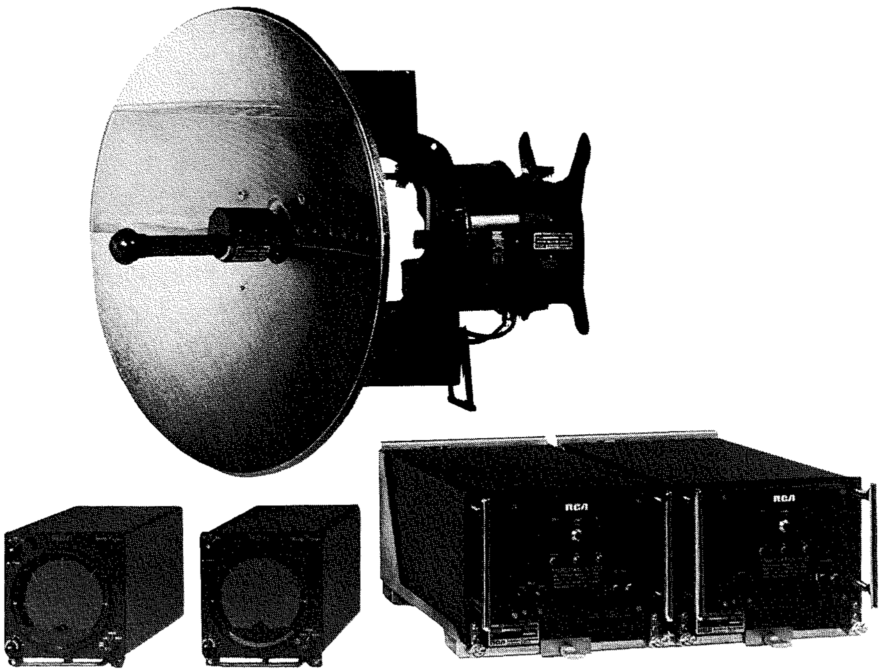


Fig. 1—The dual system AVQ-30X (ARINC Characteristic 564) Weather Radar for commercial transport aircraft.

Preliminary studies showed that it would not be easy to do this under "penetration" conditions at X band and very difficult for both "penetration" and "avoidance" at C band. However, the performance index formula includes a 7-dB allowance for installation losses (waveguide and radome) and allows correction to be made for losses that differ significantly from this. It is known that losses are considerably less than this at C-band and this permitted a 4-dB increase in the C-band figure.

When the performance index equation (Eq. 1) is examined, it can be seen that the factors under control of the designer which most significantly affect the total are transmitter pulse width and noise figure. Transmitter power is limited by the availability of suitable magnetrons, equipment size and weight, and voltage breakdown problems. Antenna gain is limited by available space; a 30-inch diameter is the greatest that can be used in most present and projected aircraft. The bandwidth factor has a lower limit, and the integration factor varies as only the 0.3 power of the pulse repetition frequency.

Since it gave a satisfactory balance between range and azimuth resolution, the maximum rated magnetron pulse length of 6 μs was used for both the AVQ-30X and the AVQ-30C. The RCA 6521 magnetron of proven reliability was chosen for the AVQ-30C, and a modern coaxial magnetron of about the same power capability was used in the AVQ-30X.

In the later versions of the AVQ-10 Weather Radar, a tunnel-diode amplifier was added to improve receiver noise figure. The availability of lower-noise mixer diodes, improved mixer designs, and low-noise transistors for the IF amplifier made the value of a tunnel-diode amplifier doubtful in the new design, particularly at X band. Studies showed that, if the intermediate frequency was lowered to 30 MHz and the best mixer diodes used, the tunnel diode amplifier would improve noise figure by only 0.2 dB at B band and 0.74 dB at C band. It was, therefore, not used. Noise figures finally attained are 8.1 dB maximum at X band and 8.2 dB maximum at C band. These figures may seem rather high, but come about mainly because of duplexer loss. Duplexer design is discussed in a later section.

Receiver bandwidth was set at 0.5 MHz which is 1.5 dB below the optimum value according to the PI formula (Eq. 1). Experience indicated that, if a fast-acting automatic frequency control system were used and sufficient attention paid to tracking the AFC and IF center frequencies, there would be little or no performance degradation due to receiver mistuning under any environmental conditions. When all the various factors are placed in the PI formula, (Eq. 1) the resulting performance index figures are as follows:

	Penetration	*Avoidance*
AVQ-30X	119.0 dB	131.0 dB
AVQ-30C	117.4 dB	120.4 dB

We have met the desired 119 dB figure for both penetration and avoidance in the case of the AVQ-30X and have come quite close in the case of the AVQ-30C. A performance index of 117.4 dB corresponds to a maximum range of 275 nautical miles.

Antenna stabilization

The successful operation of an airborne weather radar depends to a great extent upon accurate stabilization of the antenna beam. In normal operation, the beam is adjusted so as to just clear the ground. If the beam does not travel in a horizontal plane, independent of aircraft attitude, ground clutter will wipe out weather targets whenever the attitude of the aircraft changes. The airlines had recognized the need for better stabilization accuracy and had written into Characteristic 564-1 a requirement for ±0.5° maximum stabilization error for all combinations of pitch, roll, and tilt with a ±20° allowance at pitch and roll rates up to 20°/second.

Previous weather radars (including the AVQ-10) have used "line-of-sight" stabilization. In this arrangement, the antenna beam is tilted as the antenna turns on the scan axis so as to keep the beam horizontal. While this system is theoretically capable of perfect stabilization, the complexity of the relationship between roll, pitch, scan, and tilt angles makes it necessary to use approximations that limit practical accuracies to more than ±1°. The ideal stabilization system is one that maintains the scan axis of the antenna vertical; but to implement such a system, rotary joints would be required in the transmission system on the four axes of movement: roll, pitch, scan, and tilt. As a compromise, it was decided to combine the pitch and tilt axes but provide a separate roll axis. This is the so-called split-axis stabilization system. An approximation in determining the tilt angle as a function of scan angle is still necessary; but since the need to correct for roll has been removed, it is possible to attain a stabilization accuracy of ±0.5°. Because the roll axis carries the whole mass of the antenna, it would require excessive power to correct for roll at the maximum error rate. This difficulty is avoided by providing for roll-error correction under dynamic conditions in the tilt axis. In other words, a complete line-of-sight stabilization system is mounted on a roll-correction axis. The combination gives fast-acting, accurate antenna stabilization.

Operational reliability

The need for greater operational reliability had led the airlines to provide for dual radar installations in ARINC Characteristic 564-1. However, no commercial aircraft have sufficient space allowance for two radar antennas. Complete duplication of all subunits is, therefore, not possible. The so-called dual system is actually a two-component switched redundant system with an extra series component as shown in Fig. 2.

In Fig. 2, λ_1 is the failure rate of the operating portion of the duplicated equipment, λ_2 is the failure rate of the duplicated equipment in standby, λ_3 is the failure rate of the non-duplicated equipment, and R_t is the reliability of the switching devices for one operation. The reliability of this system (probability of survival for time t) is

$$R(t) = \left\{ \exp\left[-t(\lambda_1+\lambda_3)\right] \right\} \left\{ 1+R_t\frac{\lambda_1}{\lambda_2}\left[1-\exp(-\lambda_2 t)\right] \right\} \quad (3)$$

To obtain the operational reliability, we would like to know the average failure rate if the system is regularly renewed at stated intervals. For the airlines, this interval is generally an operating day. The aircraft normally starts every day with all components operating. The general equation for the average failure rate of a redundant system regularly renewed at periods t_m is given by

$$\lambda_{AVG} = Q(t_m) \Big/ \int_0^{t_m} R(t)\,dt \quad (4)$$

where $Q(t_m)$ is the probability of failure in time t_m, and $R(t)$ is the probability of survival for time t.

When Eq. 3 is substituted in Eq. 4 and normalized to the failure rate of a non-redundant system consisting of block 1 and block 3, the following expression results:

$$\frac{\lambda_{SS}}{\lambda_{SR}} = \frac{(1+R_t r)\ (1-e^{-T}) - \left(\frac{R+r}{M}\right)(1-e^{-TM})}{1-e^{-T}-R_t r\ (e^{-T}-e^{-TM})} \quad (5)$$

In this equation, $r=\lambda_1/\lambda_2$ and $M=(1+r-K)/r$ where $K=\lambda_3/(\lambda_1+\lambda_3)$, and $T=t_m(\lambda_1+\lambda_3)$. The quantity $(\lambda_1+\lambda_3)$ is the failure rate of the non-redundant system; T is the ratio of the renewal period to the mean time between failure (MTBF) of the non-redundant system. Eq. 5 gives the ratio of the reliability of the redundant system to that of the non-reundant system.

As one would expect, for renewal times small compared to single system MTBF, the reliability improvement factor approaches the reciprocal of K, because under this condition the system failure rate is determined almost entirely by that of the non-duplicated parts.

In Fig. 3, $\lambda_{SS}/\lambda_{SR}$ is plotted as a function of K for various values of T. It is assumed that r, the ratio of the failure rate of the duplicated portion of the duplicated portion of the operating equipment to that of standby equipment is 4, and R_t is assumed to be unity. These curves illustrate very well 1) the large improvement possible in operational reliability when a dual system is used, and 2) the importance of reducing to a minimum the equipment common to both systems. This led to the decision to duplicate as many as possible of the electrical parts in the antenna to attain a low value of K. It is estimated that, with no duplicated parts, the failure rate of the Antenna may be 20% of the single system failure rate, and that, with the degree of parts duplication used, the failure rate of the non-duplicated parts is about 4% of the single-system failure rate. Then, for a single-system MTBF of 1000 hours, and a renewal period of 10 hours (an operating day), the operational reliability improves by a factor of 22/5=4.4 because of the additional Antenna redundancy. Compared to a non-redundant system, the improvement factor is 22.

The improvement in operational reliability attained by redundancy is, of course, attained at the expense of a greater equipment failure rate, and a greater number of required spare units. But the airlines appear to be willing to pay this price to reduce the chances of having to delay aircraft departures for equipment replacement during an operating day.

Unit reliability

While redundancy helps to give relatively good operational reliability even with not-so-good unit reliability, unit reliability cannot be neglected. Most airlines today insist that contracts for new equipment include a clause specifying the minimum MTBF of each line-replaceable unit. The penalty for failure to meet unit MTBF requirements is that extra spare units must be provided to allow the airline to maintain the operational reliability it could normally expect.

There are three important factors involved in attaining high unit reliability in airline operation.

1) The obvious need to use reliable components, properly derated, and reliable circuits with plenty of margin for degradation;

2) Because each unscheduled removal is treated as a failure, the need to provide means for checking the performance, and the need to indicate which unit is at fault when a failure occurs;

3) The need to establish overhaul and parts-replacement schedules which will insure that the units do not reach the wear-out stage. This requirement is complicated by the fact that the airlines will perform preventive maintenance only on an opportunistic basis. An operating unit will not be removed from an aircraft on a time schedule. However, when a unit is removed because of failure or suspected failure, any maintenance scheduled to be done at, or before, the number of operating hours actually reached will be performed.

Experience with the AVQ-10 and other earlier weather radars showed that the two components which contributed most to receiver-transmitter failures were the gas transmit-receive (TR) tube used in the duplexer, and the hydrogen

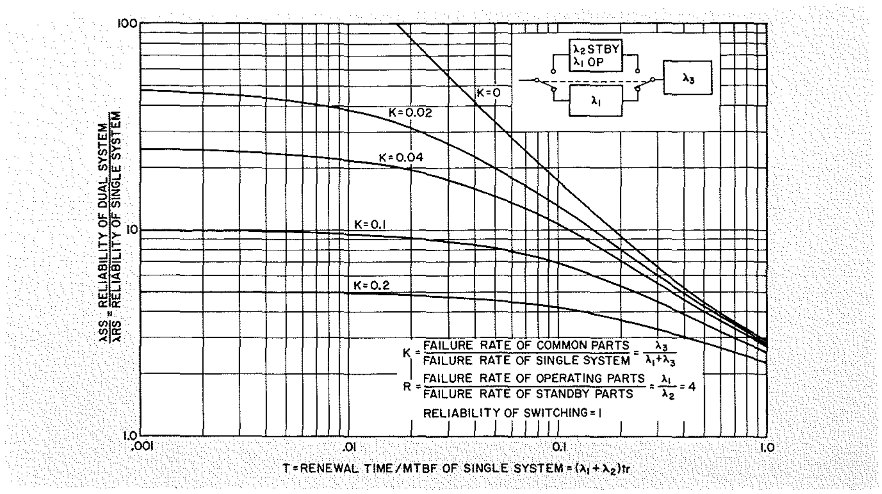


Fig. 3—Single-system versus dual-system reliability.

thyratron switch tube used in the modulator. Both these components have been eliminated in the AVQ-30. The TR tube has been replaced by a solid-state switching duplexer, and a completely solid-state modulator eliminates the hydrogen thyratron. These new components are described in more detail below. Other components replaced by solid-state devices with greater reliability are the klystron receiver local oscillator, replaced by a transistor oscillator-frequency multiplier, and power relays replaced by silicon-controlled rectifier switches. A new display-storage tube developed by the Electron Tube Division has already been used in other weather radars with improved reliability.

To meet the second requirement listed above, an extensive monitoring, self-test, and failure-indicator system has been designed into the AVQ-30. This system, which is described in more detail below, is expected to indicate the proper unit to remove in case of failure at least 90% of the time.

The third requirement, that overhaul and parts replacement schedules insure that wearout does not occur, is difficult to attain when maintenance is performed opportunistically. Inspection, overhaul, and parts-replacement schedules have been established that should prevent wearout. However, calculations indicate that in the Antenna, which contains most of the components subject to wear, the wear-out period will be reached if the guaranteed MTBF is attained. It seems probable that the policy of opportunistic maintenance will have to be modified in the case of the antenna unless the lower-than-maximum MTBF determined by the wear-out failure function proves to be acceptably high.

Self-test and fault isolation

As mentioned above, considerable attention has been given to self-testing in the AVQ-30 design. Self-test provisions are of three general types:

1) On-line monitoring for automatic fault indication and isolation,
2) Pilot-actuated to aid in making operating adjustments and for further fault isolation, and
3) Service-technician-operated for fault-isolation and performance checking both in the field and during bench testing.

The idea is to reduce the number of times the wrong unit is removed when a fault occurs, and to give the pilot a means of checking general operation before he takes off or at any time during flight.

In the Receiver-Transmitter, the following signals and operating parameters are monitored:

1) Control signals from RT to Indicator and Antenna (on-off and high-voltage control);
2) Transmitter power output;
3) Receiver automatic sensitivity control voltage;
4) Sensitivity-time control (STC) signal;
5) Automatic frequency control (AFC) lock-on;
6) Receiver local oscillator power level (mixer crystal currents);
7) Waveguide voltage standing wave ratio (VSWR);
8) Antenna azimuth and stabilization drive changeover-clutch currents; and
9) Servo error signals (average levels in roll and pitch channels).

In the Indicator, only two quantities are monitored; the sweep voltage to the Antenna, and the resolved sweep voltages from the Antenna.

Two types of failure indicators can be provided; two lights on the control panel, and two latching-type annunciators on the front panel of the RT. Some airlines want both, others want only the annunciators. One light and one annunciator are marked RT; the other light and annunciator are marked ANT. If any of the monitored parameters (1 through 6 listed above) go outside limits, the RT indicators are energized. If parameters 7 or 8 are out of limits, the ANT indicators are energized. If signal

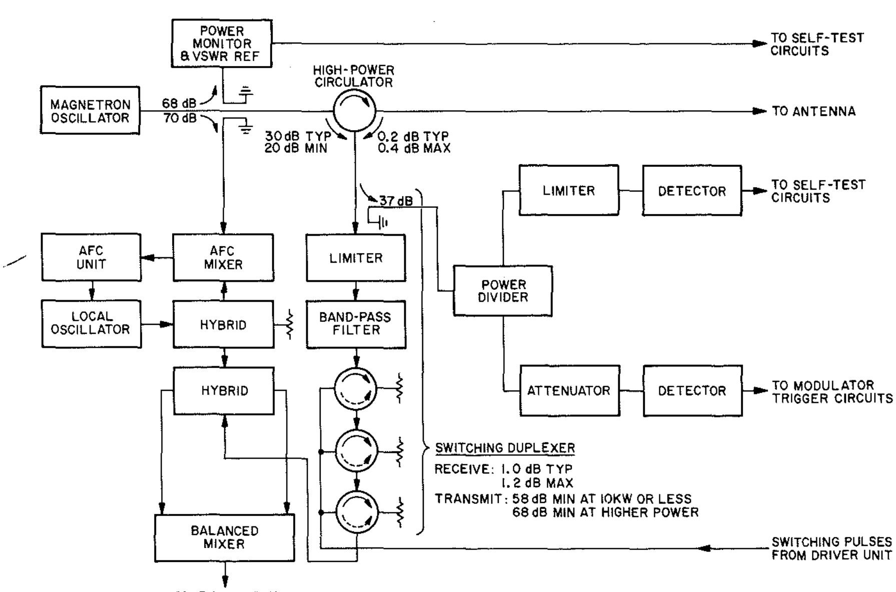


Fig. 4—Block diagram of microwave system.

9 is out of limits, both the RT and ANT indicators are energized.

Most faults that occur in the Indicator result in a faulty display and can be recognized by sight. There is, therefore, no Indicator fault-indicator. Absence of Indicator sweep could be due to either absence of drive from the Indicator or a faulty sweep resolver in the Antenna. This ambiguity is resolved by energizing the ANT indicators if there is sweep drive to the Antenna but none from the Antenna. If there is no sweep and the ANT indicators are not energized, the fault is assumed to be in the Indicator.

Stabilization system faults are difficult to isolate to the RT or the Antenna without applying test signals. For this reason, both the RT and ANT indicators are energized when a stabilization fault occurs. Servo test pushbuttons on the front panel of the RT make it possible to inject test signals into the servo system and to determine whether the fault is in the RT or the Antenna by means of two indicator lights. This test will normally be performed by a service technician when he discovers that both the RT and ANT annunciators are tripped. To aid the pilot in setting the Indicator controls and give him an indication that the radar is operating prior to take off, a TEST position is provided on the Control Panel function switch. In this position, the RT is connected to a dummy load and two simulated signals are injected into the receiver. One is a noise signal which is applied to the receiver input. It is pulsed on for the first 60 miles of sweep. Due to sensitivity-time control (STC) action, it shows up on the Indicator as a noise band increasing in amplitude from zero miles. The other signal is a triangular video pulse which starts 10 miles after the noise signal and lasts for 30 miles. Its amplitude exceeds the normal contour setting and results in two bright bands separated by a dark band. It checks both range-mark accuracy and contour-level setting.

Switching duplexer

The duplexer used in the AVQ-30 deserves special attention because, as mentioned above, it is an entirely new type. Fig. 4 is a block diagram of the microwave system. The primary separation between the transmit and receive channels is accomplished by a high-power ferrite circulator. This provides from 20 to 30 dB isolation under normal conditions. Another 60 dB of attenuation is required to reduce the power due to reflections in the transmission system and leakage through the circulator to a value which will insure long life to the mixer diodes. This attenuation is provided by a series of three latching-type switchable ferrite circulators. A single current pulse is required to reverse the direction of circulation of the three circulators. Once switched, they remain in that direction until a current pulse of opposite polarity is applied. These circulators were developed by the RCA Microwave Research Laboratory at Princeton under the direction of Dr. F. Sterzer and are produced by Electronic Components at Harrison.

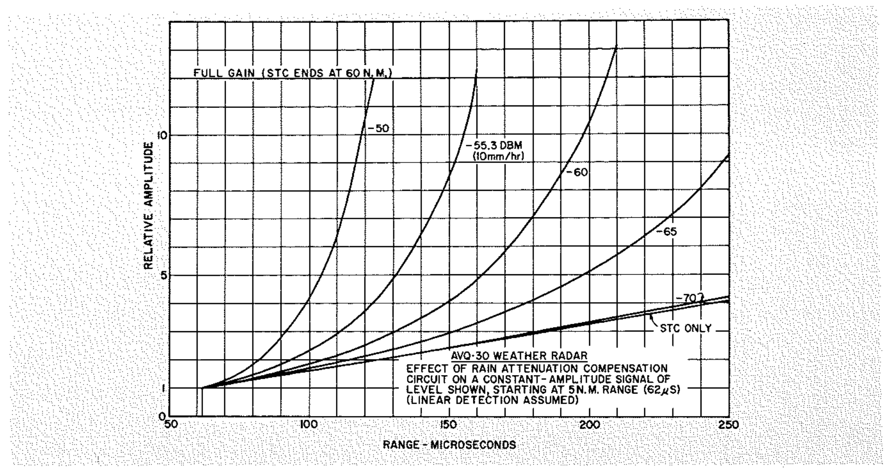


Fig. 5—Gain versus range in rain-attenuation-compensation circuit operation.

Switchable ferrite circulators of the type used are limited in both their peak and average power-handling capability. If an arc occurred in the waveguide or if the antenna were damaged, almost all the transmitter power could be reflected into the receiver channel.

To protect the circulators and the receiver diodes under such a condition, a ferrite limiter is installed between the high-power circulator and the switchable duplexer and the power in the receiver arm during transmission is monitored. At power levels above 10 kW, the limiter provides up to 10 dB of additional attenuation. At the same time, the power monitor causes the transmitter duty cycle to be reduced to limit the average power to a safe value.

Another problem with the switchable circulator duplexer is that it has a relatively narrow band over which full attenuation is maintained. To prevent out-of-band power from reaching the circulators, a band-pass filter is also placed in the line between the high-power circulator and the switchable duplexer. Out-of-band power might result from "moding" of the magnetron or from external power entering the Antenna.

Still another possibility that must be guarded against is that of excessive in-band power resulting from the antennas of two nearby radars pointing toward one another. This power cannot be prevented from reaching the receiver, but, under the usual conditions the power will build up gradually as the scanning antennas begin to point toward one another. A second detector monitors the received power in the receive mode. When this power reaches a level that represents a danger to the receiver, the duplexer is switched to the transmit mode and held there until the power level is reduced below a safe lower threshold for 10 milliseconds.

Other protective circuits are provided to insure that the system is always in the transmit mode when the transmitter modulator is triggered and to prevent the system from switching to the receive mode if the magnetron arcs.

Special design features

There are several special features to the AVQ-30 design, some of which are not specifically called out as requirements in ARINC Characteristic 564-1. These include a ground-mapping mode, automatic sensitivity control, isocontour display, rain attenuation compensation, and television display.

Ground-mapping mode

The ground-mapping feature, which is provided in the AVQ-30X only, requires an antenna which can be switched from a pencil beam to one which varies as $\csc^2 \alpha \cos \alpha$ where α is the depression angle. This type of pattern produces equal-amplitude return from targets of equal reflectivity on the ground and thus gives improved ground-mapping performance. The change in beam shape is accomplished by means of a "spoiler" on the antenna dish, responsive only to horizontally-polarized waves. The radiation is changed from vertical to horizontal by means of a mechanically-rotated section in the antenna feed.

Automatic sensitivity control

Automatic sensitivity control helps to simplify operation for the pilot by making it unnecessary for him to set receiver gain. Receiver noise is sampled in the time between the end of a 300-mile sweep and the next transmitter pulse. Gain is automatically adjusted to hold the noise level constant at a value which produces a satisfactory false-alarm rate.

Isocontour

Isocontour operation has been provided in practically all weather radars and is not much different in the AVQ-30. In the isocontour mode, all signals above a certain level are inverted. This produces a display having dark areas representing the locations of the heaviest rainfall in the normally-bright PPI display. In accordance with ARINC requirements, the contour level is set at that which corresponds to a beam-filling storm precipitating at about 11 mm/hour. Contouring can only be used as an indicator of actual rainfall rate within the sensitivity-time-control (STC) range of the radar, because only in that range is signal strength proportional to target reflectivity and independent of range. Both contour level and STC range are adjustable so that different airlines can set them to what they consider to be optimum conditions for their operations.

Rain-attenuation compensation

The accuracy of contouring is improved somewhat by the addition of what is called rain-attenuation compensation (RAC) in the AVQ-30X. This feature was originally suggested by H. P. Reichow of Deutsche Lufthansa. It operates on the principal that, since the relationships between rainfall rate and radar reflectivity, and rainfall rate and attenuation, are both known, it should be possible to compensate for the effects of attenuation by increasing system gain as a function of the integrated signal return. The compensation can only be accomplished within the STC range where extra system gain is available, and it is necessary to assume that all targets are beam-filling in this range. If the commonly-accepted equations for reflectivity factor and rain attenuation at X-band are substituted in the equation for power returned from a radar target, and the gain is assumed to vary with range in such a way as to make the receiver output in the presence of rain attenuation equal to that when no rain attenuation is present, the following equation is obtained:

$$G_r = K\int_0^R R^{1.64}\, P_r^{0.818}\, dR - 20 \log \frac{R_s}{R}. \qquad (6)$$

Here G_r is the receiver gain in dB relative to the maximum that is reached at the end of the STC period; R is the range in nautical miles, P_r is the power input to the receiver in milliwatts; R_s is the range at which the STC ends in nautical miles; and K is a constant of the radar set given by $K = 2.071 \times 10^{10} (L/P\theta^2\tau G_a^2)^{0.818}$, where P is the peak transmitter power in kW; θ is the beam width in degrees; τ is the pulse length in microseconds; G_a is the antenna gain; and L is the system loss $(L>1)$.

In practice, it is not possible to begin the integration at zero distance; it is necessary to wait until after any possible ground return from the antenna sidelobes—a distance corresponding to at least 5 nautical miles. For checking the RAC circuit, is it convenient to use a constant signal level P_{in} gated on at some range R_1. When this is done, it can be shown that the receiver output voltage E at range R relative to the output E_1 at range R_1 is given by

$$\frac{E}{E_1} = \frac{R}{R_1} \log^{-1}\left[\frac{K}{52.8} P_{in}^{0.818} (R^{2.64} - R_1^{2.64})\right].$$

It is assumed that the receiver detector is linear. This equation is plotted in Fig. 5 using the value of K calculated for the AVQ-30X, for various values of P_{in} starting at 5 nautical miles. The actual gain-vs.-range curves approximate the theoretical. In setting up the circuit, most attention is paid to the point at which the gain reaches maximum.

It is difficult to test the RAC circuit under operating conditions; but during one widespread storm of relatively constant rainfall rate in Los Angeles, the receiver gain control voltage wave shape was checked against the theoretical curve calculated for the reported rainfall rate, and was found to agree quite well.

Display variations

Several airlines are interested in using the radar indicator to display information other than storm and terrain returns. The displays are derived from closed-circuit TV systems or from LORAN equipment. Choice of display information is particularly attractive in dual-indicator installations. The TV display allows the flight crew to view parts of the aircraft not normally visible from the cockpit: for example, the landing gear and the relationship of the wheels to the runaway during landing. Used in conjunction with the aircraft LORAN set, the DST indicator becomes the A-scope presentation of the LORAN output.

The AVQ-30 Indicator can be provided with a TV display capability. After a modification of the characteristics of the display storage tube normally used in airline weather radar indicators, it was found that the erase speed could be made fast enough to give acceptable TV pictures, but at the same time retain the proper erase-rate capabilities for radar returns. The TV raster can be adjusted to either of two standards:

1) CCIR 625-line/50-field-per-second, or
2) EIA 525-line/60-field-per-second.

The TV module, which can be added to any AVQ-30 Indicator, accepts synchronizing and video signals from an external TV system and enables the indicator to be switched from radar to TV or LORAN operation as commanded by a switch on the Indicator front panel. LORAN sets are now being built that are compatible with the AVQ-30 Indicator. An additional circuit is required in the DSTV Indicator to operate with the LORAN set. For LORAN mode operation, part of the TV blanking circuit is used along with a dynamic-erase unijunction transistor which is a part of the DSTV/LORAN adapter circuit.

Human factors for an instant airport

P. H. Berger

A mobile air traffic control tower that can be assembled by four men, be completely operational in 90 minutes, and provide full 360° visibility for three air traffic controllers imposes some unusual human factors constraints. This paper describes the deployment techniques, console arrangement, equipment design, workspace allocation, environmental control, and maintainability of the AN/TSW-7 tower with major emphasis on the human factors involved.

IN CONJUNCTION WITH THE U.S. AIR FORCE, Aerospace Systems Division has developed the AN/TSW-7 mobile air traffic control tower. When operational, the control tower may be used autonmously or in conjunction with fixed or tactical air traffic control facilities and other communications systems. During operation, tower personnel control all incoming and departing aircraft, ground vehicles, and personnel within the airfield.

The tower, with its ancillary equipment pallet, can be delivered by helicopter, fixed wing aircraft, or vehicle. After delivery, it can be deployed at a specific site and be totally responsive, under all climatic conditions, in approximately one hour. Fig. 1 shows the AN/TSW-7 as it is deployed.

Normal deployment requires three operators, or controllers. They are designated as local, data, and ground. These three operators perform all of the various interrelated tasks required to land and launch aircraft and control ground vehicles and personnel. For this reason, human factors engineering recommendations became a primary input to the system design during the development phase of the AN/TSW-7.

The AN/TSW-7 configuration is based on the AN/TSW-6 control tower which was part of the AN/TSQ-47 Air Traffic Control/Communications System designed for the Air Force in the early 1960's. The present mechanical, electrical, and human factors design requirements are based on the acceptance test results of the AN/TSQ-47 as reported by RCA and the Air Force. The author was charged with the task of designing to conform to these requirements rather than establishing a design criteria and then configuring.

Reprint RE-15-6-21
Final manuscript received January 5, 1970.

Most of the problems discussed are not uncommon to other field-deployed, enclosed shelters. Some of the problems are unique, because, in this case, they are associated with a shelter which has more than half of its wall area covered by glass. To fully understand the areas of human factors consideration and the solutions implemented, a review of the performance requirements, as they apply to the operating personnel, are presented prior to discussing the individual problems:

Rapid deployment: A capability for rapid field deployment is vital to any tactical system, especially one that would be the first piece of equipment "into a hot" area. Specifications require that the AN/TSW-7 have a limited operational capability within forty-five minutes and be fully operational within ninety minutes after arrival on site. Another requirement is that the system be assembled for operation by a trained team of four men.

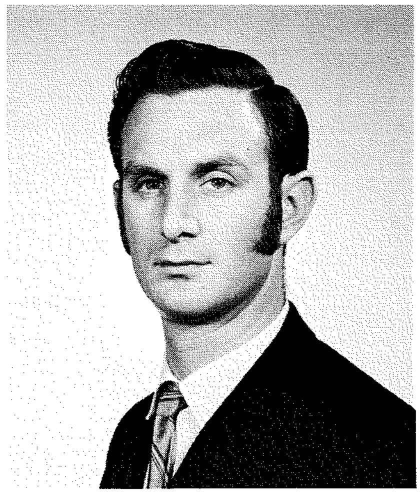
Control console design: The control console design had to accommodate three controllers yet permit them maximum comfort and easy access to the control panels and associated equipments, while in either a standing or sitting position. A further consideration was the visibility of controls and indicators during night operation.

Control panels and equipment: The configuration of the console, equipment, and control panels had to facilitate performance of air traffic control tasks, as defined by Air Force procedures, and also those tasks employed by active controllers as determined by detailed conversations with these personnel. Basically, the configuration had to allow for one to three controllers to perform the duties required to launch and land aircraft and to control ground vehicles and personnel.

Operator workspace: Console placement and equipment installation had to be arranged to allow sufficient aisle space to permit one operator to pass behind another during operation. In addition, sufficient space had to be provided to allow operators to manipulate their chairs while controlling and monitoring the surrounding equipments. Maintainability requirements dictated a need for workspace to allow rapid removal of any chassis from either a rack or floor mounting.

Illumination: Internal shelter and console panel illumination had to adhere to human factors and Air Force standards to assure that the operator's night vision, outside the tower, would not be degraded.

Visibility: The visual acquisition of aircraft, and control of ground vehicles



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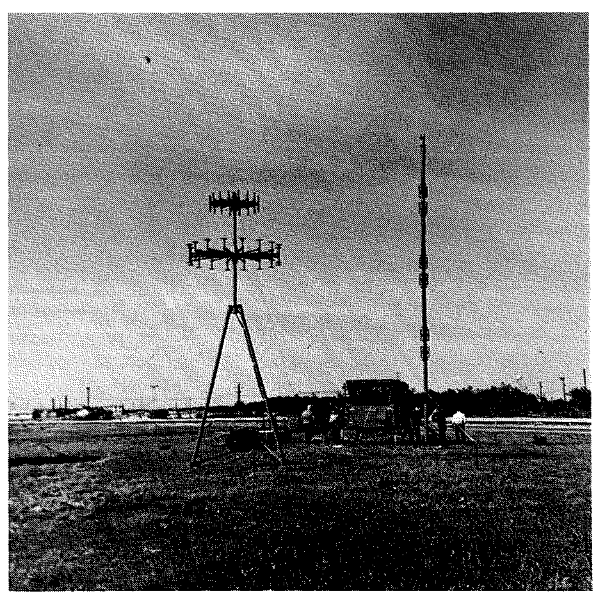

Fig. 1—Operational AN/TSW-7.

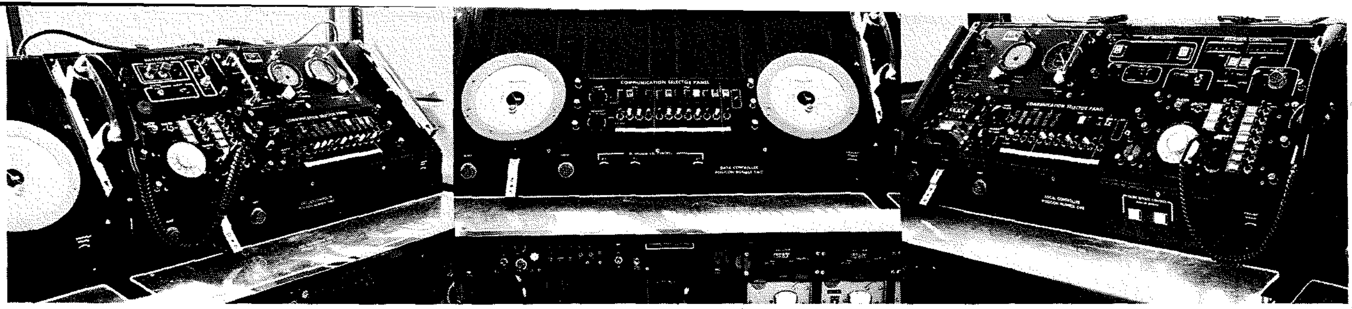

Fig. 2—Control consoles (left to right): local controller section; data controller section; ground controller section.

and personnel demanded an unobstructed 360° field-of-view from either a seated or standing position. Therefore, minimizing or eliminating overhead obstructions had a high priority when equipment positions were designated.

Noise level: Audible background noise had to be attenuated to a level that would permit any combination of radio, telephone, or face-to-face communications to proceed efficiently. The established level could not exceed the noise criteria (NC) level of 45dB in the speech interference level (SIL) range.

Shelter atmosphere: The environmental control unit chosen had to provide 1) sufficient air flow to cool equipments in any ambient temperature; 2) heat, during winter operations, to defrost the windows and prevent ice build-up; and 3) sufficient cool air, during summer months, to allow a shirtsleeve environment for the operators while keeping the windows clear regardless of the outside ambient temperature.

Maintainability: Maintainability requirements specified that repairs would be accomplished in a repair hut. Therefore, from the maintainability aspect, each item of equipment had to be designed for easy access for ready checking and easy removal and replacement. Chassis weights had to be held to a level so that one or two men could lift and carry them.

Human factors considerations

Rapid deployment

The rapid deployment capability is achieved by using a trained team and easy-to-assemble components. Specifically, four men can assemble the various components in 45 minutes, allowing limited capability, or in 90 minutes, allowing full operational capability. Because of the stringent time requirements, rigorous attention was given to the system installation procedures. The installation procedure is essentially predicated on the concept of two, two-man teams working simultaneously. Occasionally the team members would alternate tasks such as, anchor-driving in order to reduce fatigue and strain (e.g., see Table I).

One of the main concerns was the weight, size, and position of components on the equipment pallet. The requirement for a multi-vehicle transport capability dictated, in one sense, the size and weight of the items. In another sense, the lifting and transport capabilities of the deployment team were to be seriously considered in view of the stringent setup time. It is commonly known that an inverse relationship exists between the amount of weight to be lifted and the height from which it is picked up.[3] The heavier the weight, the closer to the ground the person must be to lift it. Hence, the components of each antenna system and shelter equipment were evaluated with regard to their position on the pallet, their weight, and the number of men required to remove them from the pallet.

Control console design

The AN/TSW-7 control console is divided into three main sections (Fig. 2). Inside the shelter, the control console sits atop racks which contain the numerous electronic equipments. MIL-STD-1472 dictates that in this configuration the rack height could not be less than 25 inches. In addition, the required width of the leg room beneath the console could not be less than 15 inches. The only requirement concerning the leg depth is that it be optimized. These physical parameters would insure that a controller with physical characteristics in the fifth to ninety-fifth percentile could sit at the console and be assured optimum acessibility to the controls and indicators.[2] The console surface was inclined at an angle of 45° to allow the controllers to sight over the top of the console when seated, and yet be able to view each display and indicator with no distortion or parallax while standing.

The console normally accommodates three traffic controllers: local, data, and ground. Table II lists the equipments available at each operator's position. Note that five of the indicator/control units are duplicated at the local and ground positions. This configuration permits either of these two controllers to assist the other during peak traffic periods, and should the wind direction change, aircraft could be landed from the ground position.

Should radio contact become impossible or an emergency arise, the *local* and *ground* controllers have access to a lightgun that can be used to signal aircraft or ground vehicles to stop, proceed, exercise caution, etc.

Control panels and equipment

The console positions listed in Table II indicate the positions of the controls and indicators on the console sections; the encircled notations indicate that the display or control is accessible during normal operation. These panels, whether purchased or RCA-built, were subjected to a meticulous human factors engineering evaluation. Particular attention was paid to the types and positions of controls and indicators for each task, as well as nomenclature, titling, and indicator color-coding. These control panels are of particular interest because of unique design considerations required to make them usable by air traffic controllers. They are the RDF (radio direction finder) display/receiver control panel (Fig. 3); the telephone control unit panel (Fig. 4); and the communications selector panel (Fig. 5).

The RDF display/receiver control panel is located in the upper right-hand corner of the local controller's console section. Positioning of the indicators and controls on this panel was determined by studying the tasks performed by the local controller. The

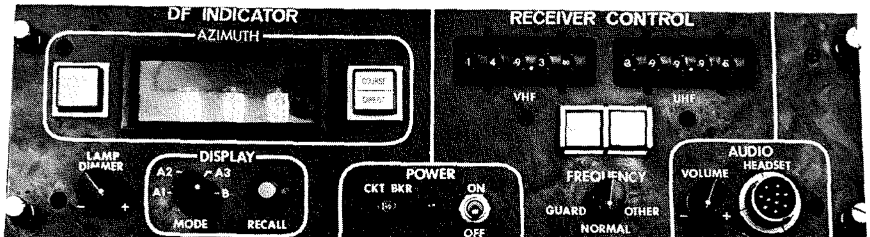

Fig. 3—RDF Display/Receiver Control Panel.

Man 1	*Man 2*	*Man 3*	*Man 4*
Remove communications antenna modules		Remove transit bags, tool kit, wind set and secure antenna baseplate	
Assemble antenna modules, attach guys, gin pole, etc.		Orient anchor A with tie-back cable and drive. Orient and drive anchor B.	
Orient and drive anchors C & D.		Connect power & signal cables	Remove wind set parts from shelter, set up chairs, light guns, erect wind set & remove screens
Erect communications antenna			
		Drive ground stakes and secure guys	

Table I—Preparation sequence for limited operation.

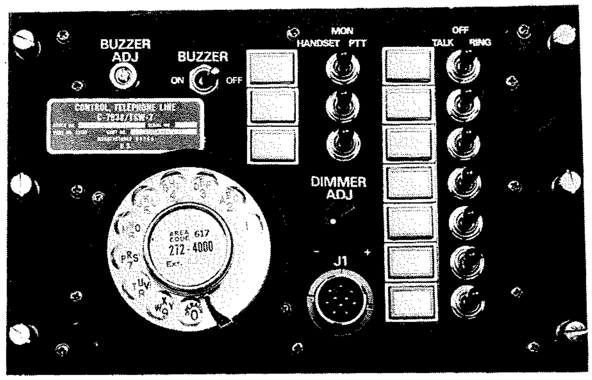

Fig. 4—Telephone control unit panel.

studies showed his performance would be enhanced by positioning the displays on the left and the receiver controls on the right side of the panel.

Table II—Equipments available and accessible from each console position.

Equipment	*Console positions* local	data	ground
Bail-out alarm		X	X
NavAids monitor			X
Flight strip holders		X	
Barometers	X	X	X
UHF remote control head	X		
VHF remote control head	X		
DF display/control	X		
Telephones	X	X	X
Wind speed/direction	X		X
Communications selector panel	X	X	X
Gooseneck lamps	X	X	X
Signal lightguns	X	X	X

X —positioned on console section
X —accessible during normal operation

The display portion of the panel contains three numerical indicator nixie tubes and two dual indicators. The nixie tubes display a numerical azimuth (heading or bearing) which is derived from digital information. The left-hand dual indicator informs the operator that a signal has been received and whether the sender is immediately overhead or at a distance from the antenna. The right-hand dual indicator is also a control. It illuminates when either a heading or a bearing is being displayed on the nixie tubes. When this indicator is pressed, the reciprocal of the heading or bearing being displayed is instantaneously shown on the nixie tubes. This type of display constitutes the most advanced state-of-the-art in processing and displaying direction-finding data and replaces the older method of determining the position of an aircraft by viewing a dot on a CRT.

Indicator color coding is consistent with indicators on other parts of the console. That is, indicators which denote normal operation are green and those designating other than normal operation are amber. On this panel, all indicators are green except the display labelled OVERHEAD and the receiver/control indicator labelled SQUELCH DISABLE, which are amber.

There are two telephone control unit panels on the console. One is located in the lower right-hand part of the local controller's section; the other is in the lower left-hand corner of the ground controller's section. This configuration allows any one of the three controllers to have access to a telephone control unit and permits two simultaneous conversations to take place. There are ten indicators on the panel and each one has its own switch. Seven of these are tied to landlines and are the normal communications channels used with a handset. The remaining three are designated as hot-lines. Hot-line conversations are received on the overhead speakers while the transmissions may be via the telephone headset; the dynamic, or hand-held microphone; or the boom microphone on the headset. Color-coding of these indicators is the same as the RDF control panel. Consequently, the telephone landlines, or normal channels of conversation, are green. The hot-lines, or emergency communication channels, are amber.

The communications selector panels are located at the bottom, center of each console section. The panel configuration emphasizes the tactile and visual accessibility to controls and indicators. The indicators serve a dual purpose in that, the top sections (which are multi-colored) denote the radio frequency being keyed by a pilot while the bottom section (which is singularly colored) tells the controller that that frequency is being used by another controller.

Operator workspace

Operators in the AN/TSW-7 respond to auditory and visual cues and their response may necessitate reaching for a pair of binoculars, a signal lightgun or even the frequency tuning head of a transceiver. Consequently, performance of these tasks may require a controller to go around another seated controller or stand next to or behind his own chair. Furthermore, numerous interviews with military and civilian controllers indicated that they prefer standing while performing their duties, especially during peak traffic periods. Therefore, aisle space and chair space were allocated with the standing operator in mind, in addition to the following two guidelines: 1) all rear-wall equipments were positioned below the air plenum to minimize their protrusion into the aisle, 2) the console writing surface was made only eight inches wide instead of the recommended 16 inches.

Illumination

There are three sources of illumination in the control console: the console lights, which are an integral part of the console; the gooseneck lamps, which are attached to the top of the console; and the panel indicator lights. Each light source has a separate intensity control which permits each controller to adjust the light level at his console section to a comfortable level.

The shelter contains two other sources of illumination but are not vital during night operation. They are the theater-type lights mounted at floor level, and the overhead lights which are used for maintenance purposes. Distracting internal reflections and external glare was accomplished by using blue-green tinted glass and by tilting the glass 18° off vertical, inclined outward.

Early in the design phase, the question arose as to whether low intensity white light or red light should be used in the console. A separate task analysis was performed to determine which light had the least effect on the controllers' night vision. The areas examined were the type, color, and probable intensity of light that might be experienced by a controller. The analysis showed that the controllers could experience medium to high intensity white light from aircraft landing lights, runway lights, maintenance lights, flares, and rockets.

As a result of the analysis, which included an evaluation of red light vs white light in reports by W. F. Grether[3]

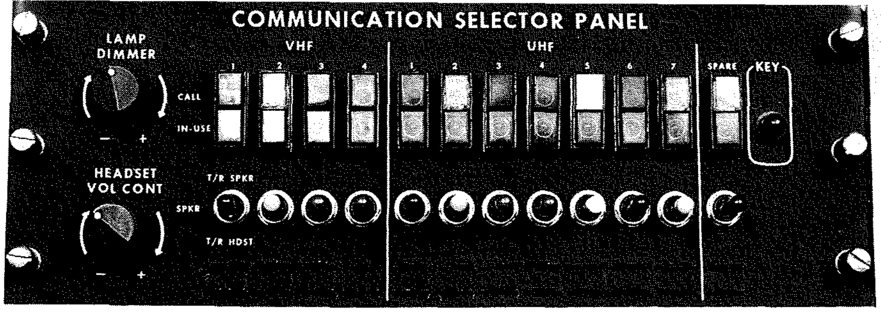

Fig. 5—Communications selector panel.

and Reynolds and Planet[4] relative to nighttime vision, the decision was made to use low-intensity white light for console and instrument lighting.

Visibility

Unlike other field shelters, control towers must provide maximum visibility for 360°. This is especially true for the local and ground controllers in the AN/TSW-7. Therefore, little or no equipment could be mounted on the ceiling, nor could, equipment to be mounted on the top of the console or on the window ledges surrounding the console. Consequently, the signal light guns were suspended between the local and data controller console sections, and between the data and ground controller sections. Although this does cause a small amount of visual obstruction, it is readily alleviated by a slight movement of the head.

The ceiling-mounted speakers do not obstruct either the controllers forward or upward visibility when either standing or sitting. However, the normal configuration of a civilian tower, which is sixty to seventy feet high and has only 3 to 5 speakers, was not acceptable. Mounting the speakers atop the console in a civilian tower does not obstruct either the forward or upward visibility. The AN/TSW-7 shelter with its sixteen speakers and only a four-foot elevation would have a serious visibility problem if the speakers were mounted on the top of the console. The solution of mounting the speakers on the ceiling resulted from a detailed anthropometric analysis of the size and proportions of the human body which showed that control accessibility was not compromised.

Noise level

Communication and command/control installations whether fixed or mobile, require that audible background noise be reduced to a level that will permit voice communications. Studies show that if these levels exceed 60dB in the speech interference level (SIL) range (600-4000 Hz), face-to-face communications is seriously compromised.[6]

RCA has found, through AN/TSQ-47 experience, that equipment cooling fans are usually the major contributors to a high background noise level. Other significant contributors are power generators, nearby vehicles, and aircraft.[7] Experience with the AN/TSW-7 during design, development, and Category-I test has shown that the glass windows are effective noise reflectors. Therefore, noise dampening efforts must be within the equipment rather than in the surrounding structure and ceiling.

To reduce the background noise to a level of approximately 45dB, the following steps were taken:

a) Equipment cooling fans, except the VHF transceivers, were eliminated because solid-state components were used throughout.
b) The controllers were supplied with noise-cancelling microphones.
c) Acoustical tile was used on the ceiling.
d) The air conditioner plenums, encompassing the controllers, were lined with polyurethane foam.
e) The environmental control unit was remotely mounted on the equipment pallet.

Shelter atmosphere

The AN/TSW-7 requires air conditioning for equipment and personnel cooling and to defrost and de-ice the windows. The required shirtsleeve environment within the shelter is defined as a relative humidity of approximately 50% in a temperature range of 68°F to 72°F with an air circulation of 15 to 25 cubic feet/minute. The shelter atmosphere is directly correlated to operator workspace. That is, if either or both are below standard, then operator performance is degraded.

Control of the air conditioner, or environmental control unit (ECU), and the ducting vents is achieved by the operators. The ECU control box is located in the knee hole of the ground controller's console. The ECU mode of operation can readily be changed from cooling to heating or vice-versa. The air flow on the personnel and windows is adjusted by positioning the duct vents in the desired direction.

Maintenance

Removal and repair of equipment inside the AN/TSW-7 shelter is not a requirement. The only maintenance tasks to be performed within the shelter are of a preventive nature. Therefore, the human factors effort in this area were the anthropometric considerations as applied to sufficient work space and access to components. Also of particular concern was the proper coding and/or labelling of cable connections, use of interlocks and/or caution labels for personnel safety and the use of failure indicators to facilitate rapid and accurate checkout.

In the task analysis for system deployment showed that component weight was an important design consideration. In the same respect, chassis weight (radios, filters, etc.) had to be carefully scrutinized to ensure that no item exceeded the limits for one and two-man transport. Specifically, the proper number and position of lifting handles were designated so that removal, transport and replacement of chassis or "down-time" was minimized.

Summary

At present, this system is to be used for tactical remote landing strip operations. However, the AN/TSW-7 may find applications in commercial aviation in the foreseeable future. With its portability and rapid assembly features, it could be rushed to a major airport as a replacement for a permanent tower that is temporarily inoperative. Also, because of its compactness and ease of convertibility for operation, it could become the most efficient and economical permanent tower for a new airport.

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Case history of an ideal reliability program

R. E. Dehm | O. E. Colgan

Field failure reporting and analysis can be more than simply a contract task. Properly established and controlled, it can pay future dividends to the performing division in terms of competitiveness and confidence. This article shows an ideal, but actual, case—how it was handled—and what resulted.

It has been said that we learn more from our failures than from our successes. This statement is particularly true in reliability. Manufacturing is concerned with building hardware that will pass inspection and test and gain customer acceptance. Design Engineering wants the clean program where nothing goes wrong. Even a repair function puts primary emphasis on the good hardware that it has produced for reinsertion into the system. The reliability engineer recognizes that everything has its failure potential, and that this can be guessed at, written about, predicted, measured and modified, as well as specified. In performing his function, he must think failure—so that others can think success.

Usable reliability data on equipment can be obtained in two ways. The first way is the special reliability testing program. Equipment conditions and environment can be regulated, and failure occurrences can be carefully observed and well documented. The limitation is the number of equipments and the number of hours that one can expect to use for such artificial application. The opposite is true in the second way: the monitoring of actual field performance. Here, equipment environment can vary in unknown ways; operation and maintenance may not be applied 'by the book' and may involve differing degrees of skills; reports of equipment failure, at their worst, may be misleading and, as a rule, may be rather uninformative. The advantage, however, is the countless hours of equipment operation that can be monitored.

The fact remains that, when the opportunity presents itself to secure such data under controlled conditions, something of value is in hand. When this opportunity includes provisions for evaluating and classifying this data while it is still fresh, that value is multiplied.

Background

A succession of contracts on the Saturn/Apollo program for NASA involved the delivery of twenty-four RCA computer systems. NASA requirements on this program called for continued integrated reliability programs that would provide for the design of high reliability into the equipment, would maintain reliability through manufacture, and would monitor and assess reliability in field use.

As a result of the unique demands of this program, NASA established a uniform failure reporting program which was implemented by the NASA equipment contractors. Prepared failure reports were distributed to contractors having design responsibility for each equipment. The contractor, in turn, maintained a data bank of failure history applicable to his equipment and provided NASA with identification of failure trends, updated reliability assessments, and prediction of mission success; the contractor also submitted a separately documented close-out report against each failure report—giving repair details, analysis of the failure and, where applicable, corrective action to the design or to existing equipments.

The effects of this extensive program emphasis on post-delivery reliability measurements were that

1) Incorrect or incomplete data could be investigated and improved while it was still fresh;
2) Classification of each failure record could be made, permitting later selective considerations;

Reprint RE-15-6-12
Final manuscript received August 18, 1969.

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joined RCA as an Electrical Design Engineer in November 1945 after having served as an instructor in the Navy R/T school during World War II. In his present position, Mr. Colgan is actively involved on several Reliability and Maintainability Programs including the Saturn Ground Computer System, Tacfire Random Access Memory (Drum) and Voice Warning Systems Signal Adapters. These programs involve Reliability and Maintainability predictions, Math Models, Failure Analysis and Corrective Action, Equipment Performance Assessment and Human Factors Analysis. While at RCA, Mr. Colgan has performed as a Design Engineer, a Systems Engineer, and a Project Engineer prior to joining the Reliability Engineering Section. Mr. Colgan has two U.S. patents and is a member of ASQC.

Table I—Discrete part reliability data.

Part type	Observed part hours	Random failure count	Average stress ratio	Temperature: Part ambient	Temperature: Normalized Junction	Failure rate (failures/10^6 hours): Observed	Failure rate (failures/10^6 hours): 90% confidence
Diode, germanium switching	19.0	56	0.1	45°C	0.35	0.0029	0.0035
Transistor, germanium (typical 2N1301)	2.89	48	0.2	45°C	0.50	0.017	0.02
Resistor, RL	20.0	2	0.3	45°C		0.0001	0.0002
Capacitor, CM	5.37	4	0.1	45°C		0.0007	0.0016
Coil, RF	1.01	8	0.1	45°C		0.008	0.013

3) The entire past history could be continuously reviewed and reclassified when later developments provided more information; and
4) Most important, the program would run for several years, providing large data sources, minimizing the effect of random errors in data from all sources, and providing high confidence in resultant computations.

Since the start of this field-data phase in 1965, over 375,000 system hours have been accrued on the RCA equipment along with a complete reliability history recorded to the component-part level. Part-hours, in turn, range up to the billions of hours. A situation like this will make eyes gleam in any reliability department. Failure-rate data in available handbooks is frequently based on far smaller samples.

Method

On this program, all data and data sources related to the RCA equipment were returned to a central collection point with the EASD reliability group. This included NASA failure report forms, repair record forms, failed parts removed in repair, and periodic elapsed-time meter readings from all equipments.

Some cause/effect interpretations could be established at this first (paper) level. In a few critical cases, immediate analysis was performed on the failed part. The emphasis of the program, however, was on the analysis for failure trends for common cause/effect and possible elimination. This would allow the long-running program to be most cost effective.

The accomplishments of this program required early planning for machine assistance. The essential data from both the failure report and the repair report was reduced to 80 columns of information in machine-card format (see Fig. 1). This permitted automatic sorting and print-out records for any item of interest in further failure diagnosis; e.g., assembly, part, failure classification, etc.

Failure classification into one of nine distinct conventional failure categories was a first step in the screening of the raw data. This reduced the total volume of data, where the basic type of cause could be determined, into smaller groups that could be separately treated and analyzed for correction, as follows:

Type 1—random failure
Type 2—dependent failure
Type 3—wearout failure
Type 4—initial defect failure
Type 5—performance deterioration
Type 6—non-operational defect
Type 7—workmanship-type defect
Type 8—design change (documenting modification action)
Type 9—design-oriented failure
Type 0—not a failure (or failure not confirmed)

Although nearly all of the above involve some degree of follow-up analysis, the one identified as *random* failure holds a special interest. This grouping contains all failure occurrences which could not justifiably be assigned to one of the other types—in a sense a screening residue. *Random* or *chance* failures can be defined as those occurring independently of known or correctable causes. Handled on a statistical basis at the part level, they also provide the source of the generic failure-rate data presented in handbooks.

Of the several descriptions offered above, the most important type of failure for the program is *residue.* Where an underlying cause of failure is significant and generally inherent in a specific part, circuit, environment, manufacture, or use, it will occur more than once and, in time, will indicate itself as a trend of similar failures. Directed failure analysis applied to each such trend uncovers correctable causes and allows more items of the *random* category to be reclassified into one of the more specific failure categories.

Fig. 2 illustrates the computer printout format used in the analysis of *random* or *residual* failures. The observed random failure rate is computed at both assembly and part levels from system operating hours, system part application records (for quantities), and screened failure records. These rates can be visually compared for differences with existing handbook values and are also statistically compared to indicate the "significance" of any difference. (A failure rate based upon a few observed failures does not have the same meaning or usefulness as the same failure rate based upon many observed failures).

In brief, the level-of-significance analysis can determine the probability (or odds in favor) of the observed results being obtained from a population of that part in the equipment truly represented by the prediction. In practice, the computation is set up to indicate a few discrete levels such as: observed results consistent with predicted failure rate (one chance or greater in ten), 5% level (one chance in twenty), and 0.5% level (one chance in two-hundred). These levels, indicating where a part or component is underperforming its prediction in a statistically significant sample, are used as a flag to direct a more detailed analysis of that item's failure history.

The complete screening operation described above is illustrated by Fig. 3. With continued analysis for failure trends, action to correct the equipment, and reclassification, the random failure category becomes more of a measure of what can be taken as the inherent failure rate of a given part in a specified application and environment.

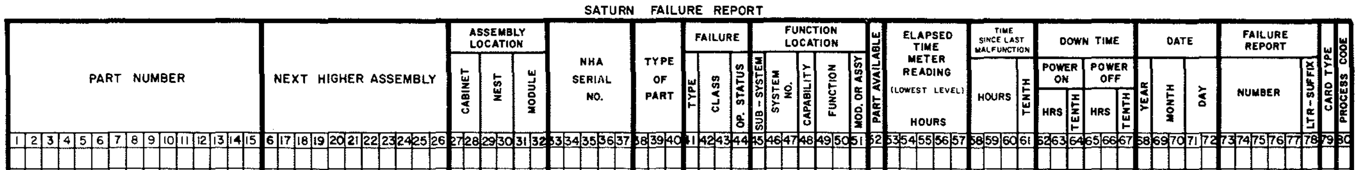

Fig. 1—Failure-report coding form.

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DATE — SATURN RELIABILITY EVALUATION REPORT — PAGE

ITEM DESCRIPTION	QUANTITY USED	PREDICTED FAILURE RATE PER 1,000,000 HRS.	TOTAL OPERATING HOURS		QUANTITY OF MALFUNCTIONS		OBSERVED FAILURE RATE PER 1,000,000 HOURS		LEVEL OF SIGNIFICANCE		REMARKS
			QUARTERLY	CUMULATIVE	QTR.	CUM.	QUARTERLY	CUMULATIVE	QTR.	CUM.	

Fig. 2—Computer readout format for random failures.

In the current EASD data bank, no significant failure-rate data exists for integrated circuits, since these were not in use in the subject equipment. Also, no new application factors (airborne, shipboard, etc.) were generated since the equipment providing the history was only used in a laboratory environment. These will have to be developed from future programs. Table I gives some of the discrete part data produced, to date, as fallout from the stages of analysis.

A second failure history screening, diverging from that performed for diagnostic purposes, was performed as part of reliability assessment. This screening did not establish inherent or limiting reliability, but was designed to measure the equipment failure-rate performance that existed at that instant of time due only to the equipment, excluding corrected problems and human foibles. The progression of this assessment measure, at the equipment and system level, established a 'present status' reliability growth curve which existed from early field performance and moved toward the measure of limiting reliability.

Problems

Collecting good screened data has several associated problems and requires controls. There is a continuous need for review and correction of the equipment user's approach to documenting failures and the repair group's approach to troubleshooting and repair reports. Misleading reports will be written, repair action may hide the original cause of failure, and failed parts will be lost preventing further analysis. This cannot be eliminated but can be minimized so that long-term cumulative records can replace weak data.

To take advantage of cumulative data, the system must provide for continual retrieval and review of the entire history. Properly screened to today's knowledge of failure occurrences and corrective action for this equipment, last year's history becomes just as useful. It does not merely involve an add-on process to older posted records.

To permit continual life retrieval of the reliability history requires organization in the data-bank system that will give living records rather than a succession of dead files. In the end, for each analysis you must leave the coded summary printouts and return to the original report text.

Machine-assisted operations and special working forms must be designed for as much flexibility as possible. All the needs of an extended data-processing program cannot be anticipated from the start, yet major changes cannot be economically introduced halfway through the program.

Conclusion

The screened failure-rate data at the part level, which resulted from the described program, is being used by EASD reliability in current new business proposals and on equipment development programs. It exists as a more current data source, and, properly used, contains more accurate data than current standard handbooks.

Since it reflects a constant, limiting performance that can be attributed to part reliability levels alone, the other factors that will exist in various degrees from early life through well-aged field performance are reintroduced by a multiplying factor derived from assessment screening. Typically, failure rates for early life, when reliability demonstration may be required, are taken as four times the basic equipment prediction, while middle-life failure rates, mostly experienced by the customer in field use, will be around two times the basic prediction for a program involving problem feedback and corrective action. The range of multiplying factors must be selected and used with caution, however, since it is here that the quality level of purchased parts and assembled equipment, as well as engineering attention to worst-case design, has its effects.

The use of this in-house prediction data in place of standard handbook data is inviting since, even when degraded by the multiplying (growth) factor, it results in a substantially higher predicted mean time between failures (MTBF). Its use can be substantiated to customer groups in terms of the source data and approach. To the degree that it permits closer predictions of reliability to what will be the actual case, it requires that more attention be paid to safety margins between contract specified requirements and current predictions. Closer, more accurate reliability predictions must be the aim of the Engineering Department — as reliability guarantees, equipment warranties, and life-cycle costing become more frequent topics in requests for quotation.

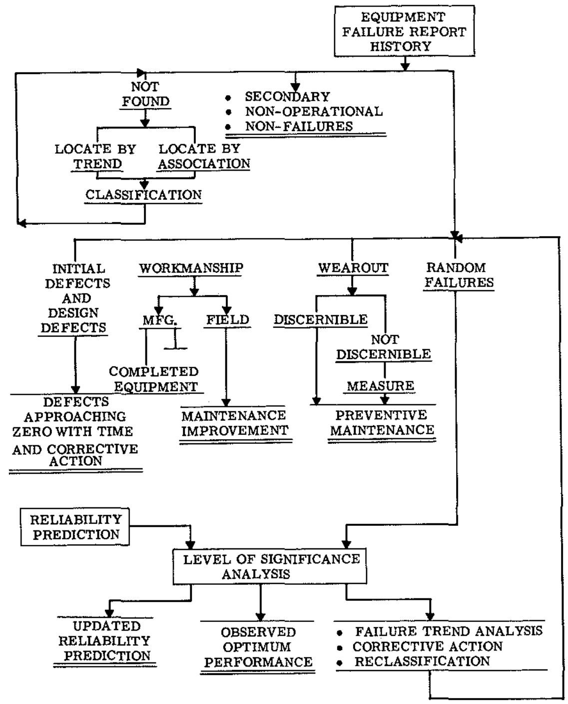

Fig. 3—Failure report classification and use.

Development of reliable reliability data is a cost item and cannot be done on every job. But, where failure reporting and failure analysis is required to any degree, the extra planning to set up and support a useful system to provide this secondary output can bring company returns in terms of competitiveness and confidence.

Value engineering at EASD

S. Steinfeld

In his program planning, the design manager must chart a course that has three basic parameters—function, schedule, and cost. In considering function, two conditions must be satisfied: 1) it can be built; 2) it will work. These two conditions of function must be proven within a time limitation, and problems mount rapidly as schedule and cost factors come into play. Costs are a prime concern but these concerns can add to the complications of restricted time. Where is priority attention placed: on function? on schedule? or on costs? A similar question is: which is the most important leg of a 3-legged stool? This paper shows how a manager can effectively use value engineering as one of many tools to help establish the success of his total program. It will explain some key factors in the effective application of value engineering relative to the rest of the company's operations, and discuss its importance toward increasing the worth of a product through the lowering of final cost at which the product provides its function.

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received his education in Mechanical Engineering at Newark College of Engineering, New Jersey. He received his professional designation in Value Engineering and Analysis at U.C.L.A. He has had over 20 years of engineering and management experience in Electro-Mechanical Packaging Product Design, Tooling, and Manufacturing—eight of these with Bendix and Lockheed, managing design groups on the Sparrow, Talos, Eagle, and Polaris Missile Programs. After joining RCA in 1962, he managed the Specifications and Standards Department engaged in Component Engineering, Design Review, Vendor Surveys, etc. He then assumed the task of Administrator, Value Systems and Control. Mr. Steinfeld is executive V.P. of the Los Angeles Chapter, Society of American Value Engineers.

Reprint RE-15-6-13
Final manuscript received November 7, 1969.

It is commonplace in the Aerospace/Electronic Industry to negotiate R&D contracts under very tight production schedules. This arrangement opposes the industrial psychologist's advice that we should have a clear, easy schedule and a relaxed atmosphere as a stimulant for true creativity. In spite of this burden, EASD has established a reputation with DoD, NASA, and the commercial world for concurrent development and production. This is a necessity in our competitive environment; we must satisfy the customer's requirements within a necessary time constraint and at a profit. A good track record with our customers proves that proper techniques have been developed by RCA to do its critical job. Each division has its own variety of these techniques, and this paper examines a specific EASD management tool—value engineering. In some cases, cost reduction and value applications may start in the proposal stage, as a marketing advantage, or to assist manufacturing in their producibility studies. The emphasis here, however, is toward its real usefulness as a management discipline when the contract arrives—to start the design, development, support planning, and implementation.

When engineering gets its contract commitment assignment, the design engineer goes into action. Because of EASD's diverse product line but relatively small organization, the design engineer has developed a jack-of-all-trades ability. He must be a Solomon to steer his program through all disciplines, and he must develop a store-house of all ingredients essential to satisfy contractual elements.

From his spectrum of talents, the engineer is capable of providing concepts; selecting parts, materials, processes and finishes; designing tools; providing test procedures; packaging and packing; writing manuals; and capably performing many other peripheral skills — including value engineering. However, if he has planned and organized his task properly, he will summon only those people and skills necessary to accomplish his goals:

Function—it must work
Schedule—on time
Cost—at a profit

The designer, like most of us, is a victim of Parkinson's law: at the moment of commencing a task, all available time is used up. He is now time-constrained and must quickly concentrate on getting the device *to work.*

Back in the cost-reduction void of post WW-II his program would have reached this point:

DESIGNER: Well, boss, here's the package ready for production. It's been successfully breadboarded, prototyped, tooled, environmentally tested and tomorrow is our deadline . . . but, one thing . . .
MANAGER: I'm impressed! Give it over to production, now!
DESIGNER: But, boss, give me another two weeks and I'll reduce the manufacturing costs by 15%.
MANAGER: I'm impressed! Give it over to production, now!

Let's carry this play to the point, where we check costs as the job progresses.

MANAGER: Do you have these costs under control?
DESIGNER: Yes, sir, we know what our costs are at all times.
MANAGER: That's fine, what do you do when you identify an over-run condition?
DESIGNER: We cry a lot.

The well-planned and organized engineer should rarely find himself in such a situation. But, if management did not provide all the engineering support functions to put at the design engineer's disposal, the above dialog could become biographical.

Value engineering is one of the engineering support functions. Over 12 years ago, DEP Procedure 0605 (Value Improvement Program) established

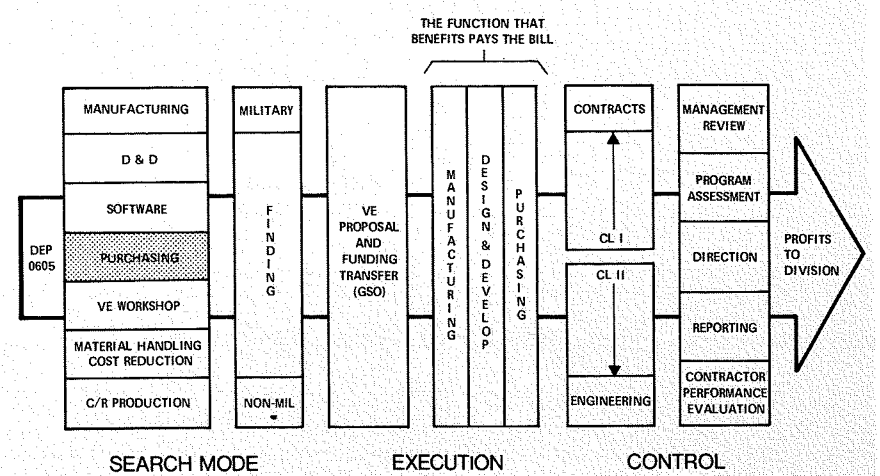

Fig. 1—EASD value engineering plan.

value engineering as a means of providing its customers with the highest value for their dollar. Like all procedures, this was a guide, and as such had to be shaped through a divisional operating instruction to accommodate the needs of EASD; the basic plan is illustrated in Fig. 1.

Upon examining other VE programs over the years, one premise stood out as an uncompromising baseline: the major factor in a successful VE function is its relation to the rest of the company's operations. Value engineering is sought after when it demonstrates consideration for the impact of change on all departments. To be meaningful, a VE program must

1) Blend with all functions without compromising cost reduction;
2) Serve the program director; and
3) Be oriented to contractual obligations and divisional procedures with cost reduction as a common denominator.

As EASD management has found, the addition of a value engineer to the staff does not provide the elixir for all economic ills and ails. There must be a plan, and there must be funding.

Funding

Pull me out of the cave and I'll give you the lamp.

No, give me the lamp and I'll pull you out of the cave.

Interchange "VE" for the "lamp" and "excess costs" for the "cave", and it is apparent how many a VE effort is as frustrated as Aladdin was.

As described before, the program director will align disciplines that will provide him the tools to 1) make it work, 2) ship on schedule, and 3) make a profit—in that order. This does not imply that profit is ignored. But, if the design doesn't work, it can earn no profit. If it is not shipped on schedule, there is an immediate negative impact—and perhaps a loss of profit, if not future business.

It may appear paradoxical that the very purpose of this engineering program should take the low order of attention. But there must be efficient execution of the first two phases—"make it work" and "ship on schedule"—to accomplish the third—"make a profit." Therefore, most resources and disciplines are brought to bear on accomplishing those phases.

As a result, funding proposed for the design task either

1) Did not include an allocation for value engineering or
2) It was there, but was used for the design effort.

Under these conditions, where value

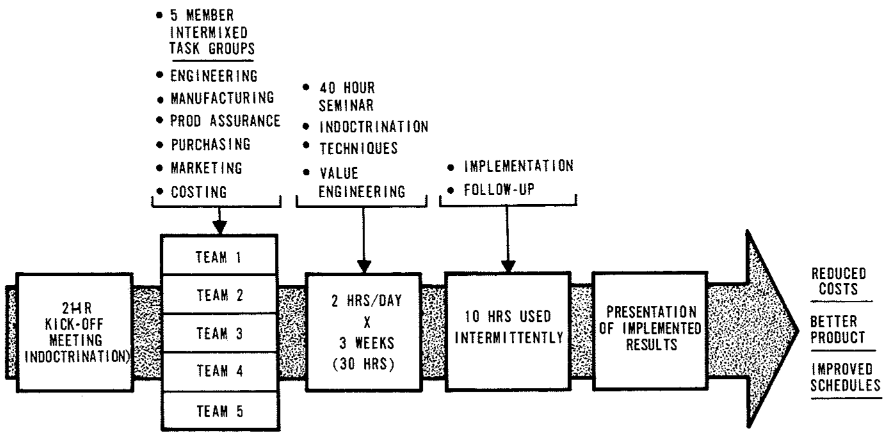

Fig. 2—Value engineering workshop plan.

engineering is not a mandatory function, it will atrophy. If we were to mediate Aladdin's problem today, we would have put his lamp in escrow while the two principals got on with the negotiation, each, later claiming his fair share of the lamp. This analogy gave EASD the breakthrough for some initial value engineering program successes. Value engineering is "investment" funded during its "search mode," that is, until it "homes in" on a specific problem.

Q: Then who pays?

A: The program that benefits.

Q: When does he pay?

A: As soon as the value engineering effort begins.

Q: How does the program benefit?

A: Its funding allocation is credited proportionately. The benefit may be cost-avoidance action and this is recognized as tangible but seldom measurable.

Q: Suppose the VE effort shows no return?

A: A feedback report is analyzed for subsequent action. It is also weighed as an input to establish the average return. A realistic recognition by management that "you can't win 'em all" relieves the perfect-record pressure from subsequent decision making.

Q: Suppose he has no funds?

A: The program director will assign the use of his Shop Order, nonetheless. A small overrun due to VE activity is preferable to a larger overrun without VE activity.

Q: How is the value engineer turned on?

A: 1) The program director calls for his service; or, 2) the VE provides the program director a VE proposal for consideration.

Q: Who arbitrates conflict?

A: The program director exerts autonomous control because he is responsible for the success or failure of his project. Therefore, it behooves any VE proposal to provide some validation of its potential. VE processing also provides substantiating test data for implementation considerations.

Plan

The value engineering activity concentrates on three basic elements to search out superfluous costs:

1) The VE workshop-training-seminars
2) An ad hoc study team
3) Cost reduction awareness program

Workshop-training-seminars

Value engineering training is an essential ingredient to any cost-reduction-conscious organization. Courses and curricula are available at accredited colleges, such as UCLA; courses are also given by the Department of Defense, RCA, and the Society of American Value Engineers. EASD has developed a curriculum to satisfy its particular needs. Most educators advise, and many insist, it is vital to run a course uninterruptedly. Were we to ask some 20 persons, including design engineers, buyers, methods engineers, draftsmen, etc., to leave their jobs for one work week straight to attend class, the program would not get off the ground. To be successful, the program must consider the rest of the operations. The in-house seminar has proven to be the answer to EASD. It not only imparts the VE methodology to 20 people at a time, but the company benefits in direct savings by having in-house "live" projects for study by the teams.

Fig. 2 shows the typical plan for a workshop. The key? It is sensitive to EASD. It does not meet the best criteria for a training program, but the tradeoff provides EASD with a working plan that pays off.

Results? Some are direct, such as one workshop that returned over $750,000 to the division—a return of 1300% on the investment. Some are intangible, such as an increase in the number of employee suggestions and the increased quality. We encourage a heavy

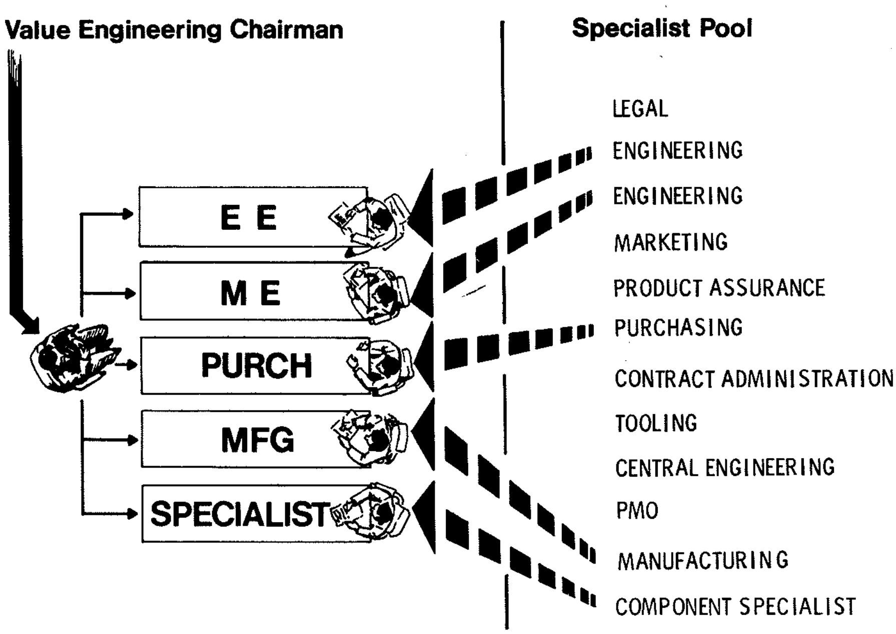

Fig. 3—The ad hoc study team approach.

mix of design draftsmen and technicians in these workshops on the premise that a healthy level of cost avoidance can happen on the drawing board. Buyers and manufacturing personnel greatly contribute to that area in producibility.

An ad hoc study team

The burdensome compliment is the management assumption that the addition of a value engineer to the staff will anesthetize the high-cost pains, or that the customer will nod approvingly by noting the presence of a VE block in an organization chart. The prescribed dollar savings goal, a percentage of the division's gross business, cannot be met by the value engineer alone. The complexity of only a few product lines and the coverage dictated by a DoD program requirement through MIL-V-38352 (contractual requirement for VE as a funded line item) demands the concerted effort of a team of experts before any appreciable costs can be extracted. So, taking a lesson from the data-bank concept, we use the expert-bank concept, generally known as the ad hoc VE study team (Fig. 3). Theoretically, this is an ideal approach. Practically, it won't work unless middle management accepts or is given to understand that value engineering is a mandatory function, much the same as design reviews. This condition arises because the value engineering studies are usually unscheduled events and the experts must now be summoned from a scheduled program and become responsive to a VE team captain. It is not easy to convince a program manager you are out to aid his cause by disengaging his people from scheduled work. How then is this reconciled? Certainly not by the DEP Procedure that holds him responsible for accommodating such an effort. But where he has seen striking results from this probing discipline, he will deposit some of his expertise in the expert bank, looking forward to the value engineering benefits that one of his subsequent programs may enjoy. In addition, his program will not suffer from unscheduled expenses because his people will be "investment-funded" or funded by the program benefiting from the services.

With that management problem solved, the value engineer selects this special team and guides them through the VE methodology. Once involved, designers will note "there's nothing too special about this cost reduction thing!" And they will be correct! Except that the goal is profit and more business, through greater value, rather than cost reduction as an end in itself. If expediting the schedule or improving performance will yield greater profit, additional cost may be invested to accomplish these ends. The only thing special is the organized approach and the stage to let it happen. Cost reduction is greatest when value engineering techniques are applied along with the basic elements of managing: planning, organizing, staffing, directing, and controlling. The teams will vary from two to six people and may complete their study within from one hour to one week. This program at EASD is a soft-sell campaign in constant motion.

Cost reduction awareness

Reporting on the effectiveness of our studies is conducive to advertising dramatic results. However, in so doing, we are apt to squelch one of the prime requisites for a fruitful cost-reduction program, i.e., the constant effort, and the think-cost-reduction atmosphere. A moderate cost reduction suggestion might very well be aborted in its embryonic stage because it would pale before a mighty five-figure saving recently published. We make no announcement which would develop a "tough-act-to-follow" effect. This makes room for a flow of motivational and technical presentations readily digestible. Posters are placed throughout the facility depicting cost savings from all functions, e.g., production, employee suggestions, material handling cost reduction team, etc., with amounts ranging from several hundred to several hundred thousand dollars saved.

Noontime presentations by specialty vendors directed toward cost reduction are arranged periodically in cooperation with our purchasing value analyst. A *Value Engineering Bulletin* is published whenever there is something of value to discuss. Bulletins can be technical or philosophical. A cost-awareness action may be no more than a casual conversation with our value engineer. Recently, following such an exchange of ideas, our shipping and receiving manager conceived the idea to change the shipping classification of a DoD commodity. At this writing, technical approval has been given to the value engineering change proposal, the negotiations are under-way for a potential six figure share for EASD.

Most changes initiated under the value engineering probe generally are subject to approval of a design manager; the implementation is then his responsibility. Where the recommendation is a class-I change on a DoD contract, the ECP will become a VECP when there is a cost savings to the customer.[1] Here, again, is the need for more team work. The value engineering incentive clause in a DoD contract allows value engineering to become a business within a business. As such, both marketing and contracts administration are needed to negotiate with the customer through the Armed Services Procurement Regulations (ASPR).

Reporting

Management cannot be expected to accept any program on good faith alone. A reporting schedule is maintained to provide management review and program assessment. Internal audits are done to satisfy DEP Procedure 0700 (Cost Reduction Program) for monthly reports to DEP Staff and to maintain an up-to-date status for DoD contractor performance evaluation. Because our government is increasing its cost reduction awareness, pre-contract award evaluation places a heavy weighting on value engineering. On most proposals to DoD agencies, we are obliged to report on the sustaining action value engineering generates. A good VE track record is good business.

Summary

Value engineering reinforces the strength of other programs and disciplines which serve management. By its complementary relationship, those disciplines and programs increase their likelihood of achieving total management objectives.

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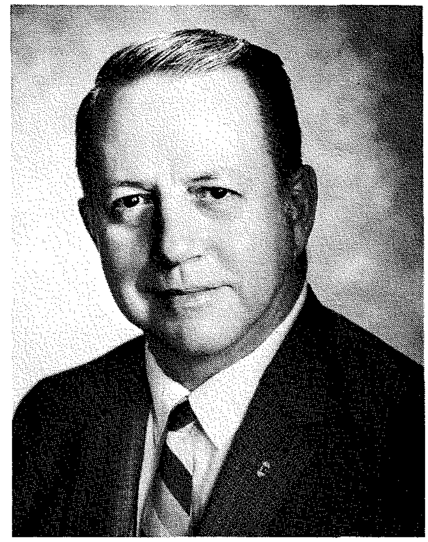
Engineering support and logistics—the EASD approach

G. F. Fairhurst

This paper describes the engineering support and logistics organization that has evolved at the Electromagnetic and Aviation Systems Division over the past four years. The increased performance and success of this group has been a gradual process—made possible by adopting the philosophy that the support function is a partner to, and an integral part of, the engineering organization. Crucial to this evolution was the recognition that RCA/DEP is basically an engineering and scientifically-oriented organization; this approach has many real advantages for the support group, for engineering, for the division, for the company and, most importantly, for our military and commercial customers.



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received the BSEE from the Worcester Polytechnic Institute in February 1943 and has over 25 years experience in Engineering and Product Support areas. He is responsible for all the integrated logistics and product support responsibilities of the division. Before his RCA assignment, he had managerial responsibilities at IBM and Litton Industries. His duties included executive management assignments in product support, customer engineering, field engineering and engineering laboratory responsibilities. He served as a Naval Aviation Radio/Radar Officer in the Central and South Pacific areas in World War II. He was employed as a civilian instructor in Electrical Engineering and Physics at the United States Naval Academy Post Graduate School from 1946 to 1948. He is a member of the Product Support Committee of Aerospace Industries Association, a member of American Management Association, was President of the Litton Data Systems Management Club, a past member of National Security Industrial Association, a member of the Board of Directors of the American Institute for Design and Drafting, a Charter member and Fellow in the Society of Logistics Engineers (SOLE), and a member of the National Board of Directors of that organization. Mr. Fairhurst was the General Chairman for the Third Annual Convention of SOLE held in Los Angeles in September 1968, and in September 1969 he was elected to the office of National President of the Society of Logistics Engineers.

THE QUICKEST WAY to describe the support approach at EASD is by a review of the engineering support and logistics organization chart, Fig. 1. Basically, this organization, which reports directly to the chief engineer, is structured into two coordinated *functions* with, roughly, equal personnel complements. The two major line organizations on the left of the chart have the function of direct support of the engineering design and development responsibilities. The two line organizations on the right of the chart have responsibility for supporting our customers during product design and manufacture and after delivery. Fig. 2 gives the charter of the engineering support and logistics organization at EASD.

Customer interest and influence

The responsibility of this double-barreled functional role in one organization allows rapid identification of, and response to, customer requirements as they relate to the basic design and development responsibilities. For example, reliability engineering (on the left side of the chart, Fig. 1) works closely with the designers in drafting and with product support engineering groups in the maintenance, provisioning and field engineering responsibilities. The structure which places parts standardization and data management within design drafting has proven to be valuable from an information standpoint, since it is within the drafting department that the basic documentation starts to become formalized for the first time.

Reprint RE-15-6-16
Final manuscript received January 5, 1970.

A more operational description of the dual-purpose engineering support and logistics organization is shown in Fig. 3. Note the almost direct repeat of the dual functional roles described in Fig. 1. To the left of this chart are the *functions* of the basic design support role as it receives requirements from the customer; on the right, again, we see the customer and the product support element *functions* which deliver the necessary data and talents after the equipment has been designed, built and delivered. An operational bridge between these two organizations is the maintenance engineering analysis function. The evolution and product of the maintenance engineering analysis influences at a very early stage, all of the important and customer-oriented functions seen on the right of Fig. 1.

Real contributions are important

In the final analysis, the successful performance of a support and logistics operation rests in the confidence of our engineering associates and in the professional service-oriented attitude of all the support personnel. With this confidence and professionalism, the support functions can truly be an integral part of every program. Competency and professionalism is also the only real factor which can overcome the basic psychological handicap which every service organization must face. There is, within all of us, this psychological trait which cries out "anything you can do, I can do better." A support organization has to continually prove, by performance, that this is not true of the specialized disciplines within its realm. Technical competence in support disciplines also means leadership in the use of new tools and techniques. The logistics organization, for example, must use the same tools that are available to design engineers; system-simulation models, queuing theory, and life-cycle cost models must be as much a part of our performance as it is in design engineering. We become and remain a part of the engineering team only by continuous educational updating of our skills and by the experienced application of those skills.

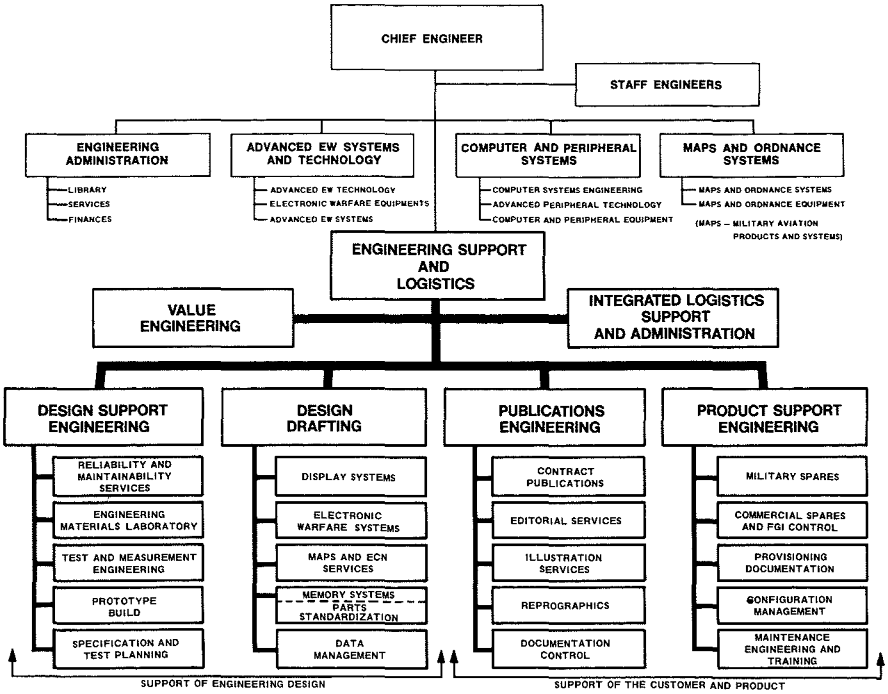


Fig. 1—Engineering Support and Logistics Organization.

CHARTER

Engineering Support and Logistics
Electromagnetic and Aviation Systems Division

ENGINEERING SUPPORT AND LOGISTICS is structured to provide this Division with a capability to meet three major responsibilities:

1. Provide design activities with the liaison and the engineering design support needed during development of new equipment.
2. Insure that the impact of logistics requirements are recognized and considered during the design phase.
3. Analyze, plan and implement the logistics support needed to insure that the operational and performance goals of the equipment are efficiently met throughout the equipment life cycle.

This organization recognizes the financial and operational performance advantages gained by a centralized grouping of technical and administrative disciplines needed to provide the special emphasis being placed on engineering design, logistics support and life cycle costing by both government agencies and our commercial customers. Specific detailed tasks and descriptive general functional responsibilities of the various support and logistics groups are shown in the two following pages.

Fig. 2—Engineering Support and Logistics Charter.

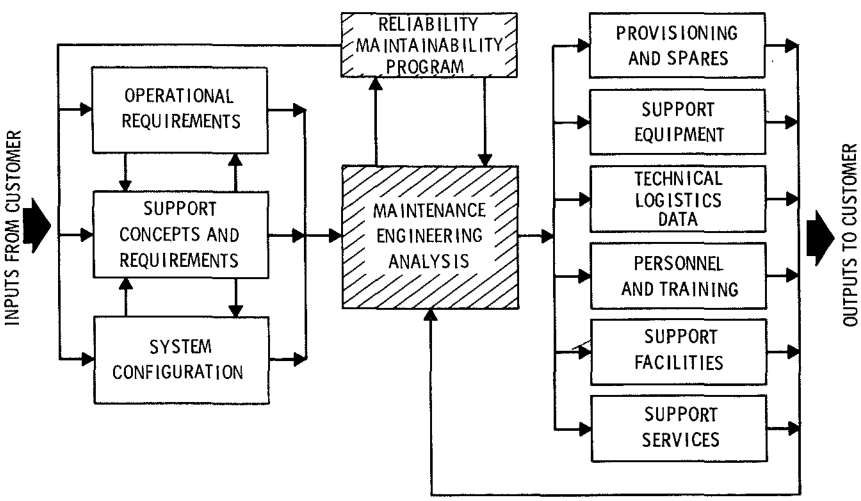


Fig. 3—Functional role of the Engineering Support and Logistics Organization.

Steps to success

The steps in management and planning of a successful support program are:

1) Interpretation of requirements;
2) Definition of tasks;
3) Selection of milestones;
4) Identification of problem areas,
5) Preparation of a plan; and
6) Implementation and control.

Program urgency, timing, and other factors will cause variations in the amount of involvement in these steps, but unless the support organization has truly considered (and can influence) these factors, then they are not the important part of the team that they should be. The performance of a service group must be better and more cost effective than can be obtained either from with the engineering design groups or from outside sources. In the areas of environmental testing, test planning, field engineering, publications, maintenance engineering, training, we must be so competent that all temptation to "do it myself" or go to outside vendors or consultants is removed. Both management and design engineers must be motivated, because of our performance, to think "in-house," The logistics organization, because it cuts across so many of the programs of a company, is in an excellent position to see which requirements keep popping up from program to program and to provide specialists to perform these tasks.

Our real technical competence is also improved by participation with the Design Engineering groups in a liberal rotation of assignments program. Design engineers can, and do, benefit greatly from a tour with field engineering; they can learn about the real problems which will be encountered in the operational environment. Assignment in test engineering, maintenance engineering, and training groups can help to give the young engineer a well-grounded background—and help him to see the big picture. The logistics groups must help groom these people and then willingly give them up to other activities, thereby creating an alumni from logistics working in design, manufacturing, and program offices.

Summary

To provide the right product and the right services and the best and most effective operational life of the equipment to our customers, there is a very urgent need for a company's support disciplines to *penetrate*, to *influence*, and to *permeate* the engineering organization. These actions take expertness, commitment, involvement, a service attitude, control and true professional performance.

Power supply overload protection techniques

F. C. Easter

Not allowing for load conditions outside the normal operating limits of the supply is the most prevalent cause for failure in otherwise well designed supplies. Various overload protection techniques are described in this paper, with particular emphasis on foldback current limiting. Foldback current limiting allows safe operation with the thermal design and current capability of the supply determined by full load requirements, rather than possible overload conditions. Such protection can be provided by the additions of a few low power components.

F. C. (Hap) Easter
Advanced Technology
Electromagnetic and Aviation Systems Division
Van Nuys, California
received the BSEE from the University of Kansas. As a Staff Engineer of the Advanced Technology group, Mr. Easter provides technical direction and consultation for the engineers in the group and support for management. He has made significant contributions in circuitry and in concept for the AN/SLQ-19 Countermeasures System and for the AN/ULQ-6 and Radio Frequency Oscillator countermeasure equipments. He has been a primary contributor in circuit development for three TWT power supply systems. Mr. Easter has pioneered in the application of solid-state devices to developmental and end-item equipments since transistors became commercially feasible. He developed the first all-solid-state power supplies RCA produced for a military equipment and designed the first two bipolar custom integrated circuits developed at RCA Van Nuys. During his 19 years with RCA, Mr. Easter was in the Aviation and Special Devices Sections in Camden and Missile and Surface Radar in Moorestown before being transferred to the West Coast in 1959. He is a member of the Tau Beta Pi and Sigma Tau Engineering Honor Societies. Mr. Easter has one patent approved and one patent pending.

Reprint RE-15-6-11
Final manuscript received September 29, 1969.

CATASTROPHIC FAILURES in otherwise well-designed power supplies occur most often from overload or short circuiting of the load. Various techniques are available for current limiting regulated power supplies. The following techniques will be examined and the advantages and limitations of each will be discussed:

1) Passive current limiting
2) Current limiting by base drive of pass transistor
3) Active current limiting
4) Supply shutdown on overload
5) "Fold-back" current limiting, with automatic recovery from overloads

Passive current limiting

A commonly used, extremely simple, regulated supply with passive current limiting is illustrated in Fig. 1, which is the schematic for a zener regulated supply. Maximum dissipation occurs in the active device at maximum supply voltage (high line) and no load. This is $(E_{out})\ (E1 - E_{out})/R1$. Maximum system dissipation occurs at high line and short circuit, where $E1^2/R1$ watts is supplied from $E1$ and is dissipated in resistor $R1$. As in most shunt regulated supplies, the short circuit

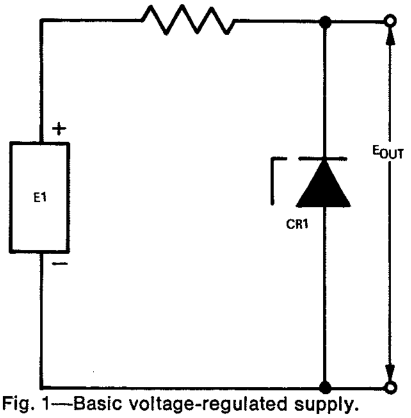


Fig. 1—Basic voltage-regulated supply.

current is determined by the source voltage and series impedance:

$$I_{SC}=E1/R1$$

Another example of current limiting via source impedance is found in ion-pump power supplies. An ion-pump power supply is used to maintain a high vacuum in a large volume cavity, such as a traveling wave tube. When the cavity is properly evacuated, the ion current is low. If an arc occurs, or the tube has not been operated for some time, a gaseous condition may exist and ion current will be high. The terminal voltage of the ion-pump power supply may decrease with load without seriously impairing the operation of the ion pump. However, short-circuit current must be limited for the protection of the load and the ion-pump power supply.

An ion-pump power supply often takes the form of a 3000-volt unregulated supply with a short-circuit current of 1mA. This can be mechanized with a transformer/rectifier/storage-capacitor combination and a 3-megohm series resistor.

Load current limited by drive of the pass transistor

A somewhat improved regulator may be obtained by using an emitter-follower configuration following the zener diode of Fig. 1. The load regulation is normally improved, as load-current variations are isolated from the zener by the current gain of the transistor. Further, a smaller, more economical zener may be used. Supply efficiency is improved as a series-regulated supply (as this has become with the added emitter follower) draws current as determined by the load requirements. In a simple shunt-regulated supply, full load current is drawn from the source even when there is no load.

The basic series-regulated supply of Fig. 2 is a straight-forward extension of the above concept. Transistor $Q1$ acts as an emitter follower, isolating the load from the transistor base circuitry; $Q2$ and its associated components can be thought of as a zener with feedback. The circuit would function so if $R3$ were returned to the base of $Q1$ rather than to its emitter.

However, the following is a more ac-

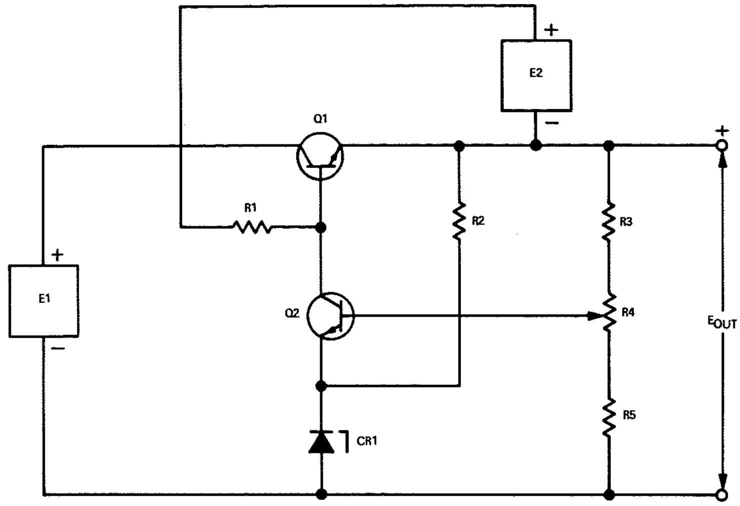


Fig. 2—Basic voltage-regulated supply.

cepted explanation of the operation of a basic series-regulated supply. Fig. 2 is a diagram of a very rudimentary voltage regulated supply. A complete supply would include protective devices, feedback stabilization, and probably greater current amplification. Power supply $E1$ is normally provided by a transformer/rectifier/filter combination. Power supply $E2$ is often a zener-regulated supply which is referenced to the output voltage. The function of $E2$ and resistor $R1$ is to provide a turn-on current to the pass transistor, $Q1$. Zener diode $CR1$ provides a voltage reference against which the supply output is compared. It may be noted that if $CR1$ is a 6.2-volt diode, its current can be adjusted such that its temperature coefficient nominally compensates for the base-emitter junction of $Q2$, resulting in an economical, low-temperature-coefficient supply.

Transistor $Q2$ amplifies the difference between the reference zener-diode voltage and a sample of the output voltage to be regulated. When the out-age divider to provide a sample of put voltage is higher than desired, transistor $Q2$ conducts more current, thereby shunting turn-on current away from transistor $Q1$, causing the supply output voltage to decrease to its desired value.

Resistors $R3$, $R4$, and $R5$ form a volt-the output voltage for regulation. Resistor $R2$ provides quiescent bias current to the reference zener diode, $CR1$.

In a supply as described above, the short-circuit current limit is:

$$I_{SC}=\frac{E2-V_{BE(Q1)}}{R1}\,\beta Q1$$

As $E2$, V_{BE} and $R1$ are fixed values, the short-circuit current is directly dependent on the beta of transistor $Q1$.

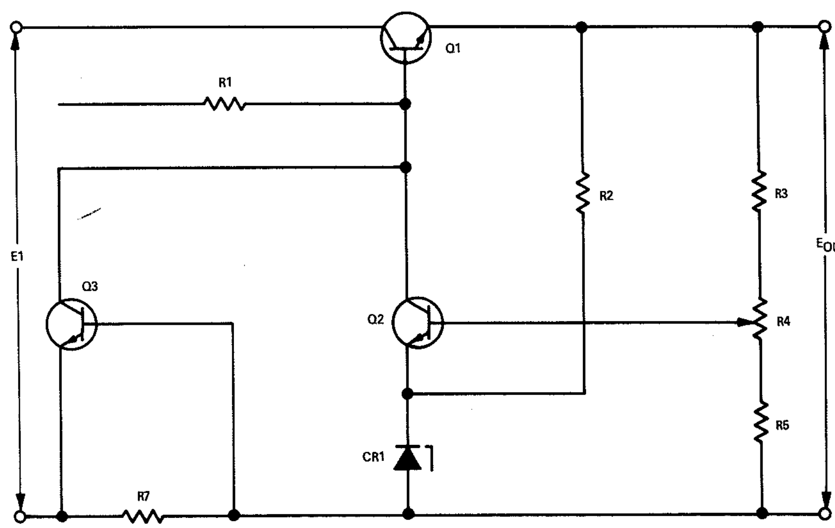


Fig. 3—Supply with foldback current limiting.

Therefore, the short-circuit current will normally vary over a range of greater than 3 to 1. For reliable operation, transistor $Q1$ and its heat sink must then be chosen to be able to dissipate three times the high-line INPUT power. This constitutes a large design penalty, to say nothing of efficiency and system cooling which will not be discussed in this paper.

Active current limiting

Short-circuit-current limiting can be provided by the technique shown in Fig. 3. In this circuit, when the load current provides an IR drop across $R7$ in excess of the base-emitter turn-on voltage for $Q3$, $Q3$ provides a shunt path for the turn-on current, thereby lowering the output voltage. It should be noted that in this configuration, short-circuit current will be slightly in excess of the maximum current which can be voltage regulated. Under short-circuit conditions, the source voltage $E1$ appears across the pass transistor $Q1$. Therefore, its maximum dissipation is considerably more than that incurred in operating at full load.

The short-circuit current can be approximated by

$$I_{SC3} = V_{BE}/R7$$

The power dissipated within a regulator circuit is determined by the characteristics of the regulator and the load. With passive current limiting, it was seen that resistor $R1$ (refer to Fig. 1) dissipated all the power under short circuit conditions.

In the circuit shown in Fig. 3, transistor $Q1$ dissipates nearly all the short-circuit power. This will closely approximate the product of source voltage, $E1$, and full load current. Thermal considerations are extremely important as most semi-conductor failures occur due to thermal stress. As systems increase in density and complexity, the problem of removing heat from the equipment often becomes the major problem.

Supply shutdown on overload

If in the circuit of Fig. 3, a silicon controlled rectifier (SCR) is substituted for transistor $Q3$, the power supply is automatically shut off when an overload condition is encountered. This limits circuit dissipation to that at full load. This has a disadvantage in that when the supply is overloaded, it remains off until external action is taken.

The SCR function can be accomplished by an NPN-PNP transistor combination as shown in Fig. 4. One advantage of this combination is that the base emitter turn-on voltage of a transistor is generally better controlled than the gate firing potential of an SCR. This configuring of an SCR is compatible with integrated-circuit techniques. An ordinary NPN transistor may be used with a lateral PNP transistor.

Foldback current limiting

Patent #3,445,751 was granted to the author for a circuit configuration that overcomes many of the disadvantages of the previously described circuits. The configuration is shown in Fig. 5. Its operation can be described as follows: transistor $Q3$ provides the same function as in previous circuits with the exception that its threshold is a function of both load current and supply output voltage. Transistor $Q3$ does not conduct and current limit the supply until the voltage drop across $R7$ exceeds the voltage across $R9$. The $R8$, $R9$ voltage divider provides a sample of the supply output voltage. When $Q3$ conducts, the output voltage will drop for the same reasons as described for the circuit of Fig. 3. When the output voltage drops, the threshold for $Q3$ decreases. This action provides a current limit that decreases as load is increased.

The voltage-current characteristic of such a circuit configuration is shown in Fig. 6. The maximum current can be set just above full load level by selection of $R7$, $R8$, and $R9$.

The short-circuit current is determined by the value of $R7$ and the base-emitter potential of $Q3$. Under normal conditions, voltage divider $R8$ and $R9$ provide a reverse biasing potential and, therefore, resistor $R7$ can be a larger value as compared to its equivalent in the previous circuit (Fig. 3). (R7 of Fig. 3)

The major advantage of foldback current limiting, as shown in Fig. 6, is that the thermal design of the supply is dictated by full load operation. The dissipation of the pass element under overload conditions is less than when the supply is operating at full load.

A second advantage is that recovery from overload is automatic. Less load current results in a decrease in voltage across $R7$. Hence, more voltage can

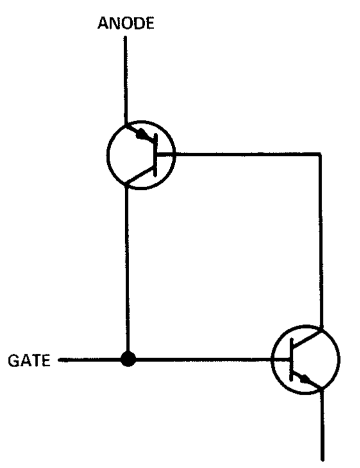


Fig. 4—This transistor pair can replace the SCR shown in Fig. 3.

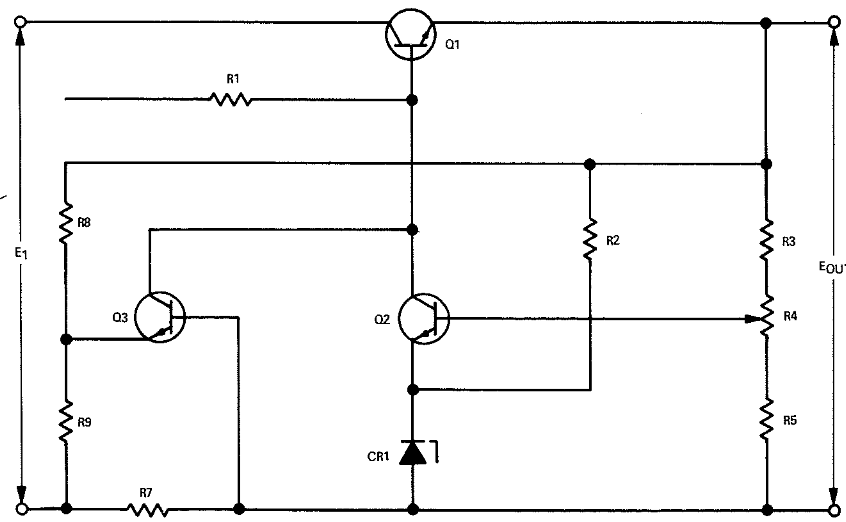


Fig. 5—A supply with foldback current limiting.

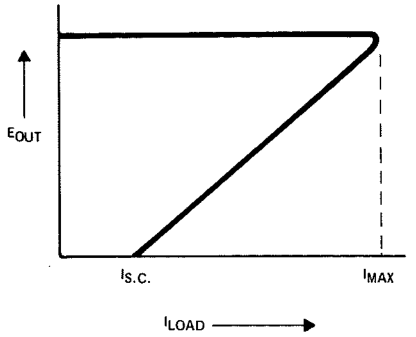


Fig. 6—Characteristics of foldback current limiting.

appear across $R9$ (and the supply output terminals) at the threshold of $Q3$ conduction. If the load is further decreased to within its operating limits, the output voltage is again regulated to the desired potential.

An alternate configuration for foldback current limiting is illustrated in Fig. 7. Again the individual components have been designated identical to those in foregoing descriptions in order to avoid the repetition of functional explanations.

The $Q1$ equivalent is more typical than a single-pass transistor. A Darlington drive of multiple-pass transistors with current-sharing emitter resistors is often used in regulated power supplies.

Under overload conditions, transistor $Q3$ again robs drive current from the pass transistor. The current-sharing emitter resistors serve a dual function as they also sense load current.

The voltage across $R9$ of the $R8$, $R9$ divider normally reverse biases the base-emitter junction of transistor $Q3$. Since $R9$ is returned to the base of the output transistors, the V_{BE} of the output transistors offsets the V_{BE} of $Q3$. The alternate configuration provides two possible advantages:

1) The short-circuit current may be reduced because the V_{BE} of $Q3$ is provided external to the current sensing resistor(s).

2) The base current of $Q3$, instead of emitter current, flows in the $R8$, $R9$ voltage divider. This further reduces the short-circuit current.

It is interesting to support the above mathematically. For the convenience of this paper, it will be assumed that V_{BE} is constant and equal for all transistors. In support of 1) assume that the beta of $Q3$ is infinite and that negligibly small current flows in $R1$. Now, in the circuit of Fig. 5, under short-circuited load conditions, the top of resistor $R8$ is at the same potential as the right end of resistor $R7$ and the base of transistor $Q3$. Then in accordance with Kirchoff's voltage law,

$$I_{SC}\,R7 = (R8+R9)\,V_{BE}/R8$$

and

$$I_{SC} = \frac{V_{BE}}{R7}\left(\frac{R9}{R8}+1\right)$$

for Fig. 5.

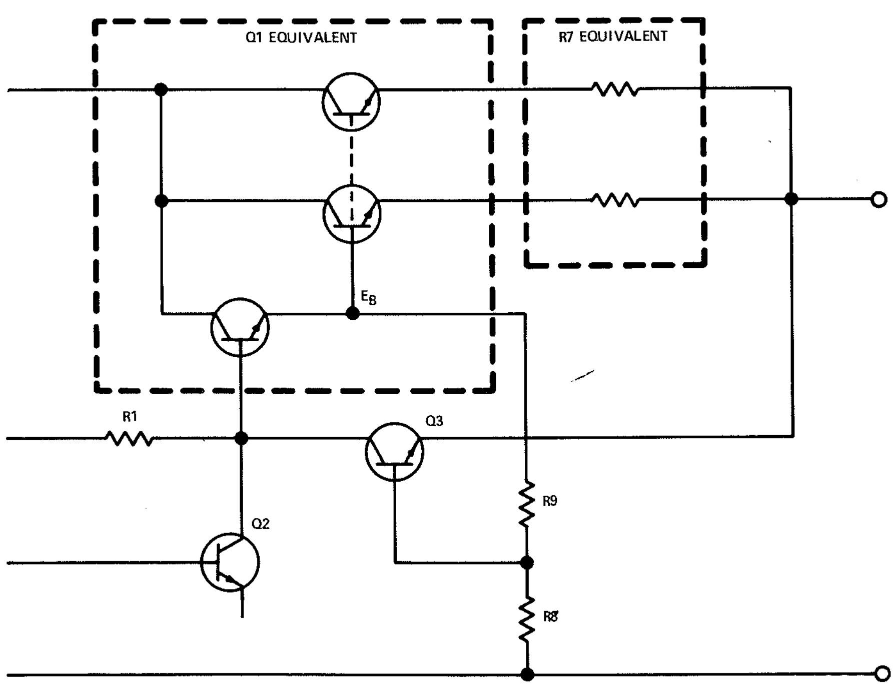


Fig. 7—Alternate configuration for foldback current limiting.

Similarly (in Fig. 7) under short-circuit conditions, the bottom of $R8$ is at the same potential as the right end of the $R7$ equivalent. The voltage of E_B (shown on the schematic) with respect to the short-circuited load is

$$E_B = V_{BE}\left(\frac{R8+R9}{R8}\right) = I_{SC}\,R7 + V_{BE}$$

from which

$$I_{SC} = \left(\frac{V_{BE}}{R7}\right)\left(\frac{R9}{R8}\right)$$

for Figure 7.

For the same voltage-divider ratio in both circuits, the above simplifying assumption infers that the ratio of the short circuit currents is

$$\frac{I_{SC5}}{I_{SC7}} = \frac{R9+R8}{R9}$$

Disallowing the above assumption of infinite beta and negligible current in $R1$, a more realistic number for short-circuit currents can be calculated. The principal error in the above equations results from ignoring the current through resistor $R1$. In Fig. 5, this current must flow through $R9$, thereby increasing the required drop across and current through $R7$. Short-circuit load current is increased by I_{R1} $(R7/R9)$.

In Fig. 7, the short-circuit load current is increased by I_{R1}, as Q3 just shunts this current around the pass transistors. Additionally, the drop across $R7$ equivalent must increase due to $Q3$ base current flowing through $R9$.

$$\Delta E = \frac{I_{R1}}{\beta_{Q3}} R9$$

$$\Delta I_{SC7} = I_{R1} + \frac{\Delta E}{R7}$$

$$= I_{R1} + \left(\frac{I_{R1}}{\beta}\right)\left(\frac{R9}{R7}\right)$$

$$\Delta I_{SC7} = I_{R1}\left(1+\frac{R9}{\beta R7}\right)$$

The short circuit currents with first order corrections are:

$$I_{SC5} = \frac{V_{BE}}{R7}\left(1+\frac{R9}{R8}\right) + I_{R1}\left(\frac{R7}{R9}\right)$$

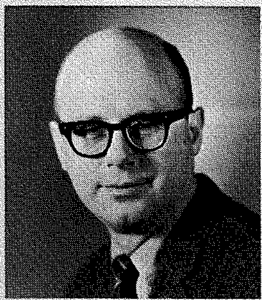
and

$$I_{SC7} = \frac{V_{BE}}{R7}\left(\frac{R9}{R8}\right) + I_{R1}\left(1+\frac{R9}{\beta R7}\right)$$

The David Sarnoff

The 1970 Individual Awards for Science

Dr. Perry Niel Yocom of the Materials Research Laboratories, RCA Laboratories, Princeton, N.J. is a recipient of the 1970 David Sarnoff Outstanding Achievement Award in Science . . . "for outstanding research leading to superior inorganic compounds for luminescent and electro-optic applications."



Dr. Perry Niel Yocom

Dr. Yocom has prepared many new sophisticated inorganic materials by a wide variety of synthesis techniques, and has made important contributions not only to their preparation, but to their characterization and utilization. Of particular significance is his contribution to improved understanding of the relationship between the synthesis of inorganic compounds and their luminescent properties, including the mechanisms of energy transfer in such systems. His work has had an important impact on the use of inorganic compounds as phosphors in commercial color television kinescopes. In addition, he has synthesized several other phosphors of practical importance, including small-particle high-brightness silicates as penetration phosphors; a very efficient *ZnS:Tm* blue-emitting phosphor having a narrow spectral characteristic, which made possible the development of a television system that can be viewed in direct sunlight with the aid of interference filters; and phosphors, double-doped with rare-earth ions, which convert the infra-red emission of a *GaAs* electro-luminescent diode to green or blue light. These latter phosphors are equivalent to the best yet produced. In addition to his contributions to the development of phosphors, Dr. Yocom has made very significant contributions to the synthesis of materials used as solid-state lasers. In the field of photochromic materials, Dr. Yocom has succeeded in synthesising $CaTiO_3$*:FE, Mo* with the highest known concentration of switching centers.

The 1970 Individual Awards for Engineering

A. Lichowsky of the Electromagnetic and Aviation Systems Division, Van Nuys, Calif., is a recipient of the David Sarnoff Outstanding Achievement Award in Engineerng . . . "for outstanding technical leadership and contributions in the fields of computer drum memories and microelectronic devices."

A. Lichowsky

Mr. Lichowsky has, in large measure, been responsible for much of RCA's success in drum memories, fuse devices, and anti-intrusion systems. As the result of a detailed analysis conducted in 1964, he found that drum memories could not be used in high-reliability applications. He then developed a lightweight, high-reliability drum memory which would meet a wide range of environmental requirements. This work resulted in several commercial and military design, development, and production contracts that have been worth more than $8 million. His contributions in microelectronics have similarly encompassed a broad range, starting with the analysis of user requirements and applications—leading through the various stages of development, design, and construction. In 1968, he designed the first three-ampere output stage of a monolithic electronic proximity fuze—a much better device than was previously available in the industry. This success convinced Mr. Lichowsky that higher current devices could be built, and a proposal was written which resulted in the award of a contract for a 25-ampere output stage to drive a ferrite phase shifter for electronically steered antennas. He has developed numerous other unique micro-electronic devices and techniques over the past several years. Mr. Lichowsky recently developed a new concept for an all-solid-state LSI computer mass memory which could replace electro mechanical memory devices. He has discovered a combination of new techniques in microcircuit-LSI and memory-cell design which shows promise of making such a concept cost-competitive. Successful demonstration of such a device could have a major impact on EASD business, as well as enhance RCA's position in the general computer market.

Jarrett L. Hathaway of National Broadcasting Company, is a recipient of the 1970 David Sarnoff Outstanding Achievement Award in Engineering . . . "in recognition of his many outstanding technical innovations in the field of broadcasting."

Jarrett L. Hathaway

Mr. Hathaway has been instrumental in developments which are highly useful in modern day broadcasting. Many of his original concepts have matured into systems and apparatus of great value to the National Broadcasting Company. Based on his early design of a radio microphone (which sold over the world by RCA), he has developed the present-day highly sophisticated radio microphone systems. These modern systems represent a new high in reliability of broadcast quality two-way communications without cable connections. The new radio microphones became practical through the application of his experience and knowledge; also through his persistence in obtaining a new frequency allocation for such devices. He also invented and developed the "interleaved sound" system which utilizes only the video circuit in supplying both picture and sound to selected stations on the network whenever there is a failure of the regular sound circuit. This unique system has saved NBC hundreds of thousands of dollars in rebates resulting from sound failures. He has developed automatic audio gain controls in cooperation with the Commercial Electronic Systems Division. The first units manufactured by RCA were based on his original equipment and since then, up to the advent of solid state components, all have followed principles described in his several patents. During the 1950's and 1960's, he developed ultra-portable camera equipment for picking up news programs such as ball games and national political conventions. His efforts allowed NBC to be the only network which obtained satisfactory close-ups via carryable cameras from the floor during the 1960 and 1964 conventions. By 1968, with new ultra-portable color cameras, he was again instrumental in successfully integrating them into programming equipment at the national politcal conventions.

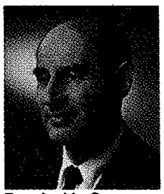
Outstanding Achievement Awards

RCA's highest technical honors, the annual David Sarnoff Outstanding Achievement Awards, have been announced for 1970. Each award consists of a gold medal and a bronze replica, a framed citation, and a cash prize.

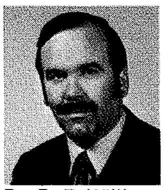
The Awards for individual accomplishment in science and in engineering were established in 1956 to commemorate the fiftieth anniversary in radio, television and electronics of David Sarnoff. The awards for team performance were initiated in 1961. All engineering activities of RCA divisions and subsidiary companies are eligible for the Engineering Awards; the Chief Engineers in each location present nominations annually. Members of both the RCA engineering and research staffs are eligible for the Science Awards. Final selections are made by a committee of RCA executives, of which the Executive Vice President, Research and Engineering, serves as Chairman.

This year, faced with two candidates for the Individual Award in Engineering whose achievements were very different but equally outstanding, the selection committee took the exceptional action of making two awards in that category.


Dr. R. E. Simon


Dr. A. H. Sommer


Dr. J. J. Tietjen

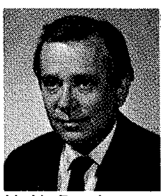

Dr. B. F. Williams

The 1970 Team Award for Science

Dr. Ralph E. Simon, Dr. Alfred H. Sommer, and **Dr. Brown F. Williams** of the Conversion Devices Laboratory, Electronic Components, Princeton, N.J., and **Dr. James J. Tietjen** of the Materials Research Laboratory, RCA Laboratories, Princeton, N.J., are recipients of the 1970 David Sarnoff Outstanding Team Award in Science . . . "for the conception and sucessful embodiment of new principles and materials technology in markedly superior photomultiplier tubes."

Drs. Simon, Sommer, Tietjen, and **Williams** have made outstanding contributions to the development of a new line of photomultiplier tubes which exhibit superior pulse-height resolution characteristics and improved signal-to-noise ratios. Applying a new principle—called negative electron affinity—which allows much higher secondary emission and photoemission in photo multiplier dynode sections, the group developed the new materials technology required to incorporate this principle and then cooperated with Electronic Components in Lancaster, Pa., to develop the means for manufacturing the new tubes. Two tube types—RCA 8850 and RCA 8851—are already commercially available, and approximately twenty five new tube types have been developed. It is estimated that this new line of photomultipliers will lead to approximately $2 million in new business for 1970 alone. In addition, the improved tubes are no more costly to manufacture than previous photomultipliers—providing substantial profit increases.


M. H. Burmeister


H. U. Burri


W. W. Carter


F. A. Hartshorne


M. J. Kurina


R. J. Mason


R. A. Morley


J. J. Napoleon


H. L. Slade


L. B. Wooten


D. W. Wern


Dr. M. Weiss

The 1970 Team Award for Engineering

Mark H. Burmeister, Hans U. Burri, Miles J. Kurina, Robert A. Morley, Herbert L. Slade, and **Lynn B. Wooten** of Aerospace Systems Division, Burlington, Mass.; **Frank A. Hartshorne** and **Daniel W. Wern** of Defense Communications Systems Division, Camden, N.J.; **James J. Napoleon** of Electronic Components, Harrison, N.J., and **Wayne W. Carter, Robert J. Mason,** and **Dr. Manfred Weiss** of Missile and Surface Radar Division, Moorestown, N.J. are recipients of the 1970 David Sarnoff Outstanding Team Award in Engineering . . . "for design, development, and construction of highly successful major electronic systems for the Lunar Module."

Messrs. Burmeister, Burri, Carter, Hartshorne, Kurina, Mason, Morley, Napoleon, Slade, Wern, and **Wooten** and **Dr. Weiss** developed and implemented the Lunar Module electronic systems, which performed flawlessly during the lunar landings and rendezvous of Apollo XI and XII. The ability of the equipment to meet the stringent performance and reliability requirements in a space environment was fully demonstrated in advance of the actual manned lunar mission. This effort, which took more than seven years and involved over $250 million worth of delivered equipment, consisted of four general tasks: 1) system development and mission analyses in which RCA participated with Grumman and NASA to determine the design of the overall mission, the hardware system parameters, and the manual and backup modes of operation; 2) development of the radar that provided precise direction, distance, and rate-of-change information during the critical rendezvous operation of the Lunar Module and Command Module; 3) development of the attitude and translation control assembly (ATCA) and the descent engine control assembly (DECA) which provided accurate attitude and position information to the Lunar Module and 4) development of the communications subsystem which provided the sole radio link between the Lunar Module and the earth while the Lunar Module was in flight and on the lunar surface. RCA's total participation in this program was characterized by a high level of interdivisional cooperation, individual technical excellence, and a sense of dedication to the overall mission goals. The successful culmination of these efforts was witnessed by more people than any other single event in history.

Two-color alphanumeric display

K. C. Adam

A two-color alphanumeric display has been developed by the Electromagnetic and Aviation Systems Division, using a proprietary cathode ray tube with two layers of phosphor (red and white) developed by RCA Lancaster. The primary design task centered around the requirement to switch the CRT anode potential between 11kV and 16.5kV in 1.5 milliseconds. Secondary design tasks included switching the deflection sensitivity and the focus voltage to compensate for the changing ultor voltage. Three units were constructed which successfully demonstrated the capability and usefulness of a two-color display.

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received the BS in Physics, with minors in Electronics and Mathematics from the University of Missouri at Rolla in 1959. Since his graduation, he has attended the University of California at Los Angeles taking courses in computer programming, transistor theory, and circuit analysis; he has also attended various in-plant classes at RCA covering integrated circuits and engineering mathematics. Since joining RCA in June 1959, he has worked in both the digital and analog fields. The analog responsibilities included transistorized magnetic deflection and electrostatic deflection circuitry developed for a direct-view storage tube used in a computer memory readout display for NASA's Saturn Program. The digital responsibilities included display equipment logic design for both the Saturn Program and the Air Force's Ballistic Missile Early Warning System Program. More recently he has been responsible for the analog design of an airborne display employing a multimode storage tube, for digital and analog design of a color CRT alphanumeric display, and for systems design involving military, ground based radar displays. Mr. Adam is a member of the Society for Information Display, Tau Beta Pi, and Sigma Pi Sigma.

Cathode-ray-tube displays are being used more frequently for the man-machine interface in large computer complexes. Such a display can supply vast amounts of data to the operator for his perusal and action. A requirement for vivid, attention-getting characteristics in certain portions of the presented data has become evident. Color has been used in the past for coding purposes[1] and it is this method of displaying certain alphanumeric information in contrasting colors that is used by the two-color alphanumeric display developed at EASD.

Former color alphanumeric displays used the tri-color shadow-mask CRT as the output device and not only suffered from poor resolution and character quality, but had stringent static and dynamic convergence requirements as well. The development of the single-gun, layered-phosphor CRT has disposed of the convergence requirement and made possible a brighter and higher resolution display.

Layered phosphor CRT

Fig. 1 represents the important construction and operating differences in the layered-phosphor (or two-color-type) CRT. The phosphor is deposited in separte layers, a layer for each color, separated by a barrier. The color of the light produced is a function of the energy of the electron beam used to excite the phosphor(s). Color switching is accomplished by changing the screen voltage (thereby changing the beam energy). For the lower anode voltage condition, the electrons strike the layer of phosphor closest to the gun causing it to emit light in its characteristic color. The electrons do not, however, have sufficient energy to penetrate the barrier and reach the second layer of phosphor which is deposited next to the face plate. As the anode voltage is increased, a point is reached where some of the electrons have sufficient energy to penetrate both the first layer of phosphor and the barrier and energize the second layer of phosphor, thus producing the second color. It should be noted that this color change or shift is continuous rather than abrupt; that is, as the screen voltage is increased, the color shifts accordingly. The tube is usually operated in a switching mode; the screen voltage is switched between two values sufficiently large to allow for the color differences to be easily distinguished.

Although the method of obtaining two colors from the layered phosphor tube may seem rather uncomplicated when compared to the shadow-mask tube, other tube parameters are functions of the anode voltage and must be modified for acceptable operation. Of primary concern is the change in magnetic deflection sensitivity and focus voltage.

The magnetic-deflection sensitivity changes as the square root of the anode voltage. For a two-to-one increase in anode voltage, a 41% larger deflection signal would be required if the page of date being displayed is to remain uniform. The focusing voltage required to maintain beam focus varies directly (approximately) as the screen voltage. A two-to-one increase in screen voltage would, therefore, require a 100% increase in focus voltage to maintain beam focus.

Other parameters which are related to the screen voltage are the spot size and brightness. The spot size is larger for lower anode voltages so that a higher resolution capability is available at higher anode voltages. Light output varies because of the difficulty in matching phosphor color and efficiency to the degree necessary to maintain a constant light output at different energy levels. Consequently, the light output at the higher screen voltage is greater than at the lower screen voltage.

Initial evaluation

For the initial investigation of the two-color CRT as a display output device, a prototype Model 70/752 Video Data Terminal was used as a test bed. This terminal is a self-contained unit using

Reprint RE-15-6-5
Final manuscript received January 12, 1970.

a delay-line memory and a monoscope character generator and may be operated off-line without a processor. Data input is made via a keyboard, and the output display is 20 lines of 54 characters each, refreshed at a 60-Hz rate. The normal output device for the Model 70/752 is a 12-inch rectangular CRT with a P4 phosphor, producing single-color white characters approximately 0.14 inches high by 0.10 inches wide. A type 7TP4 monitor kinescope was modified at the Electronic Components facility at Lancaster using phosphors developed by the David Sarnoff Research Laboratories and by Electronic Components. Operation of this tube was similar to the two-color tube previously described, with green being produced at 16kV DC and blue at 20kV DC.

The simplest method of integrating this tube into the Model 70/752 display and demonstrating two-color capability was to use a frame-sequential system. Using this method, a green-color frame was alternated with a blue-color frame—each frame consisting of 10 lines of 54 characters each. The 10 lines of characters for each color occupied the same physical positions so that the combined display consisted of 10 lines of 54 characters per line. Any character position of a line was available for either a blue character or a green character, with the refresh rate remaining at 60-Hz. To effect this mode of operation in the prototype display, changes were made in the logic, deflection amplifiers, tickler amplifiers (used for character generation), and the high-voltage power supplies of the Model 70/752. The most difficult of these changes to implement was in the high-voltage power supply area. The Model 70/752 used a fixed screen voltage of 12kV DC, while the blue/green two-color CRT required a supply with the capability of switching between 16kV and 20kV DC. Ideally, it would be desirable to have the high voltage switched as rapidly as possible. For a frame-sequential system, high voltage switching during vertical flyback would be satisfactory.

The vertical-retrace time required for the prototype display was 130.2μs. For evaluation purposes, laboratory high-voltage power supplies were used in conjunction with a 6BK4 vacuum tube as a high voltage switch. The characteristics of the switch resulted in a switching time of 1.8 ms from blue to green and 5.1 ms from green to blue. As a penalty for these long switching times, only the last 8 lines of the green field and the last 4 lines of the blue field were usable.

Initial results

The results of this initial investigation demonstrated the importance of color as a means of encoding additional information for display on the CRT. However, this feature would be more pronounced, and perhaps more appealing to the operator if colors with more separation than green and blue were used. Red and white, for example, would prove more satisfactory and perform better as an "attention getting" device in a display full of data. Also, to provide a usable display in a saleable configuration, the switching time would have to be improved to make available all 10 lines of data, and the necessary circuit changes would have to be packaged in the final unit.

Subsequent developments

As a subsequent development, three Model 70/752 Video Data Terminals were modified to display 540 characters with a two-color capability. The 12-inch rectangular CRT normally employed in these production units was modified by RCA Lancaster by replacing the P4 phosphor with red and white two-color phosphors (Lancaster presently designates this CRT as RCA developmental type C24092). The resulting two-color CRT produced white at an ultor voltage of 11.0kV DC and red at an ultor voltage of 16.5kV DC. Circuits were developed to switch the ultor voltage between these two levels and to switch the focus voltage between 2.4kV DC and 1.8kV DC. Other circuit changes were made to switch the horizontal and vertical deflection sensitivity, tickler sensitivity, and video signal amplitude. Fig. 2 shows a block diagram of the unit as modified.

Although the basic character timing of the Model 70/752 was retained, i.e. 13.02 μs character and 10 character-times for horizontal retrace, the delay-line memory was changed from 16.7-ms unit to a 10-ms unit. The logic was modified to allow the red and white data fields to alternately pass through the delay line, with the red characters being identified by the presence of the format bit. The format bit is part of the 10-bit character code in the standard Model 70/752 logic. This bit is, in turn, used by the logic to control gain and high voltage switching.

Data organized in this manner increases the page-refresh time from 16.7 ms (60 Hz) to 20 ms (50 Hz); one-half of the additional 3.3 ms was used at the end of each color field to increase the vertical retrace time (originally 130.2μs) by 1.65 ms. Thus, a total retrace time of approximately 1.78 ms is available for ultor voltage switching and stabilization.

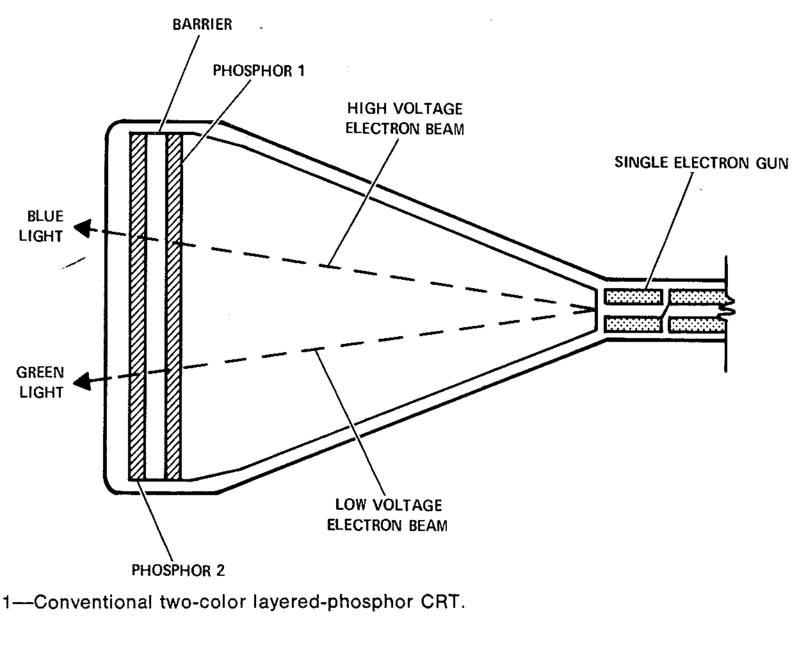


Fig. 1—Conventional two-color layered-phosphor CRT.

Switching-regulator circuit

As previously noted, the principal technical problem was that of switching the ultor voltage between 11.0kV DC and 16.5kV DC during the 1.78 ms vertical retrace. Fig. 3 represents a compromise solution in that it is a hybrid system employing both vacuum tubes and transistors rather than being entirely solid state. The unavailability of transistors with V_{CEO} ratings of several thousand volts resulted in the use of the type 7235 vacuum tubes for voltage switching. This tube is rated at 10kV DC maximum and, as used in the circuit of Fig. 3, provides an active drive for both positive and negative switching signals. This is important because both the tube capacitance of 50 pF and the stabilization capacitance of 250pF must be alternately charged and discharged by 5.5kV in the 1.78 ms allocated.

A voltage switching signal derived from the format bit is applied to the positive input of the MOS FET differential amplifier (A1) and after further

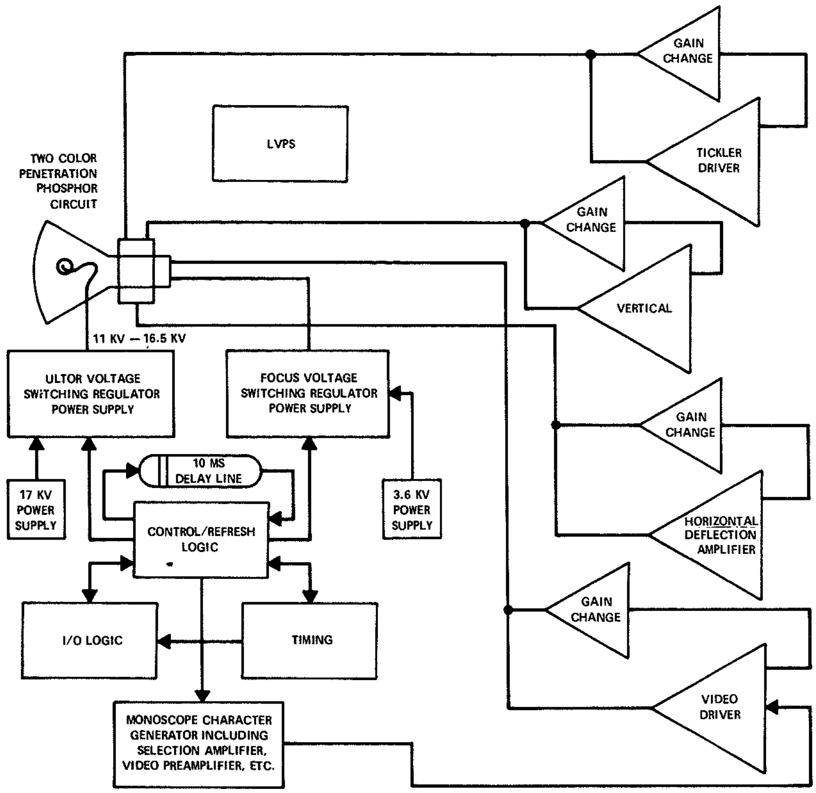


Fig. 2—Simplified block diagram of the two-color display.

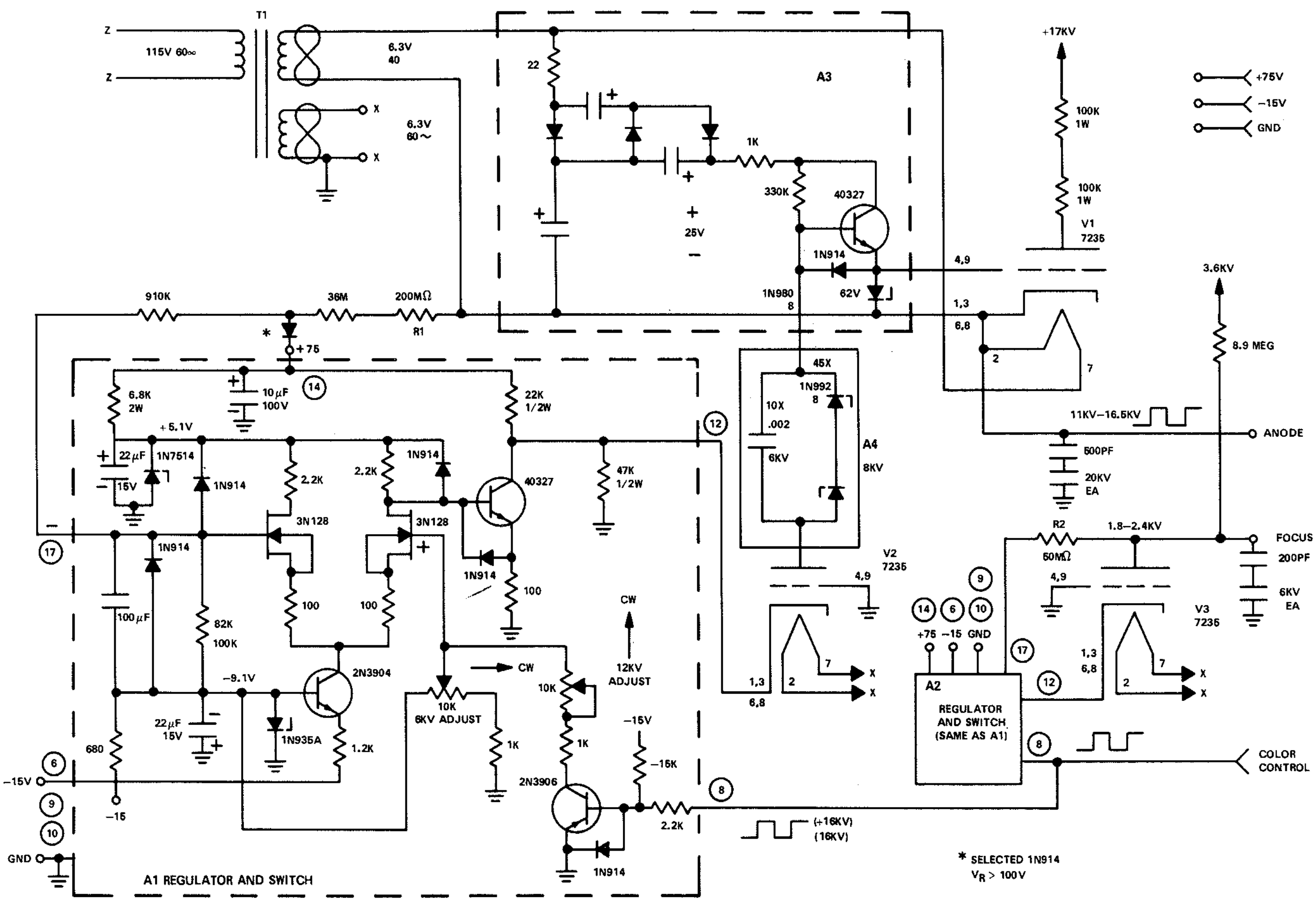


Fig. 3—High-voltage switching for the two-color display.

Fig. 4—Two-color video data terminal.

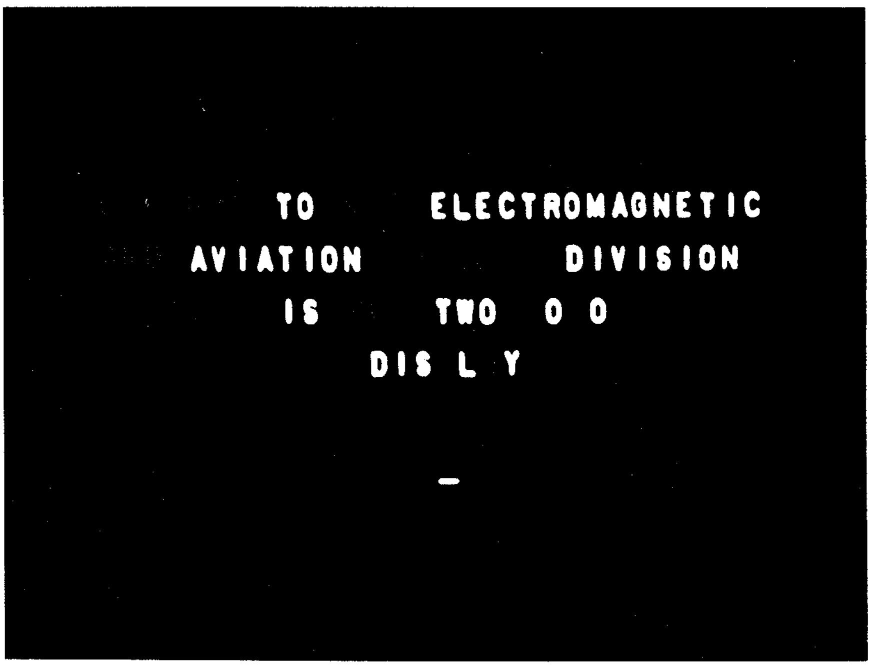


Fig. 5—Output of the two-color display.

amplification by the 40327 transistor is used to drive the cathode of V2. The 40327 transistor switches approximately 45 volts under transient conditions and the anode of V2 switches from 3.0kV to 8.5kV. The 8-kV zener-diode string (A4) translates this to the desired output voltages of 11.0kV and 16.5 kV. While V2 is used to actively remove charge from the load, V1 is used to actively recharge the load capacitance to 16.5 kV and ultor voltage switching is accomplished in 1.5 ms.

Drive for V1 is obtained from the emitter follower on A3 which derives its supply voltage from a voltage tripler operating off the floating filament supply for V1. In this fashion, it is possible to supply charging currents at the high-output-voltage level without requiring excessive currents be drawn from the 17-kV DC power supply at the low-output-voltage level. Finally, the output voltage is sampled by the 237-megohm feedback-resistor string and used to drive the negative input of the MOS FET differential amplifier regulator.

Results

Three two-color video data terminals were constructed using the circuit modifications previously described. An enlarged rear cover was employed to contain the bulky components comprising the high voltage power supply. The unit was packaged as shown in Fig. 4 with only this minor modification to its external appearance. These units functioned satisfactorily, and have created considerable attention wherever demonstrated. The 600,000 inches/second writing rate, which results from the use of the monoscope character generator, limits the brightness of the red characters to somewhat less than optimum, however, they are quite vivid in a room not brightly illuminated. Fig. 5 shows the two-color output of the display.

Conclusions

The feasibility of a two-color display is undeniable, and its merit under certain circumstances is also unquestioned. Additional efforts to implement such a display with graphic capabilities would be well spent. Utilization of such a machine might for example encompass printed circuit layout with one side of the board in one color, and the opposite side in a second color. Benefit would also accrue if more than two colors could be generated.

The switching circuit and deflection-gain-change circuits should be improved, and transistorized if feasible. A multiple-gun CRT with the guns held at different potentials would obviate the requirement for voltage switching. Such a study is in progress at the RCA Laboratories, utilizing a partial deflection-yoke-shielding technique on the lower-voltage guns to automatically compensate for the increased deflection sensitivity.

While the layered-phosphor CRT is not anticipated to replace the shadow-mask CRT for general use, the characteristics are such as to assure it a place for high resolution applications such as high quality alphanumeric display terminals.

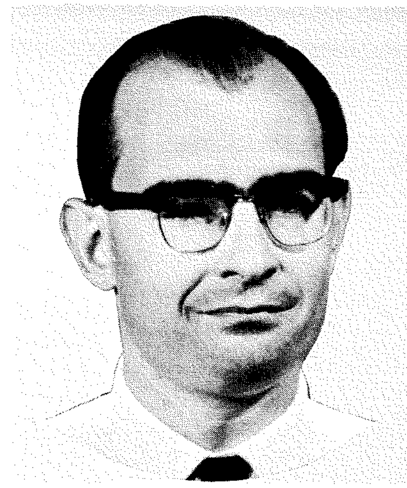
Reference

1. Conover, Donald W., and Kraft, Conrad L., "The Use of Color in Coding Displays," Wright Air Development Center Technical Report 55-471, ASTIA Document No. AD 204214 (Oct. 1958).

Character generators

R. C. Van den Heuvel

Character generators and their associated display circuits represent a vital link between man and computer. However, the development of character generators is lagging far behind the state-of-the-art of computers; as a result, the resources of present-day computers are not yet fully utilized. This paper outlines some general design problems and surveys the current state of development of character generators. It concludes with a description of two RCA-developed systems.



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received the BSEE in 1960 from the Milwaukee School of Engineering, Milwaukee, Wisconsin. Mr. Van den Heuvel has had experience in RF measurements and camera tube manufacturing (image intensifiers, vidicons, ebicons). He has also had experience in CRT design, including monoscopes. He was the main designer on Mars Mariner isolation circuits, high-speed stroke-writer, vector and circle generators (RCA alphanumeric/graphic display terminal), and character generators for 70/752 VDT and Moduler Display System. He has designed analog circuits for video data terminals. Specific assignments include the design of character generators, vector generators, D/A converters and high voltage power supplies. He is a member of the IEEE.

A CHARACTER GENERATOR can be compared to a typewriter—both are machines used to write. The typewriter prints on a sheet of paper, and the character generator "paints" on the screen of a display CRT. The major difference is that the typewriter is a mechanical (or electromechanical) device, limited in speed by the mechanical moving parts; the character generator, is electronic, capable of writing up to a million characters/second.

The CRT display is analytic device in that the illuminated spot can be in one location at a time only. Thus, any presentation on the screen must be generated by moving the spot about—much as a drawing is created by the point of a pencil as it moves across a sheet of paper. The spot can be moved from one point of the screen to another without leaving a visible trace by turning off the electron beam; this corresponds to lifting the pencil away from the paper. Like the hand guiding the pencil, deflection circuits exhibit inertia, and the accuracy depends on writing speed and transient characteristics.

Digital versus analog circuitry

Character generation in a computer system involves a transition from digitally- or incrementally-coded information to analog or continuous pictorial messages. The digital mode presents few problems with precision; the contrary is true of analog circuits. On the other hand, the generation of continuous (smooth) functions is easy with analog circuits but incompatible (by definition) with digital circuits. As a consequence, the success of a given method of generating characters is a complex function of the assignment of digital and analog sub-circuits to the generation of precise and continuous analog deflection waveforms.

Emphasis on analog circuits can lead to overly critical circuits, subject to cumulative errors (drift, lack of closure, etc.), while emphasis on digital circuits can result in poor continuity. Disturbances and discontinuities also result from the need to reset and reprogram analog circuits, such as ramp generators and integrators, during the character generation cycle.

Character storage

A special memory circuit (usually a local read-only memory) is used to store the information needed to generate the characters. In simpler terms, the character memory stores information as to what the characters should look like. The amount of data to be stored is a function of the number and complexity of the symbols to be generated. Memory capacity, in turn, has a direct bearing on the cost of the character generator, and often constitutes the major part of that cost. Another element which strongly influences the type, criticality, and cost of the memory is the data rate from the memory to the rest of the generator circuits. Finally, the ease with which the memory can be modified or expanded is an important consideration.

Cross-coupling problems

At high generation speeds, signal paths play an important role in preventing unwanted signal components from reaching the output of the generator. Digital signals and their derived transients too often contaminate the analog output of character generators, causing "wiggles," "hooks" and other disturbances to occur in the line segments that compose the characters. The propagation of unwanted signals takes place mostly in the power distribution and ground return busses. In particular, a solid, unified ground reference in the analog portion of the circuit is a must. Special problems are also due to arise when analog signals must be generated in the memory itself, or in remote areas of the generator. Analog signal wires act as antennas and pick up ambient noise.

Human factors

Perhaps the most significant factor to consider is the operator. His reaction to what he sees on the screen is the end result. In evaluating the quality of the characters, one must not only consider their legibility, but also their psychological effects. Little is known as to how the brain recognizes written patterns, and the effects of font (or style), flicker, color, and background are difficult to determine. Since character font as well as the total number of characters to be generated have a direct impact on required memory capacity and generator cost, the end product invariably involves a hazardous tradeoff between cost and functional aesthetics.

A common pitfall is to neglect or underestimate symbol degradation originating in the electronic circuits. The

Reprint RE-15-6-7
Final manuscript received January 12, 1970.

human operator (especially the untrained variety) is quick to react to the slightest distortion and cannot always be reconciled with such accidental effects as variations in brightness, wavy lines, inability to close such symbols as *B, O, 8*, etc., or failure to effect a smooth yet well-defined transition from one line segment to the next.

Types of character generators

Character or symbol generators exist in many types and categories which can be differentiated according to method of generation, symbol memory, style or aspect of the generated symbols, reliability, speed and efficiency of the circuits, versatility, and cost. Typical generators include the monoscope symbol generator, the dot writer, the lissajous generator, and the stroke writer.

Monoscope symbol generators

The monoscope symbol generator is, in effect, a modified, closed-circuit television system. The camera tube (Fig. 1) is known as a monoscope because the target (screen) image never changes. That image consists of an array of all the symbols required and is printed or etched on the target. To generate a symbol on the screen of the main display CRT, a scanning raster similar to that used in conventional television, but of smaller size, is used to explore an area corresponding to the size of a symbol—both on the main CRT screen and the monoscope target. The raster scan used on the main CRT screen is synchronous to, and exactly duplicates, the one used on the monoscope target. However, the gross positioning of the raster on the main CRT display screen corresponds to the location where a symbol is to appear; while on the monoscope target, it corresponds to the location of the symbol to be generated. Whenever the monoscope cathode-ray beam sweeps across a symbol element (that is, line portion, etc.), on the target, an intensifying video signal is generated and applied to the main CRT electron gun, which paints a bright dot or line at the corresponding location on the main display screen. As a result, a faithful rendition of the selected symbol, as inscribed on the monoscope target, appears at the chosen location on the CRT screen.

The monoscope symbol generator is relatively simple and inexpensive, hence its popularity. The symbols generated are not limited in style and have a very pleasing aspect (Fig. 2). On the other hand, the scanning feature makes high-speed scanning deflection and very high-speed video circuits mandatory. The efficiency of the system is low in terms of the time spent writing versus time spent scanning. The use of a monoscope tube greatly simplifies the selection circuitry and takes care of all symbol memory requirements since the memory is embodied in the high-resolution, two-dimensional, and permanently-inscribed image on the target. Perhaps the greatest shortcoming of the monoscope symbol writer stems from the use of a monoscope camera tube, which is fragile, has a limited lifetime, and is subject to drift and structural changes.

The electrical output of the monoscope tube consists of a rapid succession of ON and OFF video voltages. The same video pulse sequence can be generated by digital circuits, as is the case in the solid-state monoscope and the digitally-generated-video (DGV) generator. The difficulty rests mostly with the relatively large-capacity, high data rates and critical timing associated with the digital memory.

The solid-state monoscope uses the same scan pattern on the main display screen as its camera-tube counterpart. The DGV generator is intended for use with television monitors and the scan pattern on the display screen is identical to that used in standard broadcast television. The problems associated with the solid-state monoscope are due to the unusually wide video bandwidth requirements, the critical timing of the video bursts, and the non-linear vertical scan function (sinewave).

In the DGV, slower digital circuits can be used, but extensive additional buffering is required at the output of the generator because the generation sequence is not such that symbols are generated one after the other in sequence. Each horizontal scan spans the whole display screen in one continuous sweep and paints a portion of each symbol in a given line of text. Thus video information pertaining to a full line of text must be held in output buffers until symbol generation can begin. The aspect of the symbols generated by the DGV (Fig. 3) and the solid-state monoscope (Fig. 4) lacks the smoothness of the monoscope-generated symbols. The illuminated cross-hatched pattern within the structure of a symbol appears as definite, distinct line segments, and the character font must usually be modified to compensate for the loss in legibility.

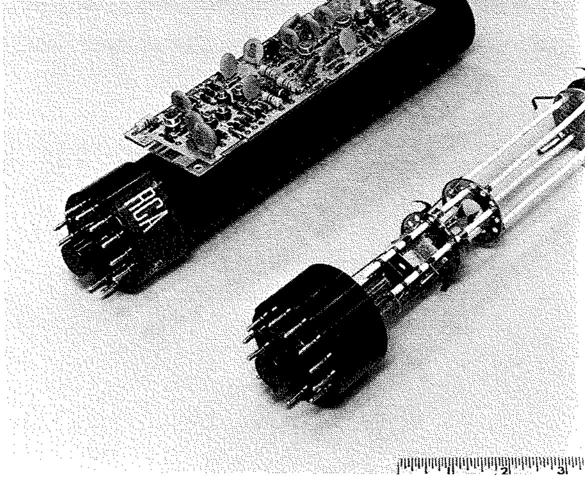

Fig. 1—In the external view on the left, the circuit board on top of the monoscope tube is the video pre-amplifier; to the right is the internal structure including socket, deflection plates, character stencil (target), and signal electrode.

Dot writer

The dot writer is a symbol generator in which the major emphasis is on digital circuits. Here, symbols appear to be drawn with dotted lines (see Fig. 5). This effect is obtained by intensifying a number of dots within a rectangular array of typically 35 dots (5 dots wide x 7 dots high). To generate a given symbol, the electron beam of the display CRT is positioned successively in each of the 35 locations corresponding to a single symbol area at the desired display-screen location. At the same time, the video circuits of the symbol generator cause an intensifying signal to be applied to the grid of the display CRT whenever the spot location corresponds to an element of the symbol to be generated. The use of digital circuitry makes it possible to use standard, uncritical solid-state circuits. There is some restriction on the quality, style, or aspect of the generated symbols, depending on the number of available dot locations—which is to say that symbol quality remains marginal where cost, speed, and efficiency are important considerations. One variation from the above method includes a version where only the illuminated dots are generated. Here, a lower number of dots is used for every symbol. In all cases, each dot corresponds to a switching operation: a jump in both x and y CRT inputs and a memory location.

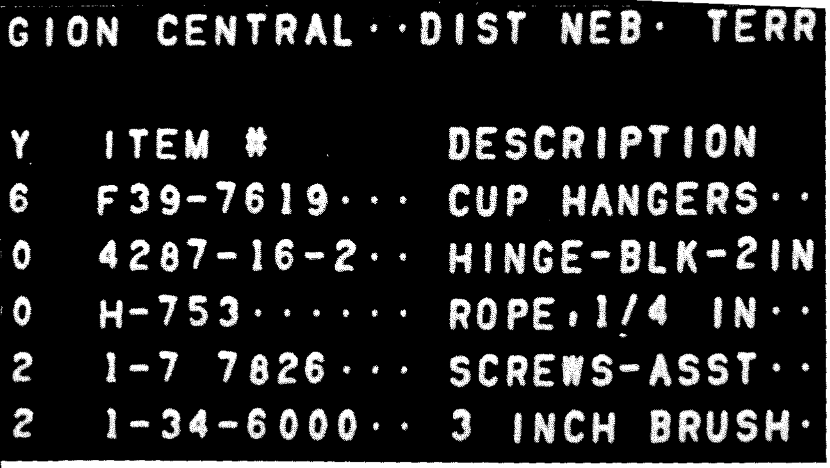

Fig. 2—Monoscope-generated symbols. Portions of typical presentation on display screen. RCA 70/752 Video Data Terminal).

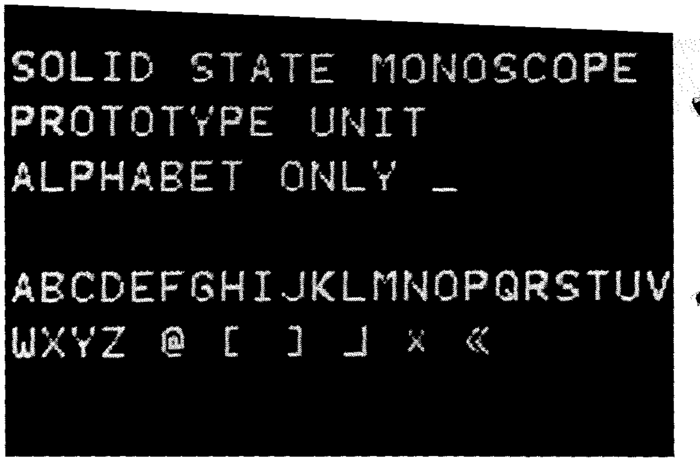

Fig. 4—Unretouched photograph of characters and symbols as generated by the prototype solid-state monoscope; the minor "glitches" are due to distortion in the vertical scan sine-wave and can be eliminated.

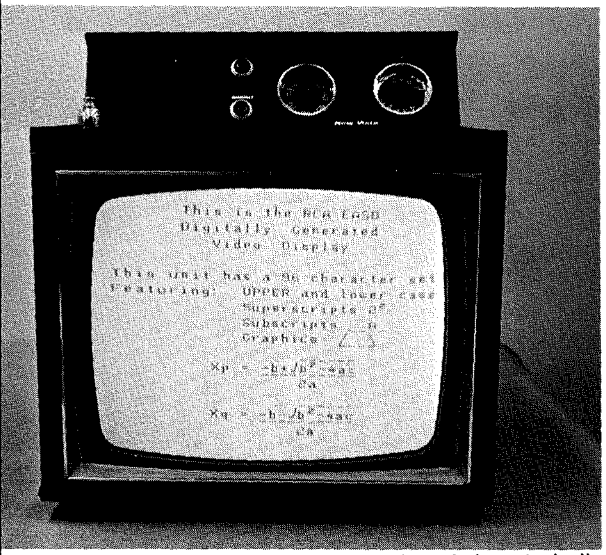

Fig. 3—Digitally-generated video (DGV) symbols as typically generated on a TV screen. White characters on a black background can also be produced.

Lissajous generator

In some symbol generators, which use both digital and analog circuits, memory locations correspond to a great variety of straight or curved line segments. As a result, memory requirements can be reduced and generation speeds increased for a given symbol quality. A typical embodiment is known as the lissajous symbol generator. By combining the outputs of a number of analog circuits (mostly ramp generators, integrators, oscillators, and gating circuits) a great variety of curvilinear shapes can be obtained. However, the critical timing and phasing of the various circuits result in complex switching requirements. The difficulty of changing the numerous time constants and periods of oscillation makes it complicated, if not impractical, to contemplate variable generation speeds. Finally, the style or aspect of the generated symbols is strongly influenced by the nature of the analog circuits. Typical of this problem could be the restriction to more or less standard circular or ellipsoidal curves, resulting in uncontrollable stylizing effects.

Stroke writer

A compromise measure—where the advantage of reduced memory requirements is in great part retained and circuit flexibility enhanced—consists of using only interconnected, straight-line segments to compose the various symbols. The resulting symbol generator is a stroke writer (Fig. 6). An economical way of building a stroke writer consists of generating the same deflection waveform for all symbols. To this end, a single basic symbol is generated which contains all the line segments encountered in the symbols of the whole symbol repertoire (the same idea was previously exploited in the Nixie tube). When a given symbol is generated, the CRT spot follows the same standard path as for all other symbols (sometimes referred to as a "track") but the video is turned on only when painting a line segment encountered in the intended symbol (Fig. 7). The memory must store only a simplified sequence of video pulses for each symbol; hence the low cost of the generator. The simplified stroke-writer just described is characterized by pronounced stylizing effects and rather unsatisfactory characters. The human engineering factors involved will prevent its wide acceptance by the public.

EASD-built displays

The Electromagnetic and Aviation Systems Division has traditionally relied on the monoscope character generator in its display product line. Where many display manufacturers have had problems with character generation, RCA has consistently maintained high quality characters and the display terminals are well received by industry.

The most recent monoscope character generator belongs to the Modular Display System. Character time is 7.5 μs; total repertoire is 96 characters (upper and lower case alphabet, plus numerals and miscellaneous symbols; see Fig 8). As a consequence, it represents probably the most advanced monoscope character generator of its kind on the market. But such performance does not come easily. The specifications of the various circuits and sub-assemblies speak for themselves:

1) The monoscope camera tube has closely controlled horizontal and vertical deflection gains; horizontal and vertical deflection linearity must be in the neighborhood of 0.1%. Also, the monoscope tube is fragile and has a limited lifetime. Periodic adjustments must be done to the deflection and centering controls because of drift in the mechanical structure.

2) The deflection amplifiers for the monoscope (one for the x and one for the y axis) are known as (character) selection amplifiers and must be accurate to 0.1% also. Risetime is on the order of 200μs, and slew rate on the order of 100 volts/μs when driving a 50pF load. The amplifier is allowed a maximum time of 1.3μs to deflect the monoscope electron beam from the target location of the previous character to the location of the new character to be generated.

3) The monoscope target accelerating potential is 1.8kV. Accumulated drift and ripple deviations must not exceed $\pm$0.4%.

4) The video pre-amplifier has a typical gain of 60 dB and a bandwidth of 40MHz (high resolution TV is 35MHz).

5) The monoscope character generator features some 12 potentiometer adjustments and is expensive to maintain because of the need for semi-periodic maintenance by qualified service-men. Subassemblies, such as, monoscope tubes, high voltage power supplies, and deflection amplifiers are difficult to specify, procure, repair, and retrofit.

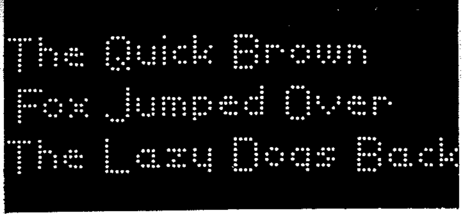

Fig. 5—Dot-generator symbols; a simulated presentation. This font was featured in the CC-30 system demonstrated by Computer Communications Corp. around 1966.

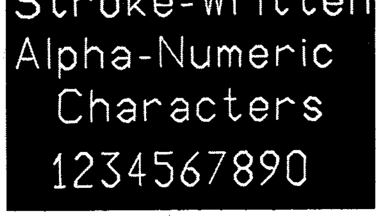

Fig. 6—Unretouched photo of alphanumeric symbols generated by prototype stroke writer. Differences in stroke width and intensity are due to lack of video control in the breadboard unit and are not problems in production units.

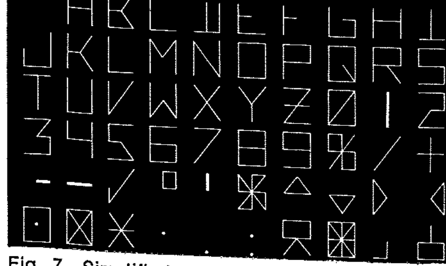

Fig. 7—Simplified stroke-writer symbols. A simulated presentation, using illuminated portions of the "starburst" track pattern (6th line, 8th symbol).

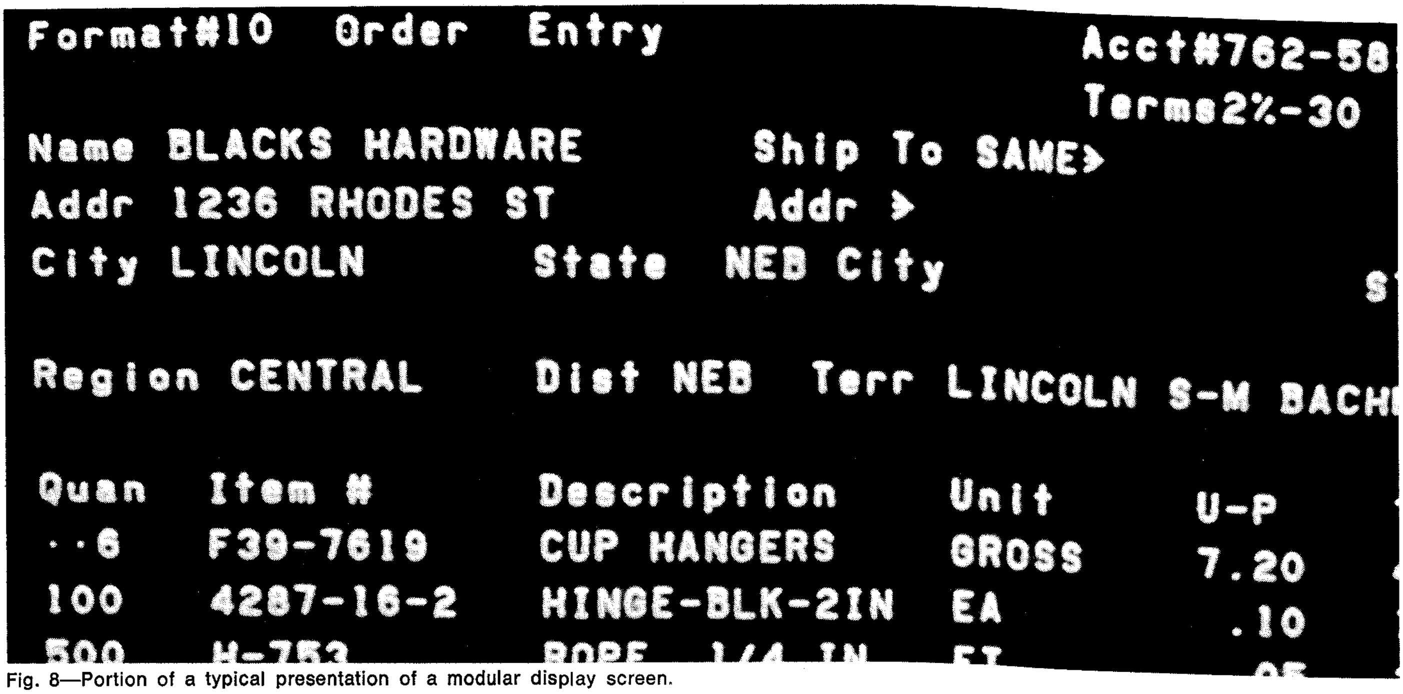

Fig. 8—Portion of a typical presentation of a modular display screen.

Because of the shortcomings and problems associated with the monoscope character generator, and because of the increasing need for faster and all-solid-state character generators in some applications, the stroke writer is beginning to receive increasing attention. Recently, new vector and stroke generation analog circuits have come of age at EASD which are capable of high speed, high quality performance. The latest among these circuits is the interpolating stroke writer. The interpolating generator uses a standard digital-to-analog (D/A) converter where the digital selection circuits have been replaced by special ramp generators. This is simple to implement with standard hardware, works well at high speeds, and offers good control over linearity and transitions between vectors. Cumulative errors are minimized and are resolved at the end of each single stroke.

A typical stroke writer capable of generating a total of 64 characters and symbols (as shown in Fig. 7) can be built for approximately the same cost of components as the monoscope character generator now used in the Modular Display System.

The high-speed interpolating circuits can be modified for the "Curviline" option as well as for constant speed of writing. The memory configuration takes full advantage of hybrid circuit technology to the extent that memory cost, per character or symbol, is now estimated at 40 cents or less (minus decoders and buffers). Because the selector (i. e., interpolating) circuits and the sense or summing amplifiers are used repetitively in great numbers, a long-range effort to produce the IC version of these circuits will further enhance the prospect of inexpensive, standard, solid-state character-generator sub-circuits. The specifications of the present stroke writer are

Total symbol time
3μs (max.) at the highest speed.

Strokes
16 max.

Symbol repertoire
64 alphanumeric and special symbols; easily modified, easily increased.

Font and special symbols
No limitation except that beginning and end points of component strokes must be located on (any) inter-section of an $m \times n$ grid pattern, where m and n are normally equal to or less than 8.

Optional features and uses
- Programmable italics (slant)
- Programmable change in height and/or width.
- Programmable variable line thickness and brightness.
- Rounding of corners (i.e., curviline operation).
- Programmable symbol rotation.
- Operation compatible with slow major deflection amplifiers as used in standard 70/752 terminals.
- Operation as both character and vector generator.
- Precision pattern generation.
- Intermediate image generation for computer generated cartoons.
- Multiple (simultaneous) character generation
- $x-y$ plotter output.

Conclusion

Character generation will have a long development future, because the fundamental requirements of data transfer, function generation, memory and display media are still difficult to define and integrate. As the necessary understanding and techniques evolve, increasingly simple and standard procedures will be available. The first step will be a transition to all-solid-state circuits. This will be followed by the evolution of universal memory and function generation circuits.

Graphic displays

G. P. Benedict | R. H. Norwalt

The Electromagnetic and Aviation Systems Division has developed a low-cost display that represents a significant advance in the field of computer graphics. Past systems have been limited either by their reliance on the computer interface and the large amount of software support needed or by their reliance on high-cost complex hardware to provide a functional capability. The RCA-developed system uses proven, low-cost techniques to provide the high degree of interactive capability without requiring that the computer input/output channels be dedicated to the display.

CURRENT TRENDS in computer graphic displays have moved in two, essentially different, directions. One approach has been to develop display systems which possess extensive capabilities in the area of off-line composition and editing of graphic and alphanumeric information. This type of system, although functionally attractive, has not received popular market acceptance because of the complexity of the hardware and the correspondingly high production costs. The other, and most popular approach, has resulted in the development of systems which are basically software oriented. These systems contain comparatively little hardware and can therefore be marketed at a significantly reduced price, e.g., $8,000 to $15,000. These systems, however, have functional disadvantages which limit their versatility and general capability, thus limiting the effectiveness of operator/computer communications. In addition, although they maintain minimum hardware costs, systems of this latter type have a significant cost impact on the software and computer time involved.

Disadvantages of present displays

Low cost, software-oriented graphic displays currently available are usually provided with either a storage-type CRT, thus eliminating the need for refresh of the displayed data, or they require that the central processor provide refresh over an input/output (I/O) channel. The inherent disadvantages of such systems are:

1) The type of storage tube currently used in this type of display has the disadvantage of low light output and low contrast ratio, thus restricting the user to low-ambient-light environments.

2) The relatively slow reaction time and transient display effects associated with changing or updating the displayed image on a storage tube of this type are relatively displeasing to the eye; thus, the application of such a display to future situations (in which rapidly changing or dynamic data conditions may exist) could be rather undesirable. In addition, "selective update" (i.e., selective erasure-and write) cannot be accomplished on these storage tubes. Old data cannot be removed or repositioned without erasing the entire screen.

3) Storage tube displays are not capable of maintaining a static presentation for any extended period of time without "fading." Repetitive message transmissions are therefore required from the computer at specified intervals when static display conditions exist.

4) Those systems which do not contain storage tubes or local memories and are refreshed from the computer have the obvious disadvantage of requiring that one I/O channel and a portion of computer memory be totally committed to the display interface. This results in inefficient communication, inefficient utilization of computer time, and renders the I/O channel useless for other devices.

5) None of the display systems under discussion provides the operator with an effective means of composing and editing graphic information off-line. This places the control of interactive graphic communication with the computer rather than with the operator, thus either limiting the display to those applications in which the role of the operator is essentially passive, or else requiring that a costly amount of complex software be generated to achieve the level of interactive communication required.

Future requirements

Future displays will have increasingly greater functional capabilities for more diverse and complex applications than currently exist, e.g., animation, figure analysis, three-dimensional projections, functions for drawing with topological restraints, etc. This will, in turn, require that the operator be given the means for rapidly converting ideas into visual objects which can be modified, repeated, expanded or contracted,

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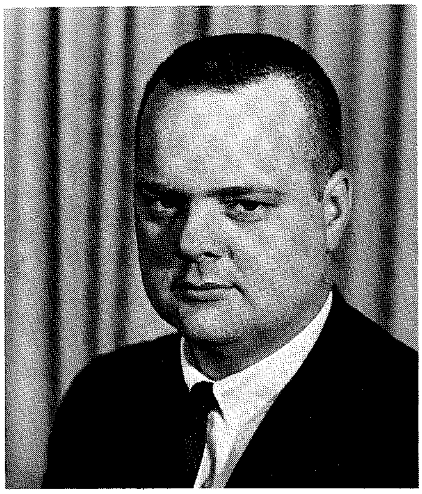
received the BS in Physics from the University of Southern California in 1961. He joined RCA at Van Nuys after receiving his undergraduate degree and has been responsible for the design and development of drum and disc memories and coincident-current core memory systems. Before receiving his degree, Mr. Norwalt was actively involved in the design and development of magnetic drum memory systems and associated solid-state control circuitry for Litton Industries and Magnavox Research Laboratories. From 1962 through 1964, he was responsible for the design and development of a large, switched-head drum memory, a large, fast, coincident-current core memory, and a miniaturized coincident-current core memory. During 1965 and 1966 he was responsible for specialized military displays and the EASD display research and development programs. Before his current assignment, Mr. Norwalt was Leader, Military and Advanced Displays Group—a position he assumed in 1966. His group is presently developing state-of-the-art character generators, memories, and deflection systems for future RCA Display Systems. He holds a patent on a semi-conductor-controlled pulse shaper and has a number of disclosures pending. He is a member of the Society for Information Display and the American Management Association.

Reprint RE-15-6-6
Final manuscript received January 12, 1970.



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developed in three-dimensions, rotated, and otherwise subjected to precise computational analysis, Therefore, the most effective approach to computer graphics should be one in which control of the display/computer communications link is given to the operator, who can then define his data, command the operations to be performed, and interpret the results of such operations.

These requirements point to the need for a completely self-contained system which, while providing the operator with an effective means of composing and editing graphic and alphanumeric information, can be manufactured at a cost that is attractive to a large percentage of the display market. The system described in this article, which was developed and produced on a recent IR&D program, provides the basic groundwork for filling this need, and, as such, represents a significant advance in the field of computer graphics.

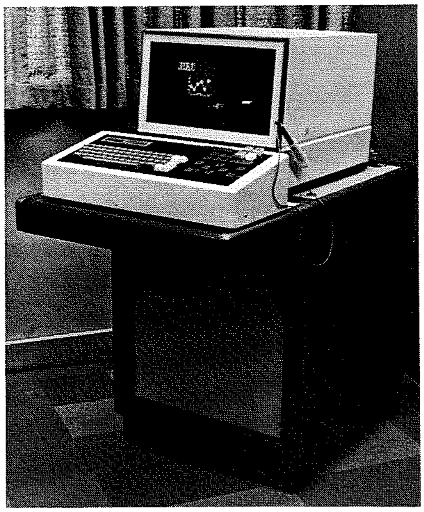

Fig. 1—RCA alphanumeric/graphic display system.

Basic design philosophy

To develop a low-cost system with extensive off-line compose and edit capabilities, the primary design efforts must necessarily be focused on the major cost items of the system, i.e., the character generator, vector/circle generator, deflection electronics, and the system logic. In addition, the cost and performance of each subassembly must be evaluated before the optimum design approaches can be determined.

For optimum character quality and resolution at minimum cost, a monoscope character generator was chosen as the best approach. In addition to the hardware savings inherent in this type of system, many of the necessary components, such as the selection amplifiers and monoscope, were readily available from other production systems.

The hardware complexity of the analog circuitry, especially in the area of the vector/circle generator, was of prime importance in reducing system costs. For this reason, the more sophisticated techniques of implementing vector operation (i.e., "constant velocity" systems, etc.) were rejected in favor of a "constant time" system. Although this type of approach requires a small amount of additional hardware for Z-axis compensation, the net simplification in circuitry resulted in lower hardware costs than otherwise could have been achieved.

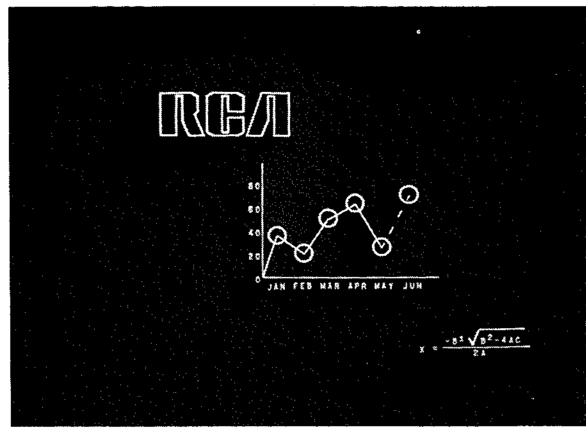

Fig. 2—Viewer screen showing a typical display.

To conserve power, and thus limit the cost and physical size of the low voltage power supplies and deflection system, the design limit of the deflection amplifiers were selected for half-axis operation only; i.e., the longest vector that can be generated without degradation of image quality should not exceed one-half the width or height of the viewing area. The remainder of the system, however, was designed with full-axis capability so that future expansion could be readily accommodated.

The mechanical design (packaging) and fabrication costs of the viewer unit were minimized by utilizing as many existing subassemblies as possible. These included the 12-inch CRT, monoscope, high voltage power supply, video-driver and tickler modules from a Model 70/752 Video Data Terminal, and the video preamplifier and character selection amplifiers from a Model 70/756 VDG system (Modular-Display Character Generator). Although most of the circuit-board assemblies required some degree of modification before being incorporated into the system, the basic design and hardware configurations remained virtually unchanged.

Two important design considerations were the selection of the refresh memory and the methods of implementing each of the logic functions of the system. A 2048-by-8 core memory was selected on the basis that

1) It is rugged and able to withstand the environmental conditions specified for most military equipment;

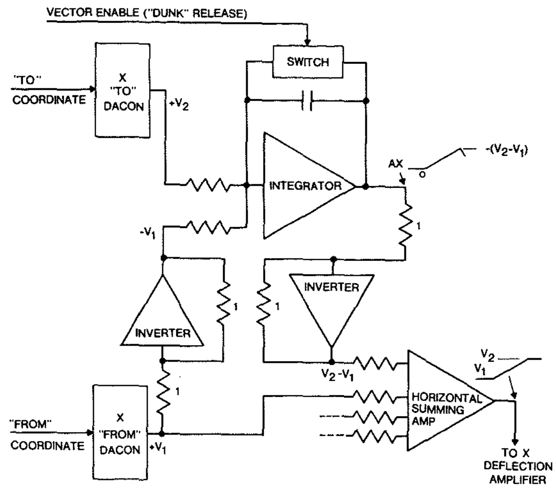

Fig. 3—Simplified block diagram of the horizontal vector generator.

2) It provides the capability of high-speed random access, thus alleviating some of the constraints which are imposed on the system by delay-line memories; and
3) It provides greater flexibility in the design of the I/O logic in that either parallel high speed or serial EIA-type interface structures can be provided without extensive logic modifications or resdesign.

Economical implementation of the system logic was accomplished by

1) Using the same integrated circuits as in standard production line systems wherever possible
2) Minimizing the total quantity of required IC's through judicious integration of system functions; and
3) Limiting the number of off-line functions in accordance with the cost goals of the system.

Alphanumeric/graphic display system

The alphanumeric/graphic display system (developed by EASD) is a stand-alone display unit which provides the operator with the capability of composing and editing text and graphic information off-line from the computer, transmitting this information to the computer, and exchanging and processing information on an interactive basis (see Figs. 1 and 2).

Table I—Functional control keys available to the operator of the alphanumeric/graphic display system

Operational mode	*Function keys*
TEXT or RANDOM/ALPHANUMERIC	SCREEN ERASE LINE ERASE CHARACTER ERASE CURSOR RETURN CARRIAGE RETURN CURSOR ADVANCE CURSOR BACKSPACE CURSOR RESET DATA INSERT
RANDOM/VECTOR and RANDOM/CIRCLE (for graphic composition)	ENTER, BLANK } graphic execute keys INCREASE, DECREASE } circle-size keys
Light-pen operation	BLINK TRANSMIT RELOCATE BLINK RESET BLINK ERASE

The system is comprised of basically three separate assemblies: the viewer, the cabinet or console assembly, and the keyboard. The viewer unit is a modified Model 70/752 VDT chassis and cabinet which contains a 12-inch, 70° CRT and yoke assembly; a high-voltage power supply; horizontal and vertical deflection amplifiers; tickler coil driver; a video chain with all associated pre-amplifier, driver, and Z-axis intensity compensation circuitry; a monoscope character generator and associated selection amplifiers; a vector generator; circle generator; and all of the required blanking, delay, and synchronization circuits. The CRT, high voltage power supply, tickler coil driver, video pre-amplifier and monoscope, video driver, and selection amplifier assemblies are packaged in the conventional manner as they are in the Model 70/752 Display System.

The remaining circuitry, which constitutes the heart of the analog system, is contained in a six-card analog nest located in the top rear corner of the viewer. The logic cards for the system were packaged in the lower cabinet or console assembly.

The lower cabinet or console assembly is a standard 30-inch high BUD cabinet with an attached shelf. It contains an 18-card logic nest, a 4096-by-8 core memory (only half of which is utilized by the system), a light-pen amplifier module, and two low-voltage power supply racks. The top of the cabinet, in conjunction with the extended shelf, serves as supporting surfaces for the viewer and keyboard assemblies.

The keyboard assembly contains all the controls and indicators necessary to the operation of the system except those associated with the alignment of the viewer. It contains a conventional 4-row alphanumeric keyboard which is used to generate ASCII data characters; a graphic function key assembly which provides the necessary mode, execute, operational, and position controls required for operation in the RANDOM mode; TRANSMIT, RECEIVE, PARITY, and OVERFLOW indicators; a function-switch interface module; and a keyboard interface module. Two connectors are provided at the rear of the unit for interface signals and power.

System operation

The system operates off-line in either of two major modes; the TEXT mode or the RANDOM mode. In the TEXT mode, the operator, using the standard alphanumeric keyboard, can compose text information in a 56-character/line, 32-line, page format (1792 total characters). A total of 64 different uppercase characters and symbols may be entered in this mode. In the RANDOM mode, the operator has the capability of composing vectors and circles as well as alphanumeric information through the use of the appropriate graphic control keys, three RANDOM sub-mode keys and the alphanumeric keyboard. Approximately 448 vectors, 61 circles, 1792 characters, or any combination thereof can be entered on the display when the system is in the RANDOM mode. Information entered in either the TEXT or RANDOM mode is displayed on a viewing area measuring 6 inches wide by 6 inches high.

A pointer-type light pen is provided which enables the operator to "hook" or identify any elements displayed on the screen. When an element has been "hooked," it is identified in memory by setting the appropriate bit. In addition, any element or elements which have been "hooked" are made to blink at a 15-cycle rate to enable identification by the operator. Once an element has been identified, it can be manipulated by the use of the various function keys that are provided. These keys enable the operator to reset the blinking element, selectively transmit information associated with it to the computer, relocate it to another position on the screen, or erase it. If more than one element has been "hooked," depression of the appropriate function key will either simultaneously or sequentially affect all the blinking elements. The functional controls available to the operator through the keyboard are given by Table I.

A GRAPHIC TEST key is provided which, when held depressed, enables the operator to observe all graphic data (blanked or unblanked) which have been entered in memory. In addition, the last 30% of each vector is made to blink at a 15-cycle rate so that the operator can also determine in what sequence and in which direction each vector was entered.

Transmission of all displayed data is accomplished by depressing the XMIT key located on the alphanumeric keyboard. This key is active in both the TEXT and RANDOM modes. A PROCESSOR OVERRIDE switch is also provided which locks out arbitrary interruptions from the computer.

Graphic generation is accomplished in the RANDOM/VECTOR and RANDOM/CIRCLE modes. When the system is in either of these two modes, positional information is indicated in the following manner:

In the RANDOM/VECTOR mode, a movable displayed (dashed) vector which emanates from the last *X-Y* coordinate entered in memory provides the operator with location information. One end-point of the vector is fixed at the point last entered in memory, and the other end-point moves at a fixed rate in response to the 4-key position control. This vector is called the "positional" vector. Once the positional vector is moved to the desired location, it is "fixed" and either blanked or unblanked with the appropriate graphic execute key (BLANK or ENTER).

In the RANDOM/CIRCLE mode, a displayed (dashed) positional circle, which moves at a fixed rate in response to the 4-key position control, provides the operator with position information. The radius of this circle can be controlled by the operator with the use of the two circle-size keys. The INCREASE key increases the radius of the circle at a fixed rate when held depressed; the DECREASE key decreases the radius of the circle at the same rate when held depressed. Once the circle is positioned at the desired location, it is "fixed" with the ENTER execute key. The BLANK execute key is disabled when the system is in the RANDOM/CIRCLE mode.

For generating vector information, the 6×6-in. viewing area is divided into 128 *X*-axis by 128 *Y*-axis position grids. The electron beam can be positioned at any point on this grid system, and straight line vectors can be drawn between any two grid points which are no farther apart than ½ axis vertically, ½ axis horizontally, or ½ diagonal. Position information is controlled by data in memory. This information specifies electron beam deflection to *X-Y* coordinates on the square grid system. Each grid point is uniquely defined by a 14-bit code (7 bits for *X* and 7 bits for *Y*). Beam deflection is always from the previously addressed coordinates to the new coordinates. In this manner, vectors are drawn in a "chain" fashion; i.e., each movement of the beam will necessarily result in the generation of a vector. Provisions are made, however, so that any one or more vectors may be blanked. Each vector, no matter what its length, is drawn in approximately 30 μs.

Vector generation

A simplified block diagram of the horizontal (*X* portion) of the vector generator is shown in Fig. 3; the *Y* portion is identical. The vector generator employs a *to-from* DACON scheme which always retains the last *X-Y* coordinate received from memory. The *to* DACONS are driven from registers in the logic nest which contain the *new X-Y* beam coordinates to which the beam will move. This information is transferred at the beginning of each vector period. The *from* DACONS are driven from registers which contain the *existing X-Y* beam coordinates. This information is transferred at the end of each vector period. It is important to note that the *from* coordinates, which are transferred to the *from* DACONS at the end of a vector period, are *identical* to the *to* coordinates which were transferred to the *to* DACONS at the beginning of the vector period. The outputs of the *from* DACONS therefore represent the reference point from which the beam will move during the current vector period. The outputs of the *to* and *from* DACONS are algebraically added to obtain the deflection distance and are fed into an integrator which generates the appropriate ramp voltage. This ramp voltage, in conjunction with the output of the *from* DACON, is fed into a summing amplifier, which then provides the resulting composite signal to the deflection amplifier. The two additional inputs shown on the horizontal summing amplifier are used to accept signals from the circle generator and text mode ramp generator.

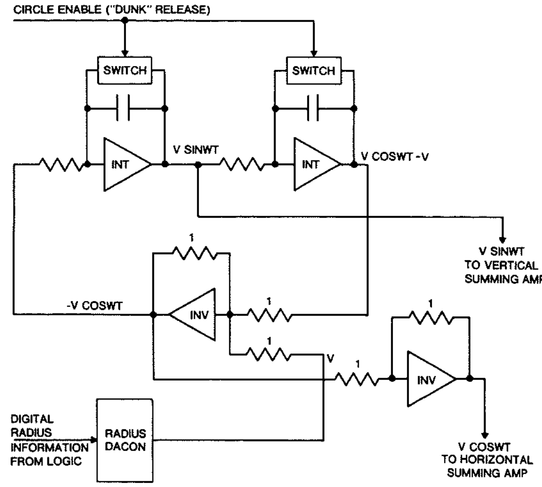

Fig. 4—Simplified block diagram of the circle generator.

Circle generation

The block diagram (Fig. 4) illustrates the principle of operation of the circle generator. First, a vector (blanked or unblanked) is generated at the desired center point. This can be any point on the 128×128 grid system. The radius of the circle, in digital form, is then transferred from the logic to the radius DACON associated with the circle generator. The radius DACON, in conjunction with the circle generator, then provides a voltage step (whose amplitude is consistent with the radius of the circle to be drawn) to the horizontal summing amplifier, thus causing the beam (which is blanked during this time) to move to the periphery of the circle. After the appropriate settling time has elapsed, the circle generator, which consists of two integrators and an inverter connected in a ring to form a sine/cosine oscillator, is enabled. The resulting cosine signal is transferred to the horizontal summing amplifier while the sine signal is transferred to the vertical summing amplifier. The beam is then unblanked, and the outputs of the summing amplifiers are transmitted to the horizontal and vertical deflection amplifiers, causing the beam to move in a counterclockwise direction. Upon returning to its original starting position on the circumference, the beam is blanked, the radius information from the logic is reset to zero, and the integrators are collapsed. The beam then returns to the center point of the circle, settles, and is ready to move again in accordance with the next positioning order from the logic.

The system timing is such that circle and vector generation periods are integral multiples of a character period. One character time is equal to 7.52 μs. One vector time is equal to four character times or 30.08 μs. The time allowed for traversing the circumference of a circle is equal to six vector times, or 180.48 μs. One vector time is allowed for the beam to travel from the center point to the periphery of a circle. This therefore limits the maximum radius of any circle to ½ the width of the viewing area (3 inches).

Character generation

The character generator converts digital data received from display memory into the video signals required for character display on the face of the CRT. The character generator employs a high quality monoscope identical to the type used in the Model 70/752 Display System. The monoscope stencil, in conjunction with the character selection amplifiers, provides the capability of selecting up to 64 different alphanumeric characters and symbols. To accommodate the relatively higher character rate associated with this system, slightly modified versions of the high speed selection amplifiers used in the modular display system were employed.

With the exception of the technique used for deflecting the main CRT beam when generating text information, the character generation scheme employed in this system is quite conventional. Main beam deflection in the horizontal direction is accomplished by providing an appropriate ramp signal to the horizontal summing amplifier. This signal is generated by the text-mode ramp generator located in the analog nest. Vertical deflection, however, is accomplished by decrementing the input to the *from Y* DACON by four counts at the end of each line of text. Vertical spacing of the lines is therefore directly related to the graphic grid system. Horizontal spacing of the characters, however, is not necessarily related to the grid system since the text-mode ramp generator is independent of the vector generator functions.

Data Transfer

The transfer of data between the alphanumeric/graphic display system and a remote processor is accomplished using voice-grade facilities terminating in a Bell System 202C or 202D data set.*

The alphanumeric/graphic interface operates in a bit-serial, half-duplex mode at a transmission rate of 120 10-bit characters/second. Each 10-bit character consists of a start bit, seven data bits, one parity bit, and a stop bit. No provisions for automatic dialing or unattended operation over the dialed voice network are included in this unit.

Character transmission is in the form of eight-bit bytes; i.e., seven data bits denoting the character code and one parity bit. Transmission of graphic information, however, is in the form of four 8-bit bytes. Normal transmission begins with the first address in memory. If transmission is initiated while the system is in the TEXT mode, transmission will continue until the first ETX that has been entered in memory is reached. If no ETX codes exist, transmission will continue until the entire content of display memory (except NULLS) is transferred to the computer. If the system is in the RANDOM mode when transmission is initiated, transmission will continue until 1) the first ETX code is reached, 2) the first NULL character in memory is reached, or 3) if no ETX codes or NULLS exist, transmission will continue until the entire content of display memory is transmitted to the computer. "Blink transmission" is accomplished by depressing the BLINK XMIT key located on the keyboard assembly. When this is done, an appropriate control code is transmitted to the computer followed by the memory location and all other data necessary to describe the blinking element (character code, *X-Y* coordinates, circle radius, etc.). If more than one blinking element exists on the display, they are all transmitted in the same sequence in which they were entered in memory.

When a received message is headed with an STX (indicating TEXT-mode data) under normal operation, all subsequent data will be sequentially stored in memory, beginning with the *first* memory location, and will be displayed in character form; i.e., *only* ASCII characters and symbols will be displayed if the message is headed with an STX. If the received message is headed with an SOH (indicating RANDOM mode data), all subsequent data will be sequentially stored in memory beginning with the first *available* memory location; i.e., the first memory location that contains a NULL (all zeros). In this case, all data are displayed in accordance with their message structure (both characters and graphic elements can be displayed).

The capability is provided for storing received data from the computer beginning at some specified address. To accomplish this, the computer will transmit a special 3-byte control word immediately following the STX or SOH header code. This control word specifies the memory address location in which the *first* 8-bit data character of subsequent data stream is to be stored. The capability is also provided for decoding and processing certain commands from the computer. These commands include ERASE and READ. When an ERASE command is received, the display immediately erases the memory. When a READ command is received, the display will transmit the content of memory to the computer *beginning* at the memory location specified in the command.

Acknowledgments

The authors thank Messrs. Johnson, Katagi, Luzansky, McAfee, Van Den Heuvel and Way for their extraordinary efforts. Also Messrs. Davis, Helbig and Turner whose counsel and guidance determined the basic configuration and aided the development of the display.

Hybrid microelectronic fabrication techniques

A. Levy

In microelectronics, hybrid technology is essentially a packaging technique. Choosing the proper combination of microelectronic techniques will yield devices with improved reliability, reduced cost, and overall optimum performance. This paper describes the methods used for fabricating hybrid assemblies in the Electromagnetic and Aviation Systems Division (EASD).

TODAY, the hybrid approach to microelectronic assembly has attained the popularity of the printed-circuit board. The reason being the unlimited flexibility it affords. In the widest sense, a monolithic chip mounted and bonded to a ceramic flat pack constitutes a hybrid assembly. A hybrid circuit could conceivably encompass thick- or thin-film networks, discrete and integrated uncased devices, plus a myriad of cased and discrete components.

Thin-film circuits

The term "thin" as applied here is somewhat ambiguous. Rather than defining thickness of deposition, it relates to the fabrication process involved.

There are a variety of methods by which thin films can be manufactured. The most common is vacuum deposition. The basic equipment used for vacuum deposition of thin films consists of a vacuum chamber with its associated pumps and gauges, plus hardware to support and manipulate the evaporation source and the substrates. Sophisticated film monitoring equipment can be added to any degree of automation or mechanization desired.

After the chamber has been evacuated and the evaporation sources are heated, atoms are emitted from the source and are propagated until they impinge on the substrate. The deposited thickness is a function of the time elapsed, the source temperature, and the chamber pressure.

Thin films may be evaporated selectively through a metal mask or over the entire surface of a substrate. Networks on substrates thus deposited are delineated through photoetching techniques.

Materials most commonly used for conductor networks are gold and copper. A variety of metals are available for resistor networks, most used being nichrome. Although glass substrates can be used for thin-film networks, high-density alumina (99.5% Al_2O_3) is commonly used for hybrid applications.

For the special case of microwave circuitry, initial layers are vacuum deposited with the subsequent buildup electroplated.

In general, the high fabrication costs of thin-film hybrid circuits limits their practical use to tight-tolerance resistor networks and high-frequency applications.

Thick-film hybrid circuits

Thick-film hybrid circuits are basically passive networks printed and fired onto alumina substrates. For defense applications, 96% Al_2O_3 alumina substrates are almost universally used. Lower density alumina, such as 85%, is used in certain industrial applications.

Conductor, resistor, and insulating materials are "printed" onto the ceramic substrate through metal mesh screens or metal masks. All process parameters in the fabrication of thick-film networks are critical as to their effect on repeatability. Fig. 1 shows a precision printer used in EASD. Printer parameters must be carefully adjusted, as their effect on deposition thickness and uniformity is considerable.

After printing, the deposited ink is dried to evaporate the solvents. Drying cycles range from 10 to 15 minutes at temperatures of 100 to 125°C. At

Reprint RE-15-6-14
Final manuscript received September 17, 1969.

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received the BS in Physics from LaSalle College in Philadelphia. Mr. Levy has been with RCA since 1953. He is responsible for the technical direction of EASD's microelectronic development programs. In this capacity he oversees the operation of the Hybrid Microelectronics Laboratory, the Wet Process Laboratory, and Microelectronic Advanced Manufacturing Technology. The groups' capabilities include the fabrication of hybrid and other microelectronic prototypes and the development of wet processes pertaining to rigid and flexible organic circuit boards. Mr. Levy has published numerous technical papers on microelectronic interconnections and applications. He is a Senior Member of the IEEE.

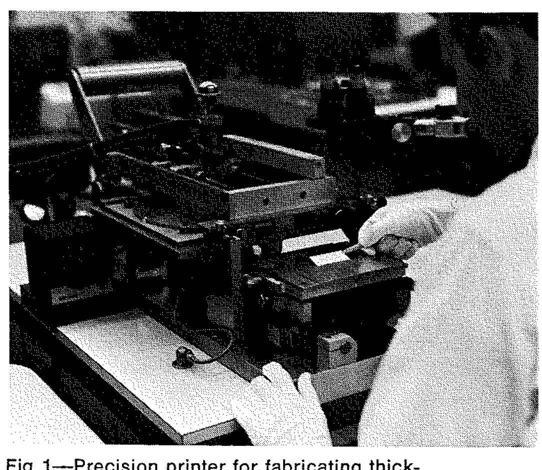

Fig. 1—Precision printer for fabricating thick-film networks.

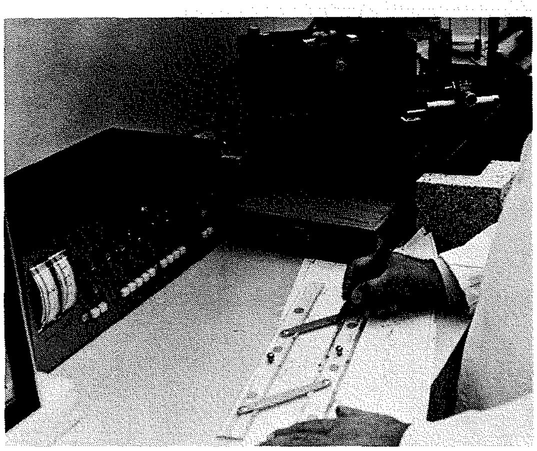

Fig. 2—Thick-film deposition analyzer.

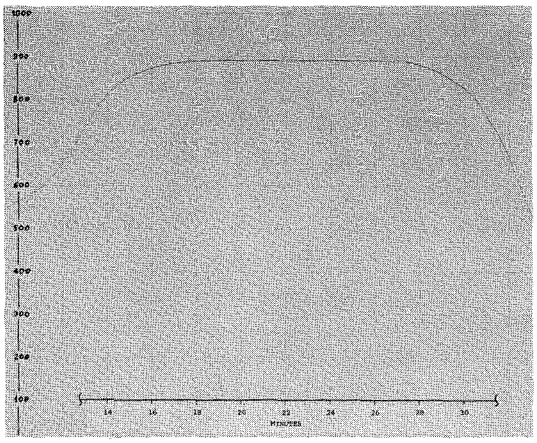

Fig. 3—Typical furnace profile for resistor firing.

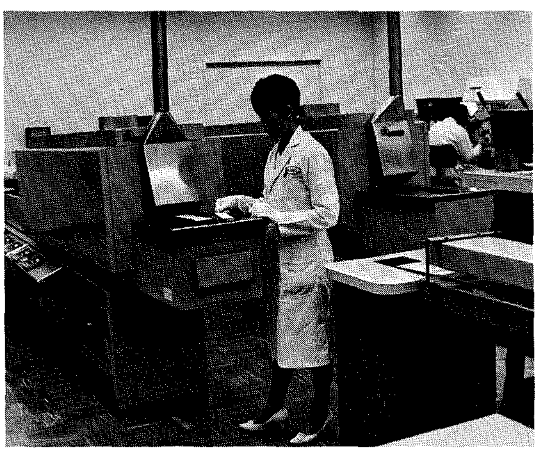

Fig. 4—Furnace equipment for firing substrates.

Fig. 5—Resistor trimming by sand abrasion.

this time, samples are checked for deposited thickness (Fig. 2) and the substrates are readied for firing. The first phase of the firing process is the burning out of the organic binders, and this is done at a temperature range of 300 to 500°C.

The next phase in the firing cycle consists of heating the substrate to higher temperatures in an oxidizing atmosphere. Most of the metallic particles are partly reduced and the glass frit particles start to soften. Temperature and time are both very critical in this phase. Typical resistor inks are fired at temperatures ranging from 760 to 900°C.

Fig. 3 shows a typical furnace profile used for resistor firing. As the substrate reaches the highest temperature, the oxidation/reduction reaction continues until the glass material melts and seals off the metallic material from further contact with the atmosphere. The melting glass also forms an intimate bond with the alumina substrate. This is a critical point in the process since it fixes the electrical characteristics of the fired film. Fig. 4 shows the placing of substrates onto a furnace belt.

With good process controls in screening and firing and careful control of substrate materials and ink viscosities, it is possible to screen resistors to a tolerance of ± 15% of the desired resistance values. Tighter resistor tolerances require a trimming operation. Sand-abrading, a highly reproducible process, is the most widely used method of trimming resistors today. The process does not damage the substrate, but merely removes fired resistor materials. The abrasive flow is started by the operator and stops automatically when the pre-selected resistance value is reached. Using equipment shown in Fig. 5, thick-film resistors have been trimmed to within 0.1%.

Depending on circuit complexity, two or more conductor patterns can be deposited with insulating crossovers, forming a multilayer interconnection media. The number of resistivity screening operations depends on the range of resistor values on a given substrate. A maximum resistor ratio of 50:1 can be achieved with one screening operation. For optimum performance and yield, however, this ratio is kept below 20:1. Fig. 6 shows a typical simplified process flow of a two-conductor, two-resistivity, thick-film substrate.

Component attachment

After fabrication of passive components on the substrate by either thick- or thin-film process, active devices are attached and their terminations are bonded or soldered to contact points on the substrate.

Cased devices are best attached using a solder reflow process. The assembly equipment shown in Fig. 7 is used for this purpose. Here, an AC current of adjustable pulse amplitude and duration is pulsed through the solder tip. Tip temperature is controlled by a miniature thermocouple to assure temperature control and repeatability. Hand soldering of discrete components must be accomplished with extreme care so as not to leach fired conductor materials into the solder compound, i.e., to prevent the combination of the materials with the solder. In extreme cases, solder leaching can cause the complete removal of the fired conductor from the substrate.

Equipment and technology for the attachment of uncased active devices, often called bare chips, is identical to that used in the semiconductor industry. The method most commonly used for chip mounting is alloying. Factors that are of primary importance are adhesion, thermal conduction, environmental stability, and cost.

Alloying consists of combining the silicon on the back of the chip with another metal to form a liquid phase which adheres to both the substrate and the back of the chip. Gold is often used because it forms a eutectic compound with silicon at 370°C, which is high enough to withstand additional processing steps, but low enough to preclude any damage to the chip. The gold is usually supplied in the form of gold, gold-germanium, or gold-silicon preform. To allow the alloy to form, the thin layer of silicon dioxide on the back of the chip must be removed. This is usually accomplished by mechanically scrubbing the chip on the gold material at 390 to 450°C. A protective atmosphere of nitrogen is used to reduce the formation of new oxides during this operation. Fig. 8 shows die-attach equipment used in EASD's microelectronic products activity.

The difficulty in attaching many active devices to a hybrid substrate is mainly in the repeated temperature elevation of the substrate. Fired resistors can be susceptible to these temperature elevations. One method used to overcome this problem is heating of the capillary tool rather than heating the substrate. Where extreme sensitivity to temperature elevation exists, chips may be attached to the substrate using conductive epoxy adhesives. Such adhesives can be cured at temperatures as low as 150°C.

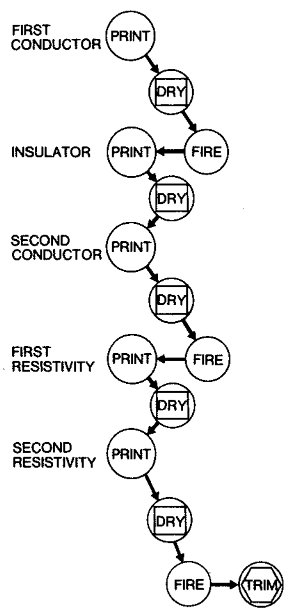

Fig. 6—Simplified process flow diagram for multilayer fabrication.

Wire bonding

Wire bonding today is the costliest operation, both on the semiconductor manufacturing assembly line as well as in the hybrid shop. Ultrasonic aluminum wire bonding and thermocompression gold bonding are standard processes used to form electrical connections between the active chips and the conductor networks on the substrate.

The ultrasonic bond is formed by agitating the bonding tool at ultrasonic frequencies (nominally around 60 kHz) while pressing the wire against the surface to which it is to be attached The agitation scrubs away surface oxides while heating the thin aluminum wire to weld temperatures. Fig. 9 shows such an operation. Sophisticated equipment is available which snips the wire tail remnants at the end of the operation. A tail-less wire bonder is shown in Fig. 10.

Thermocompression bonds are formed by pressing a thin gold wire lead against the surface to which it is to be bonded by a heated capillary or wedge tool. The heat and pressure cause the gold wire to melt, thus forming the connection.

Beam leads and flip chips

The next generation of hybrid circuits will contain discrete and integrated beam-lead or flip-chip devices. The main advantages to their use in hybrid assemblies will be their sealed or glassivated junction and the ability to mass bond, i.e., to make all electrical connections with one operation.

Final package sealing

Until active devices become available in flip-chip and beam-lead form, final hybrid modules for most military applications must be hermetically sealed. Packages without temperature sensitive components can be sealed through a conveyorized sealing furnace. Seam or perimeter welding is used where package temperature cannot be elevated. Sealed modules are then tested for hermeticity in the same manner and to the same specifications as semiconductor packages.

Conclusion

Microelectronic applications of the future will utilize hybrid techniques in the same manner as multilayer boards are used today. The ability to fabricate high-quality resistor networks at low costs will see the emphasis placed on the thick-film approach. Where extreme tolerances are required, small thin-film resistor networks can be mounted onto thick-film substrates.

Monolithic devices will be utilized in combinations that yield best performance at cost effective prices. In tomorrow's world of electronics, the lion's share of business, both military and commercial, will be reaped by those who understand the interrelationships between all microelectronic techniques and have access to quick turn-around low-cost total hybrid capabilities.

Fig. 7—Solder reflow process equipment for attaching cased devices to substrate.

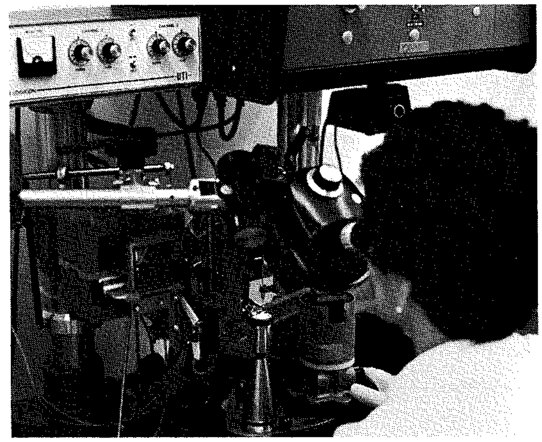

Fig. 8—Die-attach equipment for chip mounting.

Fig. 9—Ultrasonic wire bonding.

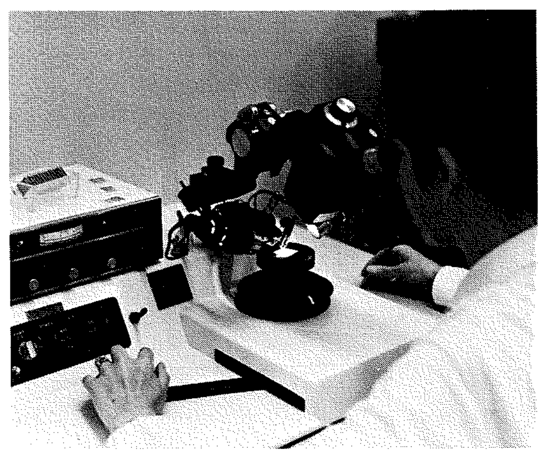

Fig. 10—Sophisticated wire bonder for producing tail-less welds.

Custom Microcircuits in product engineering

A. Lichowsky

In the more progressive engineering organizations, microcircuit technology is gradually becoming a way of life. The daily routine for the average electronics engineer includes working with the microscope and microprobe, wire bonding diagrams, thick-film mask layout, etc. In short, the tools of microlithography, chip handling, and hybrid devices are beginning to replace the soldering iron, wire clippers, and vector board.

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received his initial engineering training at the Technical High School of Hebrew Technical College, Haifa, Israel. He also attended Columbia University from 1951 to 1953. Mr. Lichowsky joined the Defense Communications Systems Division in 1962 and became Manager of Design and Development Engineering in the magnetic recording activity. In this capacity, Mr. Lichowsky was responsible for the successful redesign of the first wideband spaceborne military recording system. He also initiated development of a low-cost television signal recorder. Mr. Lichowsky was transferred to EASD in 1964 as Manager of Design and Development Engineering in the RCA 3488 Mass Memory Program. In this capacity, he was responsible for the redesign of the Mass Memory Recording System prototype and system integrated prior to production release. As a staff engineer, reporting to the Chief Engineer, Mr. Lichowsky is presently responsible for technical innovations and concepts applicable to all EASD product lines. His recent major contributions have included a low-mass high-performance drum memory, a spiral-scan disc memory, a very high current monolythic IC pulse amplifier, advanced monolythic proximity fuze circuits, and other significant advances in microcircuit technology. Mr. Lichowsky also acts as a consultant on recording and memory devices to other RCA activities.

THE TRANSITION from vacuum tube circuit design to transistor and standard "off the shelf" integrated-circuit utilization was gradual and, for the average engineer, relatively painless. While many were reluctant to learn the details of the new technology, the interface between the component manufacturer and the circuit designer was not seriously disturbed. The familiar data sheet remained the principal communications media, with some new vocabulary causing only temporary confusion concerning the significant properties of the new tiny black boxes.

The microcircuit era

A more drastic change, perhaps revolutionary, seems upon us as microcircuits become of age. The MSI and LSI concepts have seriously disturbed the interface between the component manufacturer and the systems/equipment design house. The search continues for clear definitions for this more complex interface.

The electronics industry is apparently convinced that the basic micro-circuit technology is sound, durable, and has fantastic potential for accelerating the expansion of automation and computerization of many tasks and industries. Direction is needed, however, in facilitation and in training of our manpower to cope with the technology. A complete realignment of business relationships between component and equipment manufacturers is not necessary or forthcoming. There exist new, simple communications media that can replace the data sheet, namely, the photomask/screen and the process rule sheet. [The process rule sheet states the component manufacturer's criteria for developing specific controlled characteristics of devices and interconnections.]

Problems in custom microcircuit technology

Much of today's product (especially defense-oriented product) is manufactured in excessive variety yet insufficient quantity to interest component manufacturers. They are talent-limited and incapable of coping even with today's initial demand for custom monolithic MSI circuits. Thus, it is up to the systems/equipment manufacturer to acquire possession and control of photomasks and printing screens for his own dedicated, in-house designed circuits and/or subsystems. He can do this by training his circuit and system designers in the microcircuit disciplines (specialized circuit design and layout techniques unique to monolithic IC's and thick-film circuits). For production quantities of his circuits, he has a choice of component manufacturers to process monolithic wafers and thick-film circuits for him through well-defined standard processes.

The component manufacturers have long recognized that they must have in-house circuit design capability (application engineers) to make their data sheets useful as the principal communications media with their customers. This means the equipment/circuit design engineer must understand the details of process rules, layout techniques, and trade-offs to communicate his output intelligently to the component manufacturer via the mask/screen. Of course, the component manufacturer will continue to fabricate more complex standard monolithic and thick-film circuits for off-the-shelf distribution. In many cases, deliverable system hardware will be completely or partially fabricated from such stock items. Certainly, system breadboarding and prototype fabrication will be greatly facilitated, and data sheets will continue to serve as the communications means in this area.

Design of a custom circuit chip

How difficult is it then for an established engineering organization to adapt to custom microcircuit technol-

Reprint RE-15-6-15
Final manuscript received August 14, 1969.

ogy? A case history of a dedicated monolithic design will serve best to answer this question. At EASD, Van Nuys, several complex custom monolithic circuits have been designed over the past two years. However, our Aviation Equipment Department at West Los Angeles had been utilizing strictly off-the-shelf IC's. In March 1969, aviation equipment engineers expressed interest in the development of a custom IC for motor control. The existing circuit design comprised several standard digital IC's and numerous discrete linear components on a printed-circuit card. On March 18, 1969, three logic and circuit designers from the Aviation Equipment Department were assigned to receive training in monolithic IC technology. One of these engineers was to design a monolithic motor-control circuit simultaneously with his training, with the other two observing and assisting. To aid these engineers, Van Nuys personnel supplied approximately 40 man-hours of lecture and consultation services. The complete circuit redesign was available in late April (only one trainee was assigned full time to detail design and layout). By the end of May, a composite microcircuit layout was ready. Approximately $1,400 was spent at Van Nuys for drafting and ruby cutting on a coordinatograph. Mask fabrication (2 sets of chrome masks, 9 layers) was subcontracted at a cost of about $2,200. Around the middle of June the masks were delivered to Electronic Components in Somerville for processing. On July 9, 1969, processing of the initial wafers of the TA 5782 new monolithic motor-control circuit (Figs. 1a and 1b) was completed at Somerville, and preliminary testing of chips was started. Before completion of the initial program, a number of new dedicated monolithic circuits were being considered and designed independently by the Aviation Equipment Engineering Department.

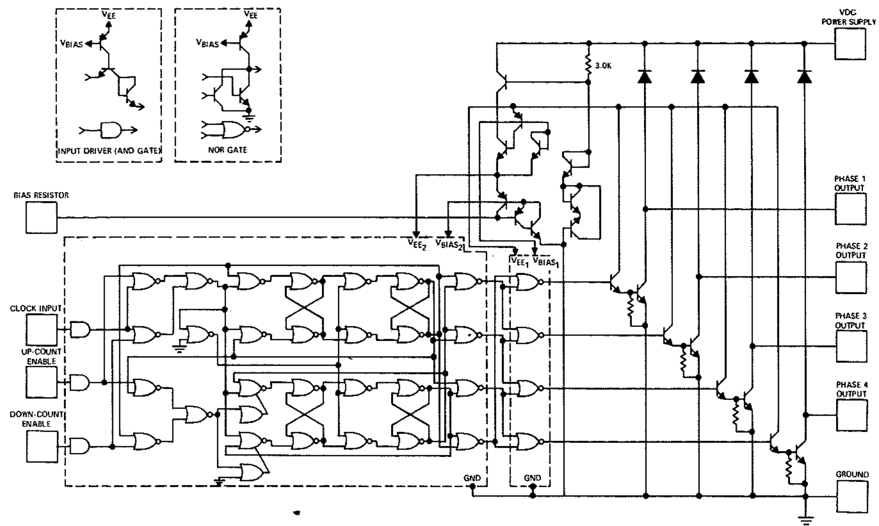

Fig. 1a—Logic and simplified circuit diagram for motor controller.

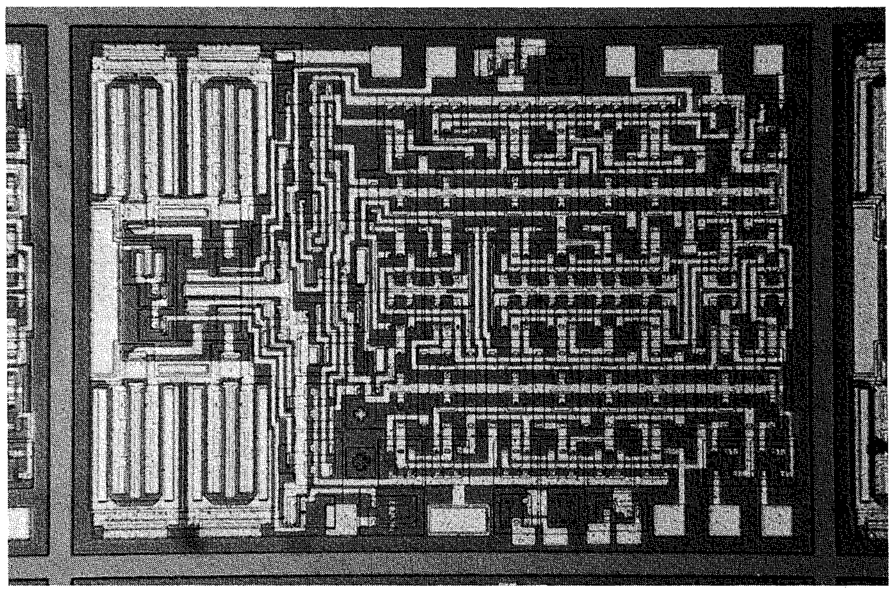
Fig. 1b—Magnified view of monolithic motor control circuit chip.

Microcircuit training techniques

Once exposed to actual experience with modern microcircuit concepts, the fantastic cost reduction capabilities (even in limited production quantities) become obvious to the Engineering Manager, and he is bound to place priority on retraining his staff to take advantage of such techniques.

How does one go about training uninitiated engineers in microcircuit technology? One method is by sending designers to a formal training class. However, for monolithic design alone, this offers several disadvantages.

1) It may take several weeks away from the engineer's home base;
2) It can cost well in excess of $10,000 per engineer, and
3) In most cases, it could result in insufficient retained capability to do independent work, thereby requiring considerable outside consultation.

Certainly such training is not regenerative and may decay rapidly resulting in a total loss of investment and a setback in timely technological development.

In contrast, a small-scale in-house facility for processing thick-film and monolithic circuits, with two or three qualified personnel, may require a somewhat greater initial investment but in the long run will be far more profitable. Such a fabrication facility provides continuous exposure to microcircuit technology. In this environment, the exercising of skills is highly regenerative, resulting in accelerating re-orientation of the entire engineering and manufacturing staffs. Thus, a minimal cost in-house training program, dependent on inside and outside lecturers and laboratory classes, will result in rapid upgrading of skills and rapid response to continuing changes and development in the field.

The RCA 110A computer—ground checkout and launch control of Saturn

A. J. Freed

The RCA 110A Saturn Ground Computer System currently being used by NASA for integrated checkout and launch control of the Saturn-Apollo manned lunar mission was originally conceived and designed for industrial process control.* To meet the early NASA requirement, the original system progressed through a series of major design changes. These changes provided larger memory storage, new discrete input/output capability, more data channels, and increased complement of peripheral equipment.

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received the BSEE from the University of Southern California in 1958. He has completed graduate studies in digital computers at the University of California at Los Angeles and finished a program through the seminar phase on advanced management techniques. Mr. Freed joined RCA in 1958 as a member of the Missile and Surface Radar Division Design Engineering Staff. He participated in a wide variety of design and development programs, including design of solid-state circuits for portable mortar-detection equipment, airborne communication receivers, BMEWS display consoles, analog switching equipment and a power amplifier for radars at the five megawatt power level. In 1961 he was assigned to Electromagnetic and Aviation Systems Division Project Engineerig Staff. His experience includes the project responsibility on three systems of electronic display equipment for the USAF. During the period of 1962-1964 he was Project Engineer on the Ranger ground display equipment and Program Manager for three general-purpose digital computers now in use as the BMEWS checkout data processors. From 1964 through 1967, Mr. Freed was assigned to the Project Engineering Staff for the design, development, and production of the Saturn Ground Computer System, its peripheral equipments, and the Saturn 1-B Displays. For the past two years, Mr. Freed has held the assignment as Manager, Saturn Program. This effort involves five major NASA contracts and responsibilities that encompass the total RCA support provided to NASA. Mr. Freed is a member of Eta Kappa Nu, the IEEE, and is a licensed amateur radio operator.

Since the Saturn's program's inception, RCA/EASD has delivered to NASA a total of 30 computer systems, and provided a continuum of Engineering and Logistics support through the present time. The precepts of the original engineering thoughts concerning checkout and launch of a complex vehicle may be summed up through the following goals for an automatic checkout system:

- Provide for processing large numbers of parameters;
- Reduce the man/machine interface;
- Remain flexible so as to accommodate change;
- Provide a high degree of reliability.

To reach these goals, NASA surveyed available equipment in the early 1960's and chose the RCA 110 System. This paper discusses the seventeen Saturn V Ground Computer Systems delivered to NASA under contract NAS8-13007.

General Characteristics

To meet the goals previously outlined, the design of the original RCA 110 was realigned to meet the requirements for increased checkout capacity with corresponding emphasis on speed and flexibility. The result was the RCA 110A Saturn Ground Computer System which provides a number of significant capabilities:

- Input/output processing simultaneously,
- General purpose data processing and reduction,
- Ability of two RCA 110A's to work in tandem via data link,
- General purpose computing,
- Real-time control monitoring and testing of multiple digital and analog systems, and
- Versatile peripheral equipments.

The RCA 110A System consists of the following complement of cabinets:

- Main frame
- Power supply
- Memory
- Data link
- Discretes
- Switching
- Peripherals

The peripherals consist of a line printer, card reader, card punch and magnetic tape stations. Fig. 1 illustrates a typical computer system configuration; Fig. 2 shows the functional interconnections of the various equipment cabinets. Note that Fig. 1 also shows the display equipment; while not considered as part of the Saturn V system, RCA/EASD did deliver a number of S1B Display Systems under contract to NASA. These systems were used during the launch of Saturn S1B vehicles from Complex 34 and 37 and Kennedy Space Center.

Speed of operation, while not outstanding by today's technology standards, is considered acceptable for this application. The clock rate is 9.36 kHz; memory cycle is 9.7 μs; word time, including access, is 28.9 μs; and the add time is 57.7 μs. Operationally, the system has sufficient speed to perform at the upper limit required by the test condition frequency in real time. Program speed may be considered as enhanced by the system's capability at the input/output level. A number of buffered input/output data channels (IODC) permit simultaneous operation of *I/O* and general calculations or processing.

The priority interrupt system was retained from the original industrial processor. Thus, a program may be interrupted by one of a higher priority with all the register contents of the lower priority program stored until the higher level program has been

Reprint RE-15-6-9
Final manuscript received November 6, 1969.

*The RCA-110 Industrial Control Computer was developed by the Industrial Computer Systems Dept., Natick, Mass.; the engineering team of S. B. Dinman, J. F. Cashen, G. C. Hendrie, G. D. Rummel, and L. W. Honans received the first David Sarnoff Outstanding Achievement Team Award for this work.

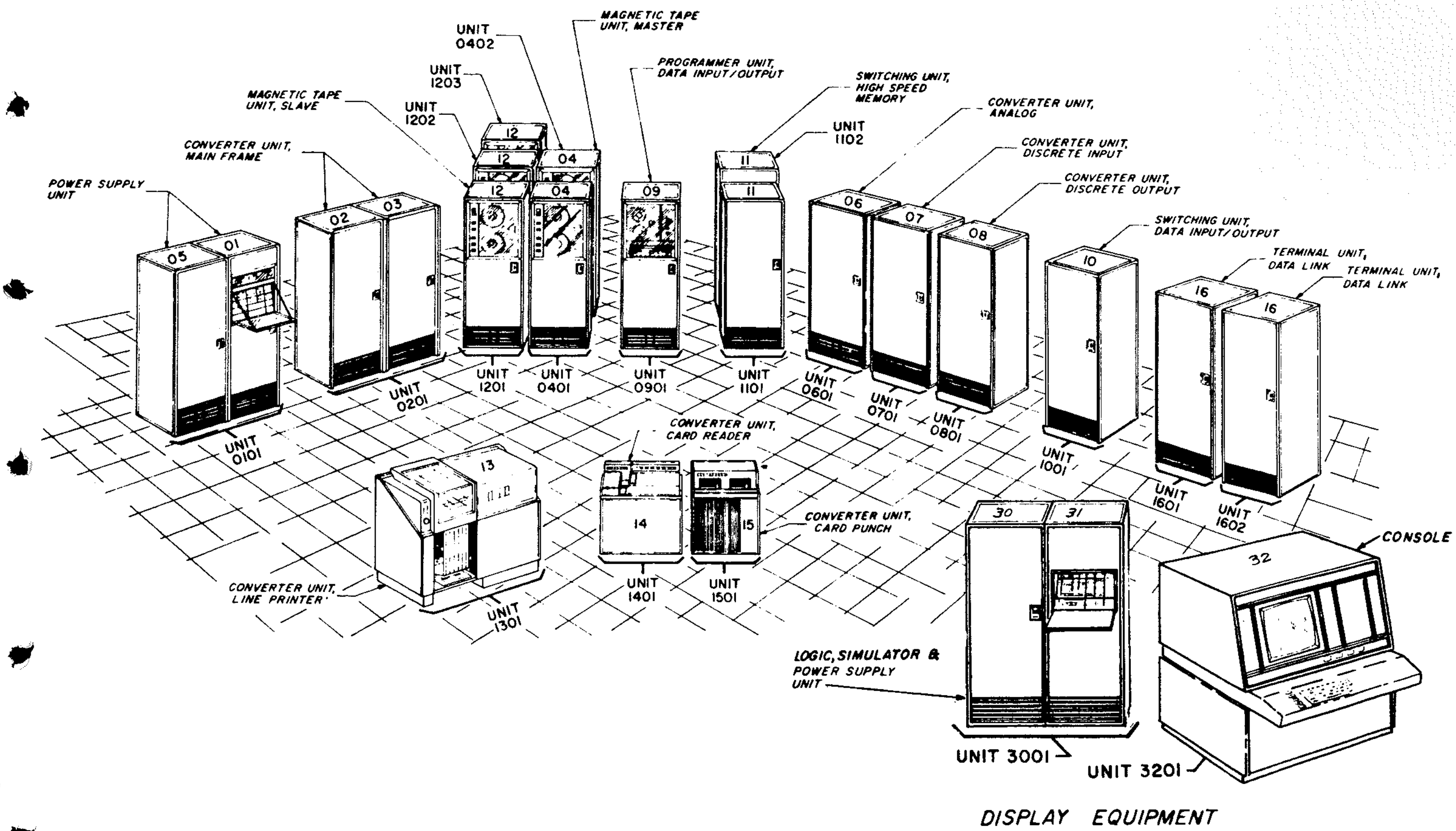

Fig. 1—The RCA-110A computer system configuration, including display equipment.

serviced. In addition to the simple form of interrupt described above, multiple-priority interrupts may cause the computer to sequence through several priority levels prior to returning to the program originally interrupted. This feature will permit incomplete programs to be finished during available time increments. This concept permits the RCA 110A to monitor overall vehicle status while servicing requests from test operators/conductors. It may be noted that in periods of slack time during the checkout of a vehicle, the computer system will run those programs assigned the lowest priority levels. These are primarily self-check routines.

The storage capacity of the RCA 110A System complements the system requirements; 32 k words of high-speed magnetic-core storage with 32 k words on drum plus up to 20 magnetic tape stations are provided. The 24-bit word length provides a precision to better than one part in eight million and the validity of data transfer is verified by an additional parity bit. During a parity alarm, the address of the executed instruction is stored to enable use of automatic software recovery routines.

Multiple computer operation is provided via a full duplex high-speed data link. This system, independent of the processor, performs all synchronization, formatting, and error detection/correction. The technique of retransmission is used for correcting errors without interruption of the word sequence. The detection of errors is accomplished through the following:

Horizontal and vertical parity,
Retransmission count,
Parity check on data channel transfer, and
Incoming modulation check.

It should be noted that the undetected error rate is 2.8×10^{-14} words/word for a 10^{-4} single-bit error rate.

Fail-safe operation in terms of local power failure has been incorporated into the system design. Upon detecting an interruption of the power, the contents of all registers required in order to reinitialize at the proper program point are automatically stored in core memory. In addition, the computer's power system is down sequenced in the proper order. These actions permit the computer to resume operation at the point of interruption once power has been restored.

System Considerations

RCA 110A computer system

The RCA 110A Saturn Ground Computer primarily supports the Saturn V manned lunar missions from Complex 39 as shown in Figs. 3 and 4. Computer systems are located in the Launch Control Center (LCC) and in each Launch Umbilical Tower (LUT). These systems provide central processing with communication to other equipment through Input/Output Data Channels (IODC); an IODC is provided to route each general class of signal (discrete, analog, command, etc.) to the central processor.

Discretes (28-volt commands) may be processed in this manner at operational speeds of up to 15,000 signals/second. The discrete IODC is capable of

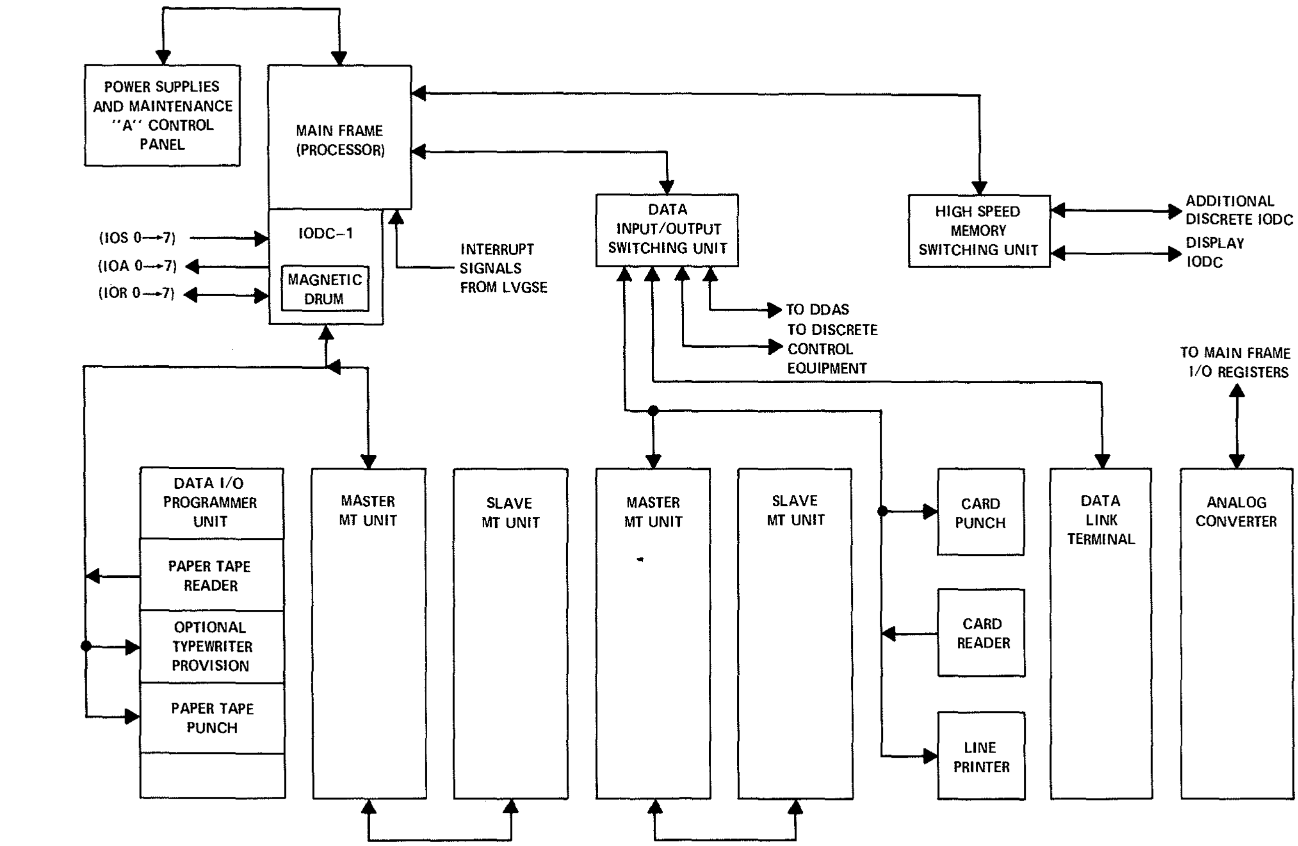

Fig. 2—The RCA-110A computer equipment interconnection.

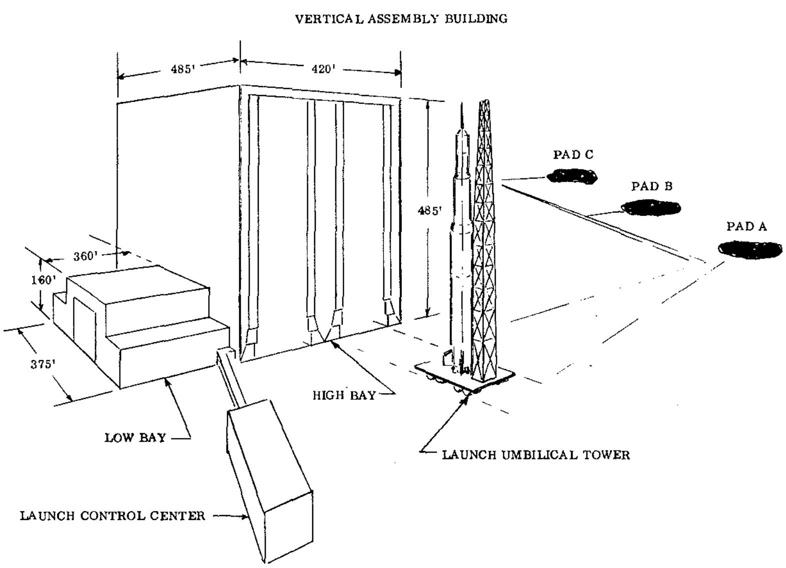

Fig. 3—Saturn launch complex No. 39.

outputting in excess of 1,000 separate command signals to the vehicle and responses from the vehicle can exceed 3,000 separate inputs. The system utilizes a converter to process the inputs in 24 increments corresponding to the 24-bit computer word in any one of four operational modes.

1) *Single-scan mode*—all discrete input lines sensed once and condition stored in core memory.

2) *Continuous-scan mode*—all discrete input lines sensed continuously with core memory updated to latest condition.

3) *Monitor mode*—when a change is detected between latest and previous condition, core memory is updated with the latest condition and the time of occurence.

4) *Selective monitor mode*—same as monitor mode with the exception that only preselected groups may be monitored. If a change occurs in a preselected group, a priority interrupt may be given the computer system.

The IODC's are capable of providing data transfers that are not under direct program control. This may be accomplished in parallel with normal computer operations. The complement of IODC's available is summarized below:

1) IODC *1*—control I/O operations of drum memory and the Ampex magnetic tape stations. This IODC is also capable of operating with an output typewriter, paper tape reader, paper-tape punch, and the RCA S1B display system.

2) *Magnetic tape* IODC—controls I/O operations of the line printer, card reader, card punch plus additional magnetic tape stations and a communications data set.

3) *Data link* IODC—controls data transfers between RCA 110A systems.

4) DDAS IODC—controls I/O operations between the digital data acquisition system and the computer.

5) *Discrete* IODC—controls I/O activity of discrete signal converters.

6) *Display* IODC—controls I/O operations between the computer and the Saturn V Display System.

Input/output registers (IOR's), input/output address lines (IOA's), and input/output sense lines (IOS's) provide alternate paths for communication be-

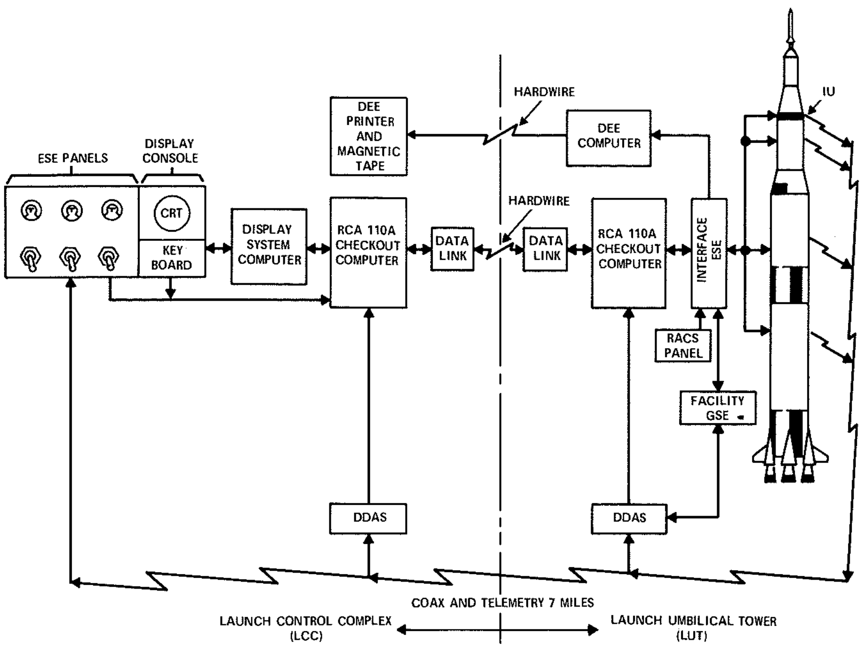

Fig. 4—Equipment interconnection for prelaunch checkout and launch control.

tween the computer and external devices. The IOR's are standard 24-bit registers that provide additional data transfer paths to remote computers and telemetry systems. The IOA's are generally used to set up command signals to external devices, while IOS's will sense the response of these devices. Contrary to the IODC concept, IOR's, IOA's, *and* IOS's are under the direct control of the program and number as follows:

1) IOR—8 registers.
2) IOA and IOS—192 lines.

Fig. 5 illustrates and summarizes the RCA 110A input/output capabilities. Additionally, the system provides other features such as D/A and A/D conversion at a rate of 2,000 signals/second, real-time clock registers to permit the reading of countdown or time inputs, and a capability for data communication with the digital computer on-board the launch vehicle.

Automatic saturn ground checkout

The Ground Support Equipment (GSE) under computer control is used to check out each stage of the Saturn V vehicle. Responses from each stage are evaluated based on the applied stimuli. Such entities as hydraulics or pneumatics may not originate with the computer and are therefore generated by devices external to the computer, but under its control. The test conductor's CRT console is the focal point for maintaining control of all test operations and the computer.

Two general modes (semi-automatic and automatic) of operation are available for use. The normal mode now being used is semi-automatic. This mode consists of the following operations (refer to Fig. 4):

Command initiated through electrical support equipment (ESE) panels or the display system keyboard in the Launch Control Complex (LCC).

Upon receipt of command, the computer at LCC transmits a signal via data link to the Launch Umbitical Tower (LUT) computer.

A command is then furnished to the stage under test via ESE, with a response returning by the same route.

The automatic mode would consist of the initial command, initiated by ESE panel or display system keyboard, being generated by the execution of a stored program instruction. All other sequences of events would remain as previously stated.

To summarize the checkout of a Saturn V vehicle at Kennedy Space Center, three basic features are available:

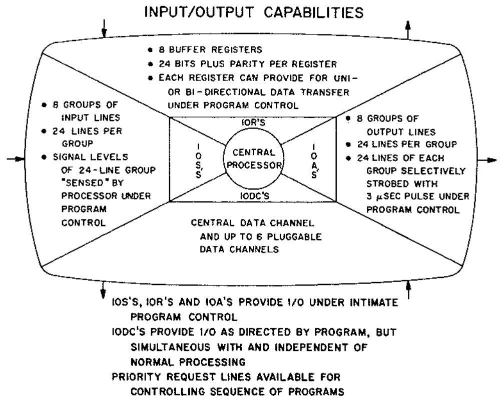

Fig. 5—RCA-110A input/output capabilities.

Discrete actions called up from the ESE switches;

Call up from the display consoles of test programs and discrete requests or monitoring; and

Periodic monitoring of test points, discrete status, and red-line values.

Data received through these tests are displayed locally at the stimulus-generating equipment. In addition, data received via the digital-data-acquisition system (DDAS) is recorded for later hard copy (strip) printout. Certain functions are monitored by test personnel on a full-time basis. To supplement the capability of the RCA-110A computers to monitor discrete events, a digital events evaluation (DDE) computer continuously scans a large portion of the ground support equipment and stage discrete information and records changes and the time they happen.

RCA's present role

Through June of 1970, RCA/EASD is under contract to the NASA Marshall Space Flight Center for program management, engineering, field service, and quality assurance in support of the RCA-110A computers. Also, in support of this contract, EASD has a 15,000 square foot facility at Huntsville, Alabama, and a sustained/dedicated group of support personnel at the Van Nuys plant.

Saturn launches

Through the writing of this article, the RCA 110A Computer System has successfully supported all Saturn 1B launches (AS 201—AS 205) and all Saturn V launches (AS 501—AS 507). This schedule included Apollo 11 and 12 and meant that NASA was able to meet all major test schedules plus all launch windows.

Safety and arming devices

S. C. Franklin

In general, fuze designs require the use of sensitive explosives, in the form of detonators, and lead charges to initiate detonation. It is essential that the fuze be safe to handle and transport, therefore, the U.S. has adopted, as standard practice, the out-of-line detonator principle to remove the possibility of detonation either because of a violent mechanical shock or because of the heat resulting from a fire. This paper describes several of the safety and arming concepts developed for mechanical and electrical fuzes by the Electromagnetic and Aviation Systems Division (EASD).

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received the BSEE from the University of Portland and the MSEE from Drexel Institute of Technology. He also completed the RCA Specialized Training Program. He is currently developing integrated-circuit timing devices for electronic time fuzes and is also responsible for supplying engineering support to manufacturing on the M414A1 program. Mr. Franklin has completed a redesign of the Mark 15 Amplifier under contract to Naval Ordnance Laboratory, Corona. He has performed and directed engineering tasks on fire control and tracking radar systems, as well as the Saturn ground checkout computer system.

THE PRIMARY PURPOSE OF A FUZE is to detonate the bursting charge in a missile at a specified time or place. The need for many types of fuzes is apparent when we consider some of the various items of ammunition in use—projectiles, bombs, rockets, and mines. The conditions to which a fuze is subjected when used as intended may be myriad.

The primary purpose of a safety and arming device is to maintain the fuze in an unarmed, safe condition until it is subjected to all of the forces it experiences when released against the enemy. The arming process provides a transition between two conditions:

1) The safe condition which is normal for handling with the detonator is in an out-of-line position, and
2) The armed condition which is normal for functioning with the detonator in an in-line position so that detonation of the bursting charge will occur at the selected time and place.

The time for the arming process to take place is controlled so that the fuze cannot function until it has traveled a safe distance from the projectile launch site. This distance is usually measured in terms of elapsed time from launching; hence, the arming mechanism often consist of a device to measure an elapsed time interval.

Arming concepts

Arming mechanisms operate upon an input of energy resulting from the launching environment. This may come from a source contained in the fuze itself, or it may arise from a potential created by the external environment such as acceleration, spin, or pressure. The space in a fuze is often small; thus, the energy stored within the fuze is much less than that obtainable from a change in external conditions. Hence, the environment is usually the more convenient source of energy. Generally, present-day safety and arming designs are mechanical devices which utilize spring-loaded g weights (Fig. 1), integrating accelerometers (Fig. 2), and runaway escapements (Fig. 3).

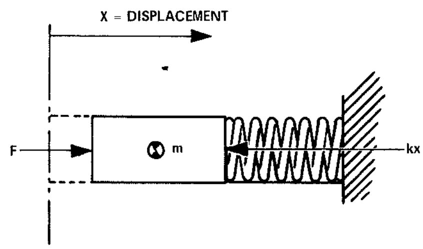

Fig. 1—Basic mass and spring system.

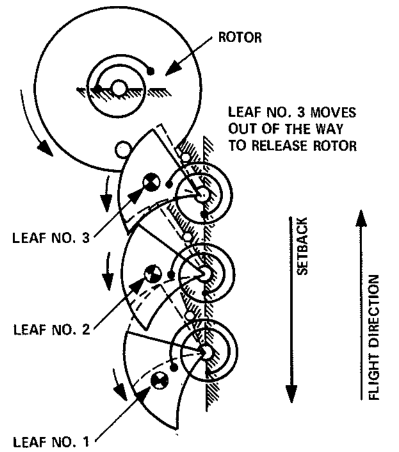

Fig. 2—First-order integrating accelerometer.

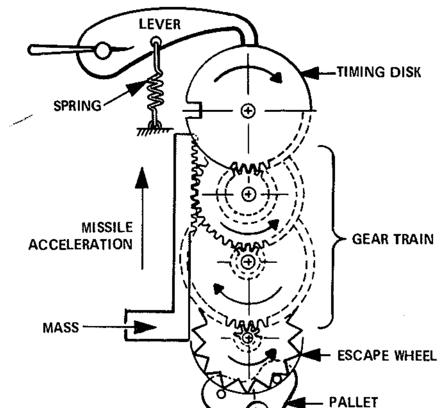

Fig. 3—Runaway escapement.

The environmental forces which a bomb experiences at launch are negligible. Also, the elapsed time required for safe separation varies as a function of launch conditions. Therefore, the safety and arming device for most bombs is an electronic timing device where the sequence is initiated at launch.

Safety and arming developments at EASD

Two types of electronic safety and arming devices have been investigated through IR&D programs at EASD. The first such device was intended for bomb applications and was an integral part of the timing fuze (Fig. 4).[1]

Reprint RE-15-6-10
Final manuscript received October 24, 1969.

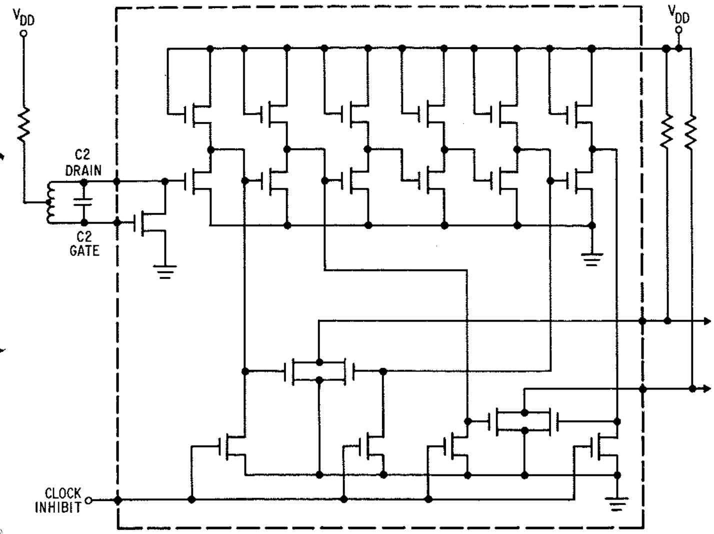

Fig. 4—Two-phase clock circuit.

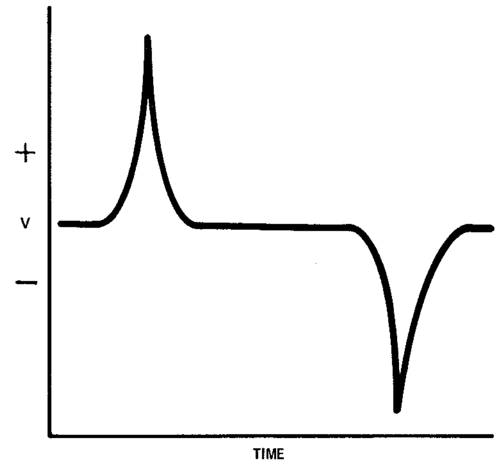

Fig. 5—Waveform generated during boost-phase of projectile trajectory.

The second type of safety and arming device can be used with projectiles, missiles, rockets, or mortars. In this technique, presently being investigated, the energy obtained from a loaded piezoelectric ceramic is used to perform the arming sensor functions.

The piezoelectric ceramic can be used in a number of ways to accomplish the arming function. The geometry, size, and loading of the ceramic determine the voltage and energy output characteristics of the sensor. When the loaded piezoelectric ceramic is used with electronic circuits, it should result in a very accurate and reliable system. If these circuits are capable of measuring amplitude and time delay, the output of the device will indicate whether the proper acceleration and terminal velocity have been attained before the arming sequence is initiated. The piezoelectric ceramic will generate the waveform in Fig. 5 during the acceleration or boost phase. The amplitude of the positive pulse will be proportional to the initial buildup of the accelerating force, and the negative pulse will be proportional to the decay of the accelerating force. The time period between the positive and negative pulses is a measure of the period of constant acceleration and is proportional to the velocity attained.

Most electronic fuzes employ a battery which is initiated when the proper environment is experienced. An electronic timing circuit can be used to measure elapsed time following battery activation to determine that a safe separation distance has been achieved and the arming process completed.

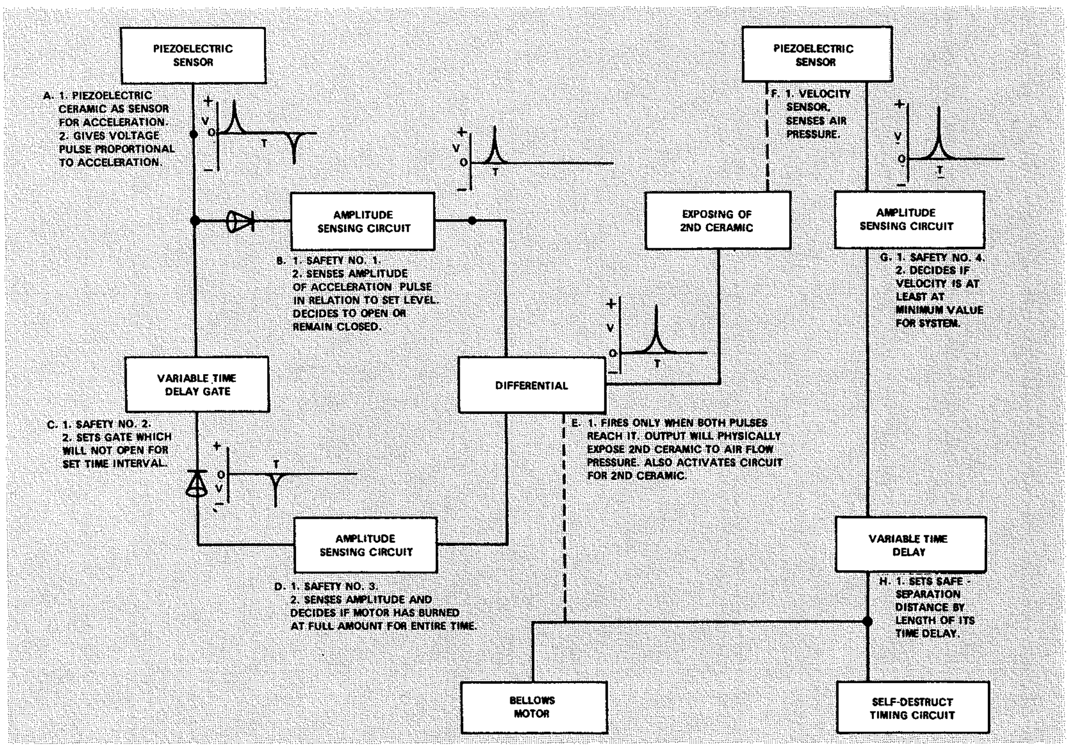

Fig. 6—Electronic safety-and-arming device.

A bellows motor is an example of a mechanical device which could be used to remove a barrier between the detonator and booster, thereby achieving the in-line armed condition.

Fig. 6 is a functional block diagram of an electronic safety and arming device for a surface-to-air missile application.

Conclusion

The mechanical type of safety and arming mechanism which is progressively becoming more expensive to produce will be replaced with electronic type devices in the near future. The electronic type device will provide greater accuracy and reliability than the existing mechanical devices.

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New one-tube color-camera for live or film use

T. M. Wagner

A new low cost 1-vidicon-tube color-camera (Fig. 1) has been designed, featuring zoom lens, special color encoding filters, and state-of-the-art modular construction. The same basic camera module, with minor modifications, is also used in a slide and film chain (Fig. 2). This paper describes the 1-vidicon camera system and explains its characteristics.

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received the *Ing. grad.* degree from the Oscar von Miller-Polytechnikum in Munich, Germany in 1953. He was employed with Rohde und Schwarz in Circuit Design of TV-measuring equipment. He was a group leader at Agfa-Gevaert's lab of physics, where he worked for six years on the solution of photographic and optical problems with electronics prior to coming to the United States in 1964. In 1964 and 1965 he worked on chroma circuits of color TV-receivers with General Electric in Syracuse, N.Y. A patent is pending from that time on syncronous detectors phase control. In 1966 and 1967 he performed basic studies on vidicon tubes and was project engineer on the design of a high resolution camera for special purposes with General Electrodynamics Corp. in Garland, Texas. He joined RCA Burbank in 1968, where he was employed in the electro-optical design of the 1-vidicon program. The author was a member of the team that received the 1968 David Sarnoff Outstanding Team Award in Engineering for the single tube color camera. He is co-inventor of two patents pending and is a member of the Society of Motion Pictures and Television Engineers.

The RCA 1-tube color camera has been greeted with considerable interest by the television world since its introduction to the public at the NAEB-show in November 1968 in Washington, D.C.

During the past two decades many attempts have been made to overcome the inherent problems of registering multiple tube color cameras. Principles of 1-tube color systems were patented 20 years ago. (See refs. 1 through 10) The closest description of our present system was made by R. D. Kell in a patent issued in 1956.[3]

Only the present state-of-the-art in electronics, optics, and pick-up tubes made it possible to forge components to yield the required performance—allowing the design of a system with a simplicity of operation similar to a home color TV-receiver and with a production cost low enough to open new markets.

Area sharing

The RCA 1-vidicon color system is basically an area-sharing system. That is, the frequency spectrum used to transmit picture content and resolution also contains color information in some encoded way. This encoding is achieved by optically converting color into stripes which create carrier frequencies by the vidicon's scanning process.

A set of stripes from a cyan dichroic filter (red-stop) is reimaged on the vidicon faceplate. For example, red color, as well as blue and green, is passed by the clear portions while red is stopped by the cyan portions of the stripes.

Blue color is similarly treated by a second set having yellow stripes (blue-stop), alternating with clear stripes.

Thus, a red or blue picture are appears to the vidicon to be chopped in stripes. The different spatial frequencies of the filters and their different angle of inclination, encode red and blue color areas in different frequencies which will later be decoded in the terminal electronics to reproduce the red and blue signals.

If needed for special applications, green can be matrixed from the red, blue, and the luminance signal. If red-yellow and blue-yellow encoding is chosen to derive an NTSC signal, green need not appear on separate terminals at all.

Resolution and bandwidth

The present state-of-the-art consumer-type color receivers were used as a criterion. Those receivers are nominally capable of 220 TV lines horizontal resolution. None of them utilize the higher definition I and Q-demodulation axis or exceed 256 TV lines horizontal resolution.

We have taken advantage of this fact and cut off the luminance bandwidth at 3 MHz. The band from 3 to 5.5 MHz is reserved for red and blue color-carrier transmission, the red being at 3.5 MHz and the blue at 5 MHz with ±0.5-MHz bandwidth each. This insures good signal-to-noise ratio and camera sensitivity while still providing at those frequencies, good resolution uniformity with the 8507 A vidicon tube.

NTSC Compatibility

In the NTSC system the color information is encoded as phase vectors of the subcarrier, each phase representing a different color and each vector amplitude the chroma saturation.

It is one of the great inventions of the NTSC-system that the decoding or encoding of a particular color does not have to be in the higher definition I- and Q-axis but can also be done in the direction of the R-Y and B-Y axis.

In fact, the values of the I and Q signal are so chosen that the resultant phase for any hue is constant, whether it is formed from detection along the I- and Q-, or the R-Y and B-Y axis.

Since the majority of receivers do not employ the I and Q system, a greatly simplified encoder circuitry is used in which the R-Y and B-Y signals directly modulate the subcarrier in a quadrature relationship.

For closed circuit use, a built-in crystal provides a non-locked subcarrier. Its moving pattern is nearly invisible at normal viewing distances. Provisions are made for a separate input where a standard locked subcarrier can be fed

Reprint RE-15-6-20
Final manuscript received September 2, 1969.

in if so desired for broadcasting NTSC-standard.

Circuit description of camera module

Video processing

The video processing amplifier does not contain any unconventional circuitry. However, great consideration has been given to the optimization of all parameters of the system.

Good signal-to-noise ratios are obtained by the use of a FET-preamplifier input stage. In fact, sensitivity is limited by the graininess of the photoconductor rather than the amplifier noise. A dark current clamp makes the black level independent of target voltage variations. An exchangeable gamma board adapts the camera to live, film or special application operations.

The bandwidth of the system is restricted to 7 MHz to increase the signal-to-noise ratio. Between 0 and 10 dB of delay-line-type aperature correction can be added, peaked at 5 MHz (the highest color carrier frequency). Besides increasing the color-carrier amplitude it adds pre- and over-shoot to the luminance transitions, thus increasing the apparent horizontal resolution.

Timing circuit

The camera system is self-contained. A standard EIA sync generator is built in and locked to the line frequency. All pulses (sync, blanking, clamps and drive pulses for deflection) are devised in the timing circuits. It is also possible to drive the camera externally from studio pulses.

Deflection and focus

A high degree of current feedback is employed to insure sweep linearity, centering, and size stability. Since any change in resolution would be interpreted as a color change, special consideration has been given to the focus current regulator. Its amplifier is referenced to a temperature-compensated zener diode.

Striped dichroic filters

The color separation in this 1-vidicon system is achieved by encoding red and blue colors into different frequencies by means of striped dichroic filters. Dichroic filters are essentially glass substrates with chemical coatings that have the characteristic of reflecting some wavelengths while transmitting others.

If a red or blue color arrives at the filter, it is chopped by the striped dichroics in the form of alternating brightness values. The horizontal scan of such an area of the photoconductor produces a frequency which is selected to be above the frequency domain allocated for picture detail (see Fig. 3).

The colorimetry of the system is determined mainly by the picture tube and the dichroic filters. The vidicon parameters are, for all practical purposes, fixed since economy does not warrant a special design.

The best dichroic filter combinations and half-peak transmittance points have been found by using computers to make speedy evaluations of the filter curves desired with all variables that affect colorimetry taken into account (see Fig. 4).

The dichroic filters must be of nearly perfect quality. Any deficiency will show up as color shading, increased chroma noise, and therefore less sensitivity if the transmittance-to-reflectance ratio is not high enough. A flat slope of

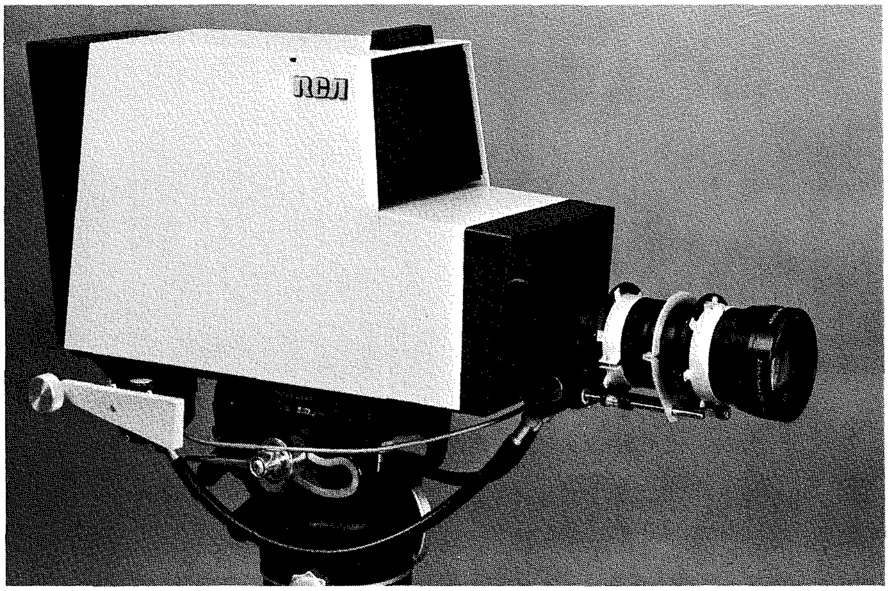

Fig. 1 (above)—One-tube color camera.

Fig. 2 (below)—Color slide and film chain using 1-tube camera.

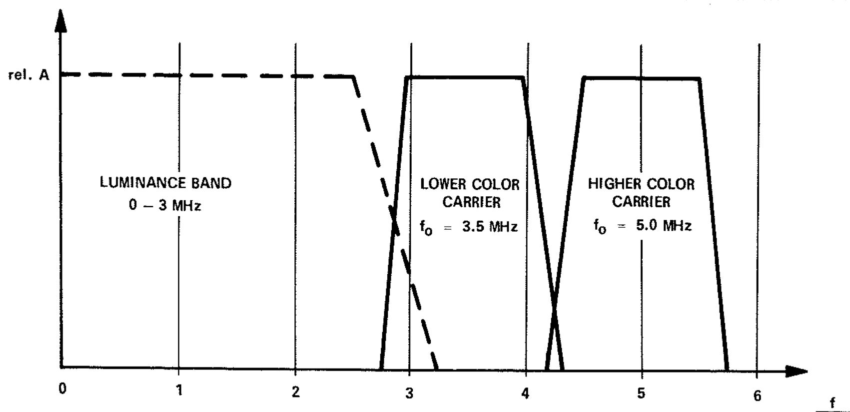

Fig. 3—Frequency allocation of luminance and chrominance.

transmittance characteristics will produce colorimetric errors, especially in the transition areas.

Carrier detection (see Fig. 5)

The camera output contains luminance information and encoded red and blue subcarriers. In the decoder, two bandpass amplifiers with 1-MHz bandwidth each (one for a frequency of 5 MHz which was chosen to be the blue carrier frequency and one for 3.5 MHz which represents the red carrier frequency), derive and detect the blue and red signal with a bandwidth of 500 kHz each.

Traps in the bandpasses insure that minimum red carrier is in the blue channel and vice versa. The luminance channel is also cleared from spurious red and blue as well as subcarrier frequencies before compatible NTSC-encoded chroma gets added at the output stage.

Color encoding (see Fig. 5)

After the red and blue signals are detected, they are either channeled out together with a green matrixed signal (if *R, B, G,* and *Y* output is desired), or the *B-Y* and *R-Y* color-difference signals are derived and fed into balance modulators.

After combining the *B-Y* signal and the *R-Y* signal and filtering out any harmonics, the chroma signal is added to the luminance signal to form the NTSC-compatible composite waveform. This signal is then fed to the output stage.

The burst is obtained by keying the *B-Y* modulator negatively during the burst duration. The burst phase must therefore always be −180° from the *B-Y* phase and need never be adjusted.

Optics

Live camera

The optical design in the 1-vidicon color camera is unique. From the many possible ways of making a single-tube color system with a standard vidicon, the configuration shown in Fig. 6 was chosen for the production live camera.

The zoom lens is an inexpensive 35-mm-format type. The basic studio lens has a focal length of 50 to 300 mm (reduced by the demagnification of the relay lens to 20 to 120 mm). This allows a horizontal taking angle of approximately 36° to 6°, which makes it very suitable for small studio use.

In the focal plane of the zoom lens are a set of dichroic filters which are imaged by a relay lens onto the vidicon faceplate.

The relay lens has a demagnification of 1:2.58 (the ratio of the 35-mm zoom-lens format to the 16-mm format of the 1-inch vidicon). This reduction ratio provides many more advantages besides the usage of a low-cost zoom lens. The dichroic filters can have a lower spatial frequency and are therefore easier to manufacture, dust spots and dichroic deficiencies are less visible, and the systems aperture is increased by the same factor which provides a much faster system than the f/4.5 aperture of the zoom lens would otherwise offer. Furthermore, a 2.5:1 relay system is much easier to fabricate than a 1:1 system which would hardly provide the resolution performance at the required opening and the short conjugate distance.

A field lens is inserted between the zoom lens and the stripe filters. It refracts the otherwise divergent rays from the zoom lens into the entrance pupil of the relay lens. This insures that no "portholing" takes place which would darken the edges of the picture. If the field lens is kept between zoom lens and dichroics, and as close as practicable to the first image plane, then the resolution uniformity of the relay lens—and therefore chroma rendition—is fundamentally unaffected.

The optical arrangement is assembled to yield the most uniform resolution possible over the entire picture area and is then locked in place. Since the picture is never optically taken apart during the stripe encoding process, no misregistration can occur with this 1-vidicon principle. Optical defocusing of the picture with the zoom lens does not alter the color rendition since the stripe filters will still be focused and re-imaged on the vidicon faceplate by the relay lens.

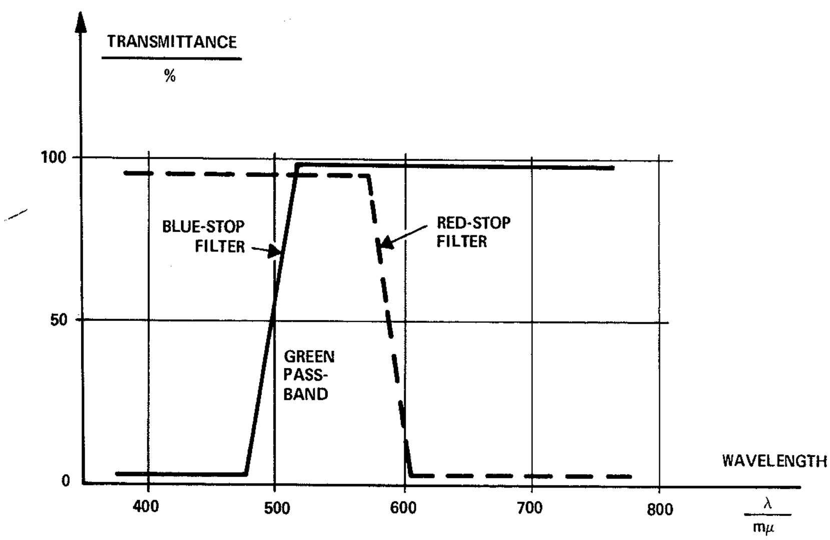

Fig. 4—Idealized dichroic-filter curves.

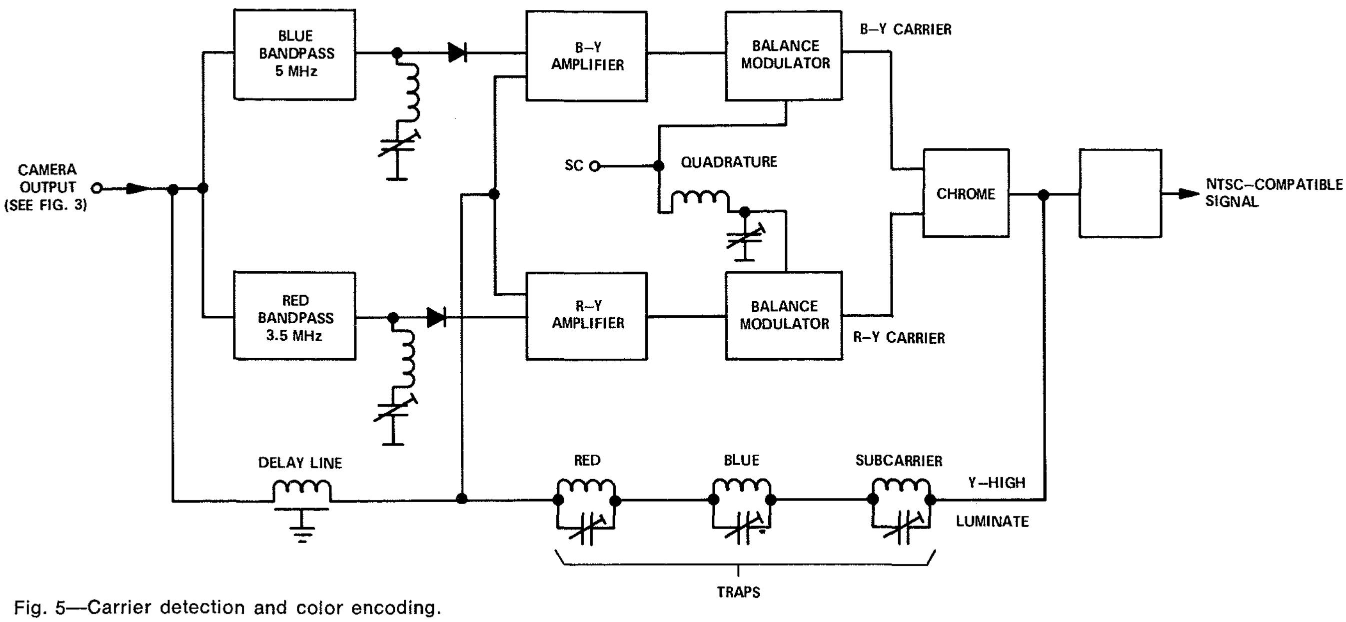

Fig. 5—Carrier detection and color encoding.

The zoom lens is fitted with ring gears which couple the focus ring with a flexible drive shaft to a twist grip control at the pan and tilt handle, and allow the zoom control to be cranked from the right hand side of the camera.

The lens iris can be operated by a push-pull cable from the camera operator's position.

Slide and film chain

The slide and film chain operates on the same principle as the live camera but is optically easier to assemble. The longer throw distances do not necessitate a short-conjugate relay lens system but can be handled with good *C*-mount lenses. Fig. 7 shows the optical arrangement of slide projector, film projector, camera, dichroic filters, field lenses, and mirror. If the mirror is in the UP position, the 16-mm film projector images its picture onto the stripe filter plane *ST*.

The field lens *FL1* insures that all the rays will enter the camera lens and avoid any portholing. An additional field lens *FL2* is needed in the 35-mm slide projector path because of the shorter throw distance of the slide projector *SL*. (see Ref. 13)

Due to higher light levels, the camera lens can be operated at f/8, and with the longer distances involved, the focal range tolerance is much greater and imposes practically no adjustment problems with the dichroic filters.

Again, as in the live camera, focusing of the object with the 35-mm slide projector or the 16-mm film projector does not affect the color rendition since the dichroic filters are in a fixed place with respect to the camera and are therefore always imaged properly on the vidicon faceplate.

Operational characteristics

Focus limitations

Utilizing the striped principle, which converts chroma information into frequencies, makes the electrical focus control of the camera a "color control." Anything that affects the frequency response and resolution of the vidicon will cause a color change in the output signal. This means that defocusing the stripes by optical means or changing the electrical focus control of the vidicon will alter the hue or even cause a complete loss of chroma. Defocussing the zoom lens in the live camera will not change the chroma because the dichroic stripe filters remain in a fixed position and are always re-imaged on the vidicon faceplate.

The same holds true when defocusing the lenses of the 35-mm slide and 16-mm film projectors. However, defocusing the camera lens in the film chain will defocus the stripes and therefore cause a loss of chroma.

Resolution

Even though the 1-vidicon color camera is basically a high resolution camera with an excellent uniform relative response, the system's luminance resolution is limited by the fact that the higher resolution spectrum is allocated to the two color carriers. Fortunately, the present low cost color receivers do limit their resolution to approximately 250 TV lines and their frequency response is 6 dB down at 3 MHz. We take advantage of this fact and limit our luminance response to 3 MHz.

The present state-of-the-art 8507A vidicons have sufficient resolution at 3.5 and 5 MHz to provide the desired chroma uniformity with the color carriers placed at those frequencies.

The utilization of a delay-line-type horizontal-aperture correction minimizes detail loss when a picture is viewed through a home color receiver.

Color uniformity

At first, one of the biggest problems seemed to be the ability to produce uniform color fields. Not only will a loss of resolution cause a complete loss of color in that particular area of the picture, but a slight degradation of resolution will change the colorimetry and show up magnified in pale areas of mixed colors like flesh tones. The dichroic filters have to be of excellent quality, as pointed out in the above discussion of these filters.

The relay lens must be specially designed and must represent the state-of-the-art in optical design to satisfy the resolution and uniformity requirement of the system.

The pick-up tube, with its associated circuitry, including the deflection assembly, is another major factor which contributes significantly to the color uniformity.

It was necessary to use a new yoke design, employ focus modulation and correct the remaining percentages of non-uniformity in the RF-bandpass amplifiers. In this way it was possible to achieve as much as 95% or more resolution throughout the entire picture area with the center being 100%.

Setup techniques

To obtain full color rendition, there are some basic setup procedures which must be observed besides optically focussing the object and viewing angle for the live camera. The 1-tube color camera is no different from any other black-and-white camera in this parameter.

Five electrical controls are provided on the back of the live camera, and the front panel of the slide and film chain, or remotely for the video engineer. They are the standard black-and-white camera controls (pedestal, beam, gain, focus, and target). Some are unique in their effect. Others, like gain and target, do not require a special knowledge of this system to be set up properly.

The pedestal control will not only affect the setup of the video signal but will be interpreted by the encoder-decoder as an increase in luminance without a proportionate increase in red and blue carriers. This will turn the picture greenish (since, by definition, picture contents having luminance values and no carriers must be green). A decrease in pedestal will misbalance the colorimetry to minus green (i.e. magenta).

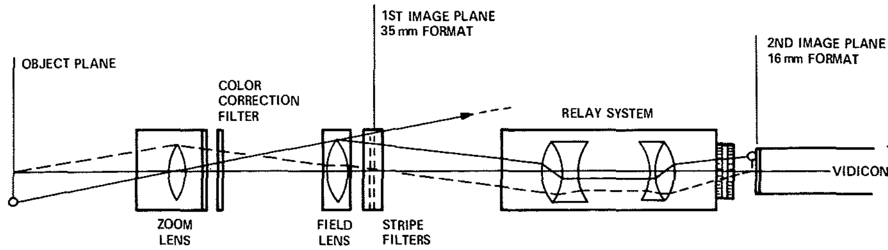

Fig. 6—Optics of 1-vidicon color camera system.

The beam control must be set to just discharge the highlights. Any excessive beam will scatter electrons around the focused beam in the vidicon and cause a loss of resolution and, therefore, a loss of color in some areas of the picture. The same effect will be experienced when the camera is electrically defocused.

A decrease in resolution means a loss of color-carrier amplitudes which causes a change in chromaticity or a complete shift to green if the picture is sufficiently defocused.

The electrical stability of the system is such that once the camera is adjusted by its five controls, readjustment will be practically unnecessary.

The warmup time of this color camera is primarily determined by the heater of the vidicon and is hardly longer than the warmup time of a simple black-and-white camera (about 2 minutes). Misregistration, the big problem in even the most expensive color cameras, can never occur.

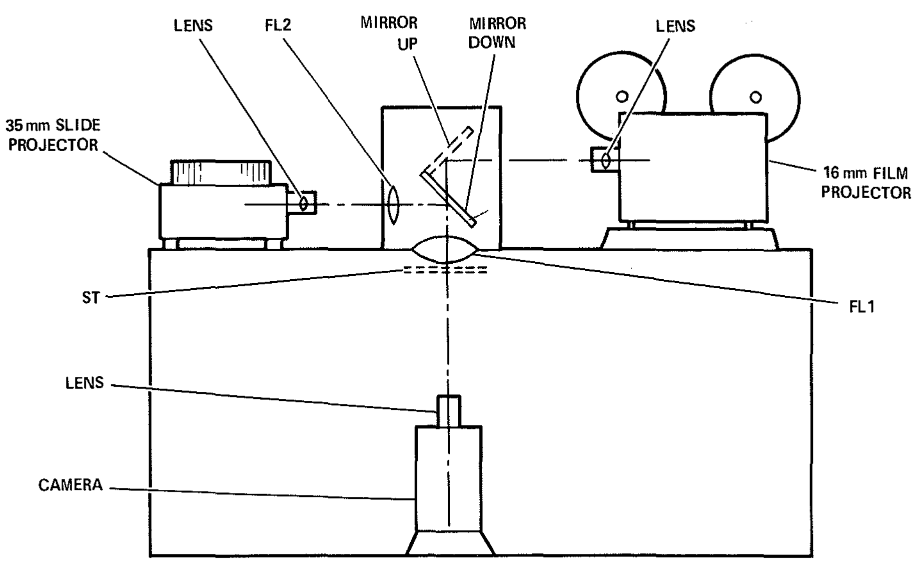

Fig. 7—Slide and film chain.

Acknowledgment

The author is indebted to Mr. H. Ball, Manager of Engineering, who made this project possible through his personal guidance and technical leadership. He acknowledges the contributions of Mr. R. Blinn who managed the first production run of the slide and film chain, having only an engineering sample from which to work. Credit for the majority of the electrical design goes to Mr. L. Briel, group leader at RCA-Burbank, and Mr. F. Lang from the Astro-Electronics Division in Hightstown, N.J.

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PK-610 color film system

R. W. Jorgenson

A simplified three-vidicon color film camera has been developed by the Professional Television Design Group in Burbank. The PK-610 is intended for service in educational and other CCTV markets, as well as in the many broadcast fields that are developing. This article discusses the useful features of the camera as a straightforward system and the design highlights of the important circuitry within the system. Emphasis is placed on design approach through explanation of block diagrams.

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THE PRICE RANGE for color film cameras has long been categorized into two classes of equipments: the top-of-the-line broadcast systems, and the less versatile industrial class of color film equipment. This product gap has suited the needs of existing markets; however, the rush for color capability, as typified by the broadcast industry, has changed the marketplace to create demands for a color film system that is more sophisticated than industrial equipment, but less expensive than full broadcast systems. This new marketplace includes the broadcasters, who are looking for auxiliary color sources to ease scheduling requirements on primary sources; the industrial trainers and school educators, who are looking toward color equipment for specialized training applications; and the cable television operators who are currently looking for color origination equipment to offer color programming to their viewers.

System concept

Several manufacturers are currently marketing simplified color cameras in both live and film versions. These cameras are designed to provide only the essential features necessary to perform the basic functions of a color camera; extra features such as elaborate remote control consoles and monitoring facilities are, for the most part, eliminated.

Fig. 1 depicts the components of the PK-610 film camera system. All electronics and set-up controls are located in the camera head, with the exception of an external rack-mounted power supply which is used to keep bulk and heat out of the camera head. The camera cable is limited to 150 feet to eliminate pulse-timing and video-equalization circuitry, and the remote panel contains operational controls (target, black, level, etc.) and status tally indicators. The necessary external support equipment (sync generator, encoder, etc.) and monitoring components are not included as part of the system, making the PK-610 a component that can be added to existing as well as new systems.

Costs were reduced in designing the camera head mechanical package. An integral optical system and yoke-assembly mounting plate defines the optical axis for the camera. This heavy tooling plate serves as a stable reference datum for mounting the camera and allows the remaining mechanical package to be fabricated from light-gauge sheet metal. The total package is of rigid structure and attractive, but inexpensive.

Printed-circuit mother boards were used to reduce wire harness costs; all interconnections between modules, including module edge connectors, are made with etched circuitry on the mother board. Camera-cable and control-panel wiring, as well as deflection yoke and preamplifier harnesses, terminate directly on the mother board. Controls and tally indicators for both the camera-control panel and the remote-control panel are similarly mounted directly to printed-circuit boards to reduce wiring costs and improve reliability.

Optical system

Two multiplex designs were considered when designing the optical system for the PK-610: the PMX-1 multiplexer with a 5-diopter field lens, and the auxiliary or "back-up" position on the TP-15 multiplexer which uses a 3-diopter field lens. These applications (plus others which are similar)

Reprint RE-15-6-19
Final manuscript received December 22, 1969.

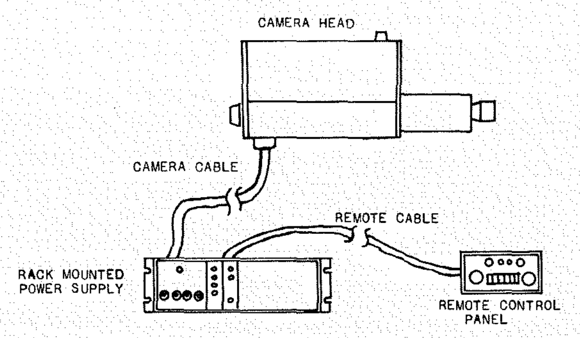


Fig. 1—System components for economical color film camera.

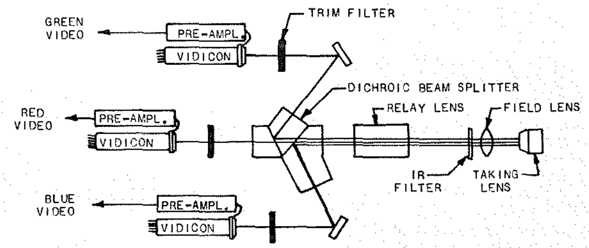


Fig. 2—Relay optical system and dichroic beam-splitter assembly.

provided the basis for the optical system shown in Fig. 2.

The optical system uses a 50-mm taking lens which images onto an internal field lens. A precisely sized mask is coated within the field lens which blocks light falling outside the standard vidicon scanning format. This masked image is relayed in a one-to-one ratio through the dichroic beam-splitter assembly and is precisely positioned on each vidicon faceplate. The spectral response of each channel is trimmed to provide the correct bandpass of spectral energy to conform with the overall system transfer function recommended by the NTSC. Optical efficiency is less stringent in a film camera than in a studio camera, but the opportunity to effect economies at the expense of efficiency was not carried too far. The vidicon, although an inexpensive and high-quality transducer, is limited by lag in its ability to operate at low light levels. Furthermore, the inherently inefficient conversion of energy in the blue wavelengths plus the effective loss of one *f*-stop in a relay system that operates on one-to-one conjugates place further requirements on the speed of the optical system.

As shown in Fig. 2, blue light is split out first, yielding the most efficiency possible, and the three preamplifiers are mounted close to the vidicons to provide optimum signal-to-noise performance for all the channels. This configuration yields high-quality results with an effective aperture of *f*/5.6.

Typically, 8507A vidicons operate at 12 to 18 volts target potential with 100 foot-candles light level at the taking lens.

Preamplifiers

The red, blue, and green outputs of a color camera will usually be processed to form encoded signals for distribution or broadcast. As this processing inherently degrades the signal-to-noise (S/N) ratio—due in part to subtractive matrixing—the S/N performance of color cameras must be the best obtainable. As such, the head-end preamplifier must amplify the camera-tube signal current with as low a noise figure as the state of the art will allow.

The block diagram in Fig. 3 shows the final form of the preamplifier developed for the PK-610. Several designs were evaluated using spectrum-analysis noise measurement techniques before the design was finalized. Essentially, the design centers around a low-noise UHF field-effect transistor, which is AC-coupled to an equally low-noise silicon transistor, to form a high-gain low-noise cascode amplifier with wide dynamic range. To further improve the noise figure of the head-end amplification, the preamplifier was mounted within a shielded case close to the vidicon. This mounting arrangement keeps the signal lead from the target electrode as short as possible to reduce interference coupling and to aid in reducing the input capacity of the amplifier. The input impedance to the preamplifier proved to be an important factor in achieving a low noise figure. Considering the vidicon as a current source and the FET as a nearly ideal voltage amplifier, an input resistor of 1 megohm was used in an attempt to obtain as much early voltage gain as possible in the first stage. This

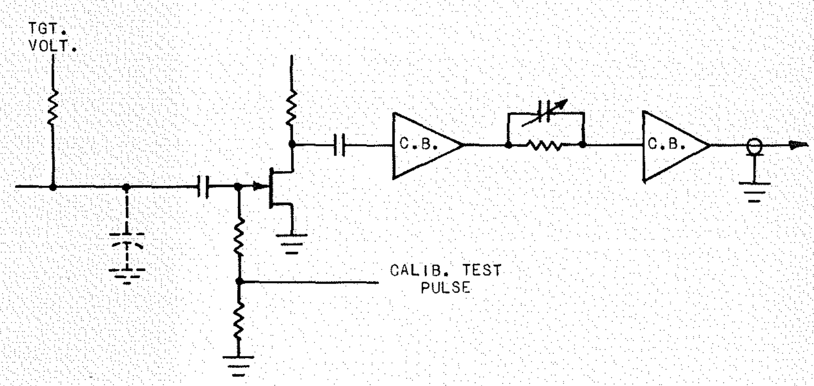


Fig. 3—Preamplifiers use a FET for low-noise performance. The calibrated test pulse serves as an aid in setting signal current levels.

value was found to be too high, as the target impedance at peak highlights is low enough to modify this value of input impedance, making square-wave compensation by a simple RC high-peaker stage impossible. This changing target impedance effect becomes neglible when an input resistance of the order of 200 kilohms is used.

High transconductance FET's were evaluated in an effort to increase early voltage amplification but, due to the larger input capacities of the higher gain FET's, the turn-over frequency for the high peaker occurs lower in frequency, which effectively causes the high frequency noise figure to be degraded. The final design parameters for the input stages and for the high peaker components, yielded a preamplifier which amplifies 0.5 μA of vidicon signal current up to nearly 2 mA with greater than 6-MHz response, and a broadband S/N of 46 dB (peak video to RMS noise).

Processor amplifiers

The salient features of the video processing amplifiers are shown in Fig. 4. Two test points and a local 75-ohm BNC output jack are the only monitoring points required to perform the three screwdriver adjustments on the front panel of each processor.

The first test point (TP1) monitors the input video, where the level is set with individual target voltage trimming potentiometers. To aid in properly setting correct signal levels, a precisely calibrated vertical interval test pulse, representing 0.5 μA of signal current, is injected into the gate of each preamplifier input stage (refer to Fig. 3), allowing the operator to match signal currents to a known reference. This pulse is also serrated with horizontal blanking pulses to provide a square wave test for adjusting the high peaker on each preamplifier. The signal level at the second test point (TP2) is set for 4 volts with the video level control. The final adjustment, black balance, is monitored at the local BNC jack.

Fig. 4 depicts a plug-in gamma correction network which is switchable from both the camera control panel and the remote panel to provide either a fixed 0.7 exponential transfer function or unity. The use of a plug-in sub-module here allows other gamma circuitry to be selected for special applications. The extension of the gamma function to a 0.5 exponential transfer function requires 6 volts of video at TP-2, so a gain plug-in sub-module was included to allow modifying the gain after the video level control, thus maintaining the same level setting at TP-1.

Two very important features of the PK-610 are indicated on Fig. 4: the automatic target control (ATC) sample and the automatic black level (ABL) sample. These two features help provide the "hands off" type of operation expected of television equipment in many of today's marketplaces.

ATC/ABL

Automatic black level (ABL) or pedestal control is a servo loop which operates on energy received from the black clippers of the three processor amplifiers to control the clamping reference of each channel. In Fig. 5, the ABL sample information from each processor is shown summing into a common point. This summing action allows the ABL loop to servo to any one input or to any combination of inputs depending on which channel

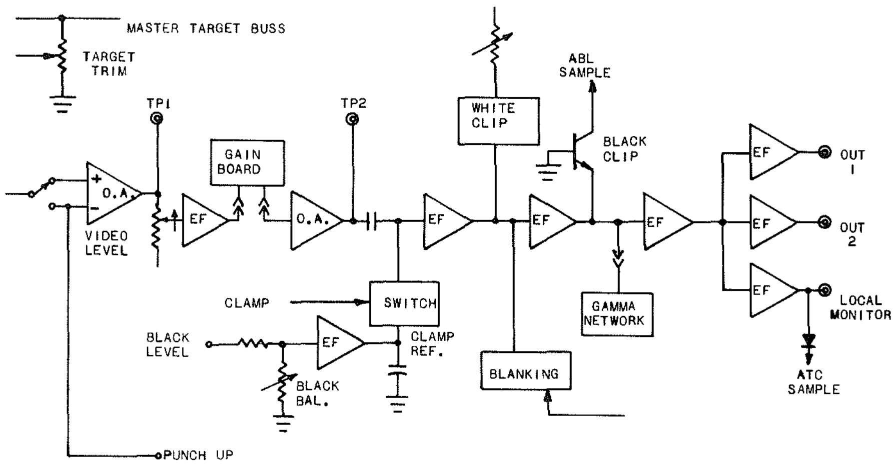


Fig. 4—Processing amplifier showing setup adjustments and plug-in submodules.

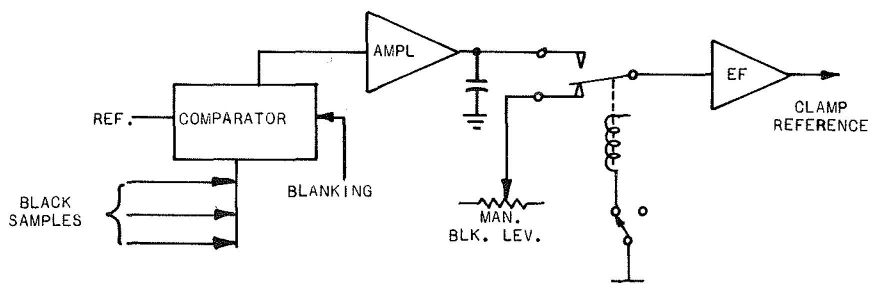


Fig. 5—Automatic black-level circuitry which servos the clamping reference for the processor amplifiers.

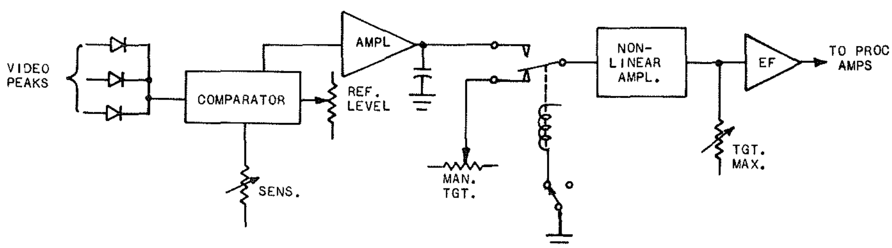


Fig. 6—The automatic-target circuit uses a non-linear amplifier to create a linear closed-loop servo system.

produces the most black clip information. This summing action in essence yields a non-additive mix type of operation. The output of the summing amplifier is filtered and the DC level obtained is distributed as a clamping reference to each processor to complete the control loop.

Clamping action is timed to occur during the last 3 μs of horizontal signal blanking. During this period, the beam is unblanked and allowed to actively scan the black region just inside the optical scanning mark. The signal generated during this interval produces a well-behaved clamping interval which represents the combination of optical black signal plus vidicon dark current. The contribution of dark current to scene black is therefore clamped out and black level settings stay fixed when target voltage and face plate temperature changes cause dark-current variations.

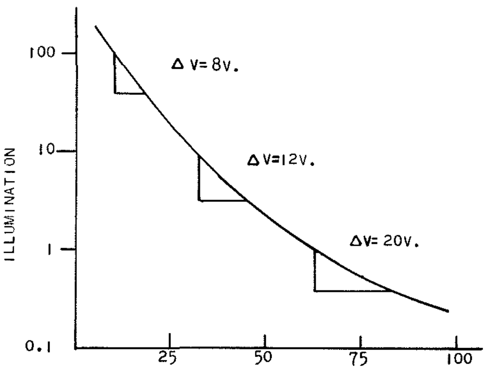


Fig. 7—Constant signal-current characteristic for a typical vidicon.

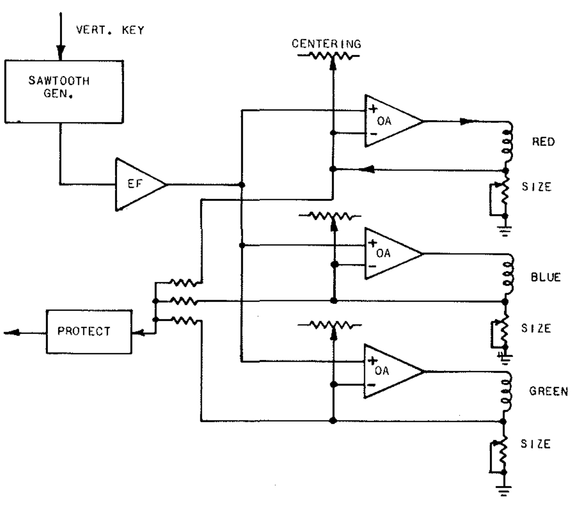


Fig. 8—The three vertical deflection yokes are each individually driven by a current feedback sweep amplifier.

A manual black level control and mode switch are located on the camera control panel as well as on the remote-control panel. The manual mode completely disconnects the ABL loop to provide the normal action of a manual pedestal control.

A simplified ATC loop is shown in Fig. 6. This loop is quite similar to the ABL loop, in that the energy which drives the loop is the sum of the white peaks that pass through video output sampling diodes. Again, a non-additive mix operation is effected, allowing the ATC to servo against the highest signal levels. An interesting feature of the ATC loop is the nonlinear amplifier within the loop which has a transfer function the is essentially the inverse or the constant-current characteristic depicted in Fig. 7. Equal increment (2:1) illumination changes at three levels of illumination are shown on this curve to illustrate the relative magnitude of target voltage change required in each case to return peak highlights back to the same signal current. This nonlinear amplifier senses voltage level, producing a gain characteristic which is directly proportional to target voltage. The resultant closed-loop is then essentially linear and exhibits uniform dynamic characteristics in all regions of operation. This desirable feature improves the ability of the ATC system to follow a wide range of changing light levels without objectionable overloads. Here again, a manual control can be switched into the circuit at either the camera control panel or at the remote panel, allowing normal manual target control from either location.

Registration

The importance of registration stability, and the ease with which this important aspect of a 3-channel camera can be obtained, is highly emphasized when considering some of the "non-technically" oriented areas of today's marketplace. The dependence of resolution on exacting registration, and the inherent characteristics and interactions of even the minimum number of controls, can easily frustrate even the most experienced operators if steps are not taken to design stability and operational ease into this circuitry.

A detailed discussion of the various adjustments involved, and the relative stability requirements controlling the various aspects of registration, are beyond the scope of this paper, but several interesting design features were evolved during the evaluation or registration design criteria.

Deflection assemblies

The deflection yoke designed for the PK-610 has the unique feature that allows removal of the vidicon from the rear of the assembly. The yoke assembly is never removed from the optical assembly so precision alignment fixtures are not required and vidicon replacement becomes a simple operation. The assembly provides a vernier mechanical focus and has sufficient range to accommodate production tolerances for vidicon faceplate thicknesses. Mechanical horizon and skew adjustments were designed using gear segments to rotate the elements of the deflection assembly. The direct action of this type of drive was found to be an advantage over similar lead-screw actuated schemes, in that the precise matching of skew adjustments (orthogonal relationship between horizontal and vertical scanning for the three channels) is more straightforward.

Deflection circuits

The design concept for the vertical and horizontal sweep circuitry is essentially the same; a precisely generated reference sawtooth is compared with a sample of yoke current in a high-gain operational amplifier to form a class A feedback loop around the deflection coils. The primary differences between these two circuits, as shown in the block diagrams of Figs. 8 and 9, are that the horizontal circuit controls only the green yoke and that the horizontal reference sawtooth is processed by a series of clipper circuits for linearity control.

Recalling that some 3 μs of the horizontal blanking interval is required for optical black clamping, it becomes apparent that a short horizontal retrace interval is required. A goal of less than 6 μs retrace blanking was established, during which time the sweep was to be retraced and restarted linearly without ringing. The design shown uses a standard 1-mH deflection assembly with the two coil windings connected in parallel. The resulting 250-μH yoke yields a retrace time of less than 4 μs and is free of ringing. The price paid for these results is the extra current demand for the lower inductance yoke—some 500 mA being required for each yoke or a total of 1.5 A for the circuit.

Control of horizontal scan linearity is accomplished by summing clipped components of the master reference sawtooth for comparison with the feedback waveform. The three clipper circuits are set to provide beam acceleration control at various positions across the left half of the raster. Once the fed-back channel linearity has been adjusted, the other two channels are matched to the master using conventional circuitry.

High power integrated-circuit operational amplifiers were tested in the vertical deflection circuit, but the cross-over distortion present in the output stages was found to be too severe for the application. The device tested was employed in a circuit with nearly 80 dB of feedback control. The distortion was barely measurable with a high gain differential comparator, but two distinct lines appeared horizontally across the video raster. It is interesting to note that a recent article on the subject applies the term *skrinch* to video deflects caused by vertical deflection distortion, and places tolerable limits of less than 0.01% distortion on the discontinuities of the deflection sawtooth. Recently announced IC's show better promise for this application, but discrete circuitry remains more flexible in that control of biasing in the output stages yields better results.

Power distribution

Overall camera stability and performance is based upon a precision integrated-circuit voltage regulator which is located in the camera head. Besides providing a stable voltage for deflection size and centering circuitry, the positive and negative outputs of these regulators serve as reference potentials for active decoupling circuitry located on the individual circuit boards. These post regulators draw load current from the power regulators in the remote power supply and provide optimum noise and ripple isolation. This approach to circuit decoupling has

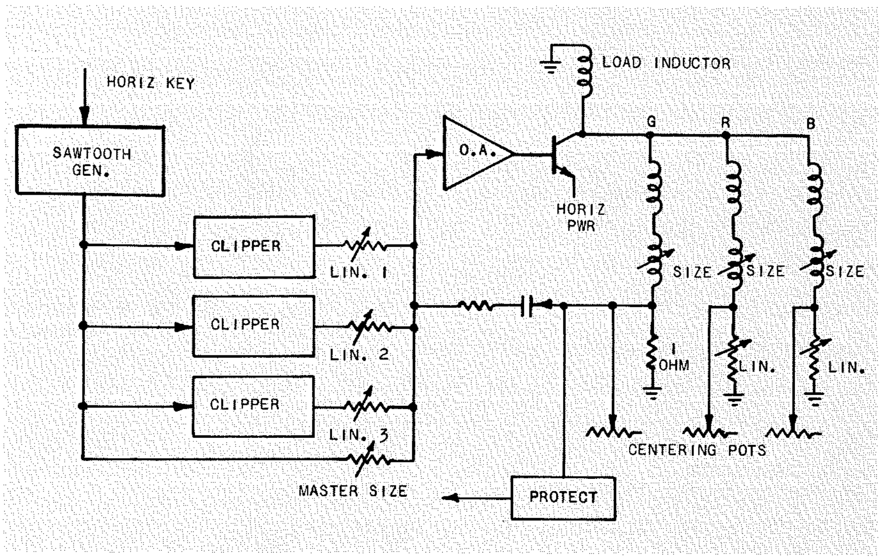


Fig. 9—The horizontal deflection amplifier uses a non-linear reference sawtooth to create a linear scan.

proven superior to RC networks and, in most cases, is less expensive.

Shading generator

Precision white balance and grey-scale balance requires that the three individual channels exhibit identical and uniform sensitivity characteristics over the target surface. In general, camera tubes are somewhat less than uniform and shading correction must be added to compensate for non-uniform sensitivity as well as to balance for differential shading between channels.

Shading compensation is accomplished by modulating the vidicon cathode with sawtooth and parabolic waveforms—thus varying the cathode to target voltage and, thereby, vidicon sensitivity. Both waveforms are generated at the horizontal, as well as the vertical, rate. Each waveform is individually adjustable with a continuous positive through negative range of about 6 volts. Three summing stages amplify the composite of the four waveforms for each channel and vidicon blanking is inserted. Low-impedance output stages directly couple the signals to the separate cathodes.

Parabolic waveforms are formed using a simple RC integrator followed by a high-gain amplifier. Feedback integrators, using IC operational amplifiers, were found to be too sensitive to noise and DC level shifts, causing undesirable modulation and noise injection. The RC integrator offers greater immunity to these undesirable effects, and the high-gain amplifier design is less expensive.

Summary

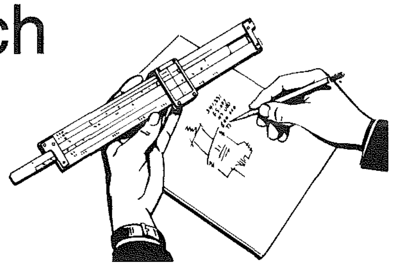
Electronic equipment is being sold in an increasing number of markets where sophisticated features are not required. In some cases, the technical capability of the end user may not prove adequate to cope with complex equipment, while in other cases, the requirement is for equipment that is inexpensive yet has the quality necessary for routine programming.

The PK-610 is designed for this type of straightforward color service. Stabilized circuitry and automated level-control circuits, together with simplified set up and operation controls, allow the PK-610 to give optimum performance for the unsophisticated operator. Precision colorimetry and quality low-noise performance make the PK-610 an attractive inexpensive color source for the broadcaster, both on the airwaves and over cable systems.

Acknowledgements

The author wishes to extend credit to Mr. Henry Maynard, Project Leader for the PK-610 program, under whose leadership much of the material in this article was assimilated. Special thanks to Mr. David Jones for his efforts on this article.

Engineering and Research Notes



Brief Technical Papers of Current Interest

Hum buckers for television remotes

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Reprint RE-15-6-22 | Final manuscript received January 22, 1970.

A law, credited to Murphy, states that the worst thing that can happen will happen, and at the worst possible time. Television engineers, especially when involved in remote pickups, are all too familiar with Murphy's law, especially as it relates to ground-potential differences. Direct current is not generally much of a factor unless the DC is subject to sudden changes which produce bobbles through AC coupled amplifiers. Small potential differences of AC, however, may ride through with the video and, in many instances seriously, degrade picture quality despite the use of stabilizing amplifiers.

Over the years broadcasters have attempted to tame ground hum by two general methods:

1) *Using differential input amplifiers.* Unfortunately these never seem available when Murphy's Law provides a ground hum problem. Existing amplifiers can sometimes be modified for differential input hum cancellation with only minor complication. NBC's first use of such an amplifier was in the late 1930's when a coax was installed from Radio City to the Empire State Building transmitter. Hum and bobble submerged the video until a differential input system was developed to cancel out the spurious signal.

2) *Using video transformers to break the flow of ground current from a distant source.* This is very effective in eliminating interference, assuming that the coax sheath is not allowed to contact ground except at the feeding end. The problem has been that video transformers seriously degraded the picture quality. Also, early video transformers were cumbersome and entailed appreciable video-level loss. At such locations as Cape Kennedy, where long coax connections are needed from cameras in different directions, the broadcasters of necessity employed transformers which on color transmissions caused shifts of hue and loss of detail. Even when followed by stabilizing amplifiers those transformers were simply terrible, but without them the pictures were completely unusable because of ground potentials. Today, vastly improved video transformers are available. One such, manufactured in Japan, is good to 10 MHz. It does create a minor low-frequency tilt, and consequently should be followed by a clamp amplifier.

NBC has now developed a third relatively simple solution to the ground potential problem. It does not entail a differential input nor does it use a video transformer in the ordinary manner. It is a so-called hum-bucker coil. An article by Yu N. Yablin in the English Edition of *Telecommunication and Radio Engineering* (April 1967), pointed out the advantages of an "antinoise transformer." Thereafter, NBC constructed a crude model which gave 7-dB hum suppression. This involved no picture signal degradation whatever, encouraging further development. More than 100 greatly improved units have now been constructed and used. These have been highly satisfactory as attested by the fact that after large remote field operations, involving other broadcasters and the telephone company, several units have mysteriously disappeared.

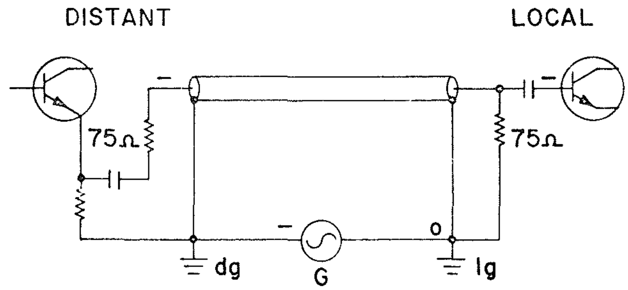


Fig. 1—Hum voltage in video by AC ground potential difference showing phase relationship from G.

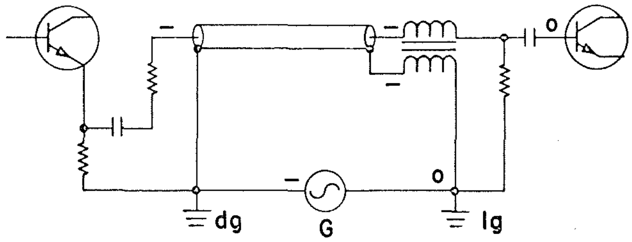
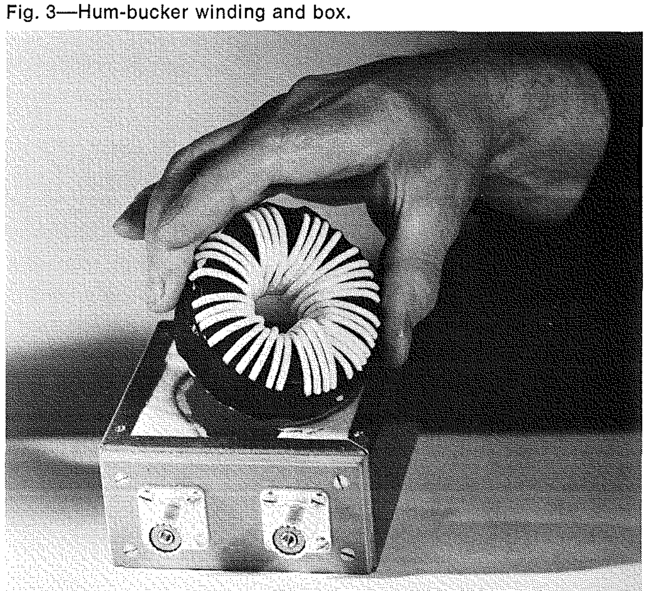


Fig. 2—Video hum voltage bucked out by transformer.

The introduction of hum into a video circuit may be explained by referring to Fig. 1. Here we have a 60-Hz potential between the "distant" and the "local" grounds—*dg* and *lg*. This might be caused by any of several factors such as three-phase power unbalances. For simplicity, the diagram shows an AC generator *G* connected to create a small AC ground potential difference. This produces relatively heavy current flow through the coax sheath. There can be no voltage from either sheath end to its ground connection but the center conducter has hum voltage applied at the distant end which cannot be grounded out without shorting the video.

Now suppose that we have a transformer whose secondary can be connected in series with the 75-ohm video circuit without degrading video response. Further, suppose that this transformer secondary has 100% coupling to its primary and that the primary is connected in series with the cable shield (as shown in Fig. 2). Current then flows from generator *G* through

Fig. 3—Hum-bucker winding and box.



the sheath, the primary, and the ground return. When the phase produces positive voltage at the local ground-connection side of the primary (negative at the sheath connection), a similar phase appears across the secondary. For this phase condition, voltage on the coax center conductor was negative, so addition of the secondary voltage tends to buck out the hum voltage. Cancellation becomes significant only if the inductance of the windings is quite appreciable. According to our measurements, a winding inductance of 8 mH gave hum suppression of 7 dB; an inductance of 30 mH gave 22 dB. For 250 mH, suppression was difficult to measure but was above 30 dB. It may seem that the conditions described would be difficult to attain without ruining video quality, but this is not the case. Actually, the hum bucker is easily constructed, inexpensive, rugged, small in size, has negligible insertion loss, and has no effect on picture quality.

NBC's present units are made by winding a short length of small-size teflon-insulated 75-ohm coax on an extremely high-permeability torroid core. The wound coil is mounted in a box with coax connectors insulated from each other. The center conductor serves as the secondary and the sheath as the primary (Fig. 2). It should be noted that primary and secondary are essentially 100% coupled. Each winding has the same inductance value and, if either is short circuited, the other drops to near zero.

The toroid core which is used has a mu of about 60,000. Including a protective casing, it measures 2⁹⁄₁₆ inches OD, has a 1⅜-inch hole, and is 1⅛ inches thick. A 14½-ft length of RG 187/U coax is cut and wound on tightly by hand, as evenly as possible. This results in about 39 turns which measures approximately 250mH with high *Q* on a 200-Hz bridge. A large toroidal core was tried with longer coax to achieve the same inductance and had the advantage of withstanding greater hum voltage without saturation. However, it required a larger assembly and was more expensive. To date, we know of no instance where saturation due to excessive hum voltage has been a factor. If Murphy's Law brings about such a condition, two of the present small units in series should help.

Because of the nature of these extremely high-mu cores, it is important to avoid dropping them prior to winding. After winding, the coax serves as a partial mechanical-shock isolator. Additional protection is provided by mounting in foam rubber in a metal box. We use a 2x4x4-inch box with a formica board mounted against one of the 2-inch sides. Before applying the formica on which the connectors are mounted, the box should have large clearance holes punched to preserve insulation between connectors and ground. Fig. 3 pictures the torroid coil held above its foam rubber nesting place in the box.

In operation, the incoming cable sheath must not contact the local ground, as that would short-circuit the primary and stop all hum cancellation. When a cable includes a number of sections with connectors, each connector must be taped and definitely insulated from building grounds. Otherwise the desired action may be shorted or, from Murphy's Law, a different hum phase introduced. Where preferable, the hum bucker can be connected in the coax line at the transmitting end or at some in-between point.

Generating cold gas for photomultiplier cooling

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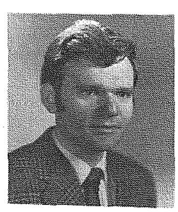

Reprint RE-15-6-22 | Final manuscript received February 18, 1970.

The somewhat obvious, but relatively unused, technique for generating cold gas by bubbling room-temperature N_2 directly into liquid nitrogen offers twice the cooling time of the conventional "immersed heater" or "continuous gas flow-through" systems. An apparatus for implementing the technique is illustrated in this note.

Because of several temperature dependent factors,[1] including thermionic emission, photosensitivity, and spectral response, many photomultipliers sensitive in the near infra-red give best[2] overall performance at some temperature between 0 and −50°C. Cold gas, about −195°C at the generating point to allow for losses, is a suitable refrigerant for this range; it is commonly generated by a heater immersed in a dewar of liquid nitrogen *(LN)*, or by flowing dry N_2 gas through a coil immersed in *LN*.

A method of cold gas generation which extracts greater cooling power from the *LN* is to bubble N_2 gas directly into *LN*. The thermodynamic calculations, summarized in Table I, suggest that the volume of cold gas obtained using this technique is about twice that of the other methods for a given mass of *LN*. Thus, the nuisances of too frequent *LN* replenishment, and condensables blocking the cooling coil in the continuous flow-through system are overcome.

The arrangement shown in the diagram has proven very convenient in laboratory use. Photomultiplier temperature is easily adjusted by controlling the input gas flow rate. We obtain about 7 hours of continuous operation at −25°C from a single 2-liter charge of *LN*: cold gas flow is through 0.75m of styrofoam insulated tubing to a large "end on" type photomultiplier (RCA C31000F) housed in 1.5-cm-thick styrofoam with a 3-mm-thick glass window. As with any photomultiplier cooling technique, care should be taken to insure uniform, gradual, refrigeration of the entire tube.

Table I—*LN* efficiencies of cold-gas generating systems.

System	*Generated volume of N_2 gas at −195° C*	*Relative operating time or volume*
Immersed heater	m/ρ	1.0
Continuous flow-through	$(m/\rho)\,(H_{vap}/220\,C_p)$	0.9
Bubbling gas	$(m/\rho)\,(1+H_{vap}/220\,C_p)$	1.9

where
m = mass of liquid nitrogen
ρ = density of N_2 gas at −195°C
H_{vap} = heat of vaporization of *LN* = 47.6 cal/g°C
C_p = specific heat of N_2 gas = 0.25 cal/g
220 = room temperature − *LN* temperature (°C)

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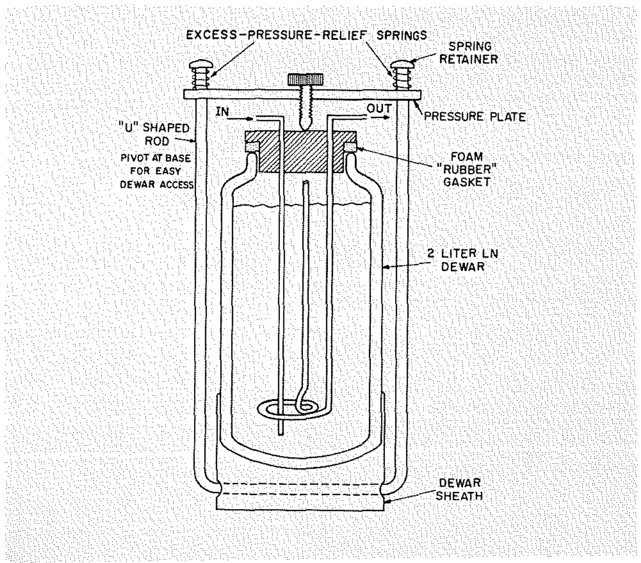
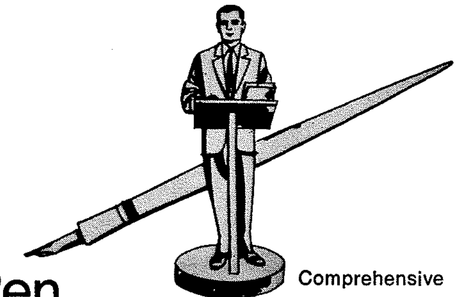
2. Krall, H., *private communication*.

Fig. 1—Typical apparatus for utilizing "bubbling gas" technique for generating cold N_2 gas.





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Cryoelectric memories employing loop cells—R. A. Gange (EC, Pr) U. S. Pat. 3,491,345; January 20, 1970.

Switchable circulator R. F. amplification fault circuit for a microwave receiver—F. Sterzer (EC, Pr) U.S. Pat. 3,491,357; January 20, 1970.

Unbalanced memory cell—R. W. Ahrons, S. Katz (EC, Som) U.S. Pat. 3,493,786; February 3, 1970.

Color killer circuits controlled by the local oscillator—W. M. Austin (EC, Som) U.S. Pat. 3,495,030; February 10, 1970

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Thermoelectric generator comprising thermoelements of indium-gallium arsenides or silicon-germanium alloys and a hot strap of silicon containing silicides—A. G. F. Dingwall, R. K. Pearce (EC, Hr) U. S. Pat. 3,496,027; February 17, 1970.

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Color Television display system with reduced pincushion distortion—I. F. Thompson, R. L. Barbin (CED, Indpls) U.S. Pat. 3,495,124; February 10, 1970.

Oval loudspeaker basket—A. L. Coen (CED, Indpls) U.S. Pat. 3,494,444; February 10, 1970.

Voltage supply—W. F. W. Dietz (CED, Indpls) U.S. Pat. 3,495,126; February 10, 1970.

Signal translating and angle demodulating systems—J. Avins (CED, Som) U.S. Pat. 3,495,178; February 10, 1970.

Variable radio frequency attenuator—L. A. Harwood (CED, Som) U.S. Pat. 3,495,193; February 10, 1970.

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Electro-optical device—G. H. Heilmeier, L. A. Zanoni (Labs., Pr) U.S. Pat. 3,499,112; March 3, 1970.

Cryogenic associative memory—R. W. Ahrons (Labs., Pr) U.S. Pat. 3,483,532; December 9, 1969; Assigned to U.S. Government.

Magnetic recording element and method for preparing same—M. Slovinsky (Labs., Pr) U.S. Pat. 3,490,945; January 20, 1970.

Magnetic recording elements—N. E. Wolff (Labs., Pr) U.S. Pat. 3,490,946; January 20, 1970.

Ferromagnetic-semiconductor composition—H. W. Lehmann, M. Robbins (Labs., Pr) U.S. Pat. 3,491,026; January 20, 1970.

Electroluminescent device and method of operating—A. M. Goodman (Labs., Pr) U.S. Pat. 3,492,548; January 27, 1970.

Photosensitive device—E. P. Kaldis, R. W. Widmer (Labs., Zurich) U.S. Pat. 3,492,620; January 27, 1970.

Television message system for transmitting auxiliary information during the vertical blanking interval of each television field—W. D. Houghton (Labs., Pr) U.S. Pat. 3,493,674; February 3, 1970.

Integrated thin film translators—P. K. Weimer (Labs., Pr) U.S. Pat. 3,493,812; February 3, 1970.

Light-emitting diodes and method of making same—R. H. Cornely, W. F. Kosonocky (Labs., Pr) U.S. Pat. 3,495,140; February 10, 1970.

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Hydrodynamically supported magnetic head—R. D. Scott (DCSD, Cam) U.S. Pat. 3,479,661; November 18, 1969; Assigned to U.S. Government.

Image transmission through a fiber optics device—H. A. Brill (DCSD, Cam) U.S. Pat. 3,489,482; January 13, 1970.

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Split beam light modulator—J. L. Dailey (MSR, Mrstn) U.S. Pat. 3,495,892; February 17, 1970.

Optical correlator for determining the longitiudinal displacement of similar information on two tracks—P. J. Donald, R. W. Chambers (MSR, Mrstn) U.S. Pat. 3,453,439; July 1, 1969; Assigned to U.S. Government.

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Converter for self-clocking digital signals—J. A. Vallee (ISD, W. Palm) U.S. Pat. 3,493,962; February 3, 1970.

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Be sure deadlines are met—consult your Technical Publications Administrator or your Editorial Representative for the lead time necessary to obtain RCA approvals (and government approvals, if applicable). Remember, abstracts and manuscripts must be so approved BEFORE sending them to the meeting committee.

Calls for papers

AUG. 18-21, 1970: **International Conference on Microelectronics, Circuits and System Theory,** The University of New South Wales, Sydney, Australia, IREE Australia, IEEE, Electronics Division of IEE. **Deadline info (1,000 words with key illustrations; 2,000 words without illustrations; 50-word abstract) 5/22/70 to:** Joint Conference Secretariat, I.R.E.E. Australia, Box 3120, G.P.O., Sydney, 2001, Australia.

SEPT. 14-16, 1970: **1970 International IEEE/G-AP Symposium,** The Ohio State University, Columbus, Ohio 43210. **Deadline info (400-600 word sum) 6/1/70 to:** Dr. Curt A. Levis, P.O. Box 3115, The Ohio State University, Columbus, Ohio 43210.

SEPT. 15-17, 1970: **Fall USNC/URSI Meeting,** The Ohio State University, Columbus, Ohio 43210. **Deadline info (two copies of absts) 6/1/70 to:** Dr. Curt A. Levis, P.O. Box 3115, The Ohio State University, Columbus, Ohio 43210.

SEPT. 21-23, 1970: **AIAA Aerodynamic Deceleration Conference,** Dayton, Ohio, Technical Committee on Aerodynamic Deceleration Systems. **Deadline info (first draft) 4/20/70:** Solomon R. Metres, USAF Flight Dynamics Lab., Recovery and Crew Station Branch, (FDFR) Wright-Patterson Air Force Base, Ohio 45433.

OCT. 14-16, 1970: **Systems Science & Cybernetics Conference,** Webster Hall Hotel, Pittsburgh, Penna., G-SSC. **Deadline info (abst) 4/15/70 to:** A. Lavi, Carnegie-Mellon Univ., Pittsburgh, Penna. 15213.

OCT. 26-28, 1970: **1970 IEEE Electronic and Aerospace Systems Convention (EASCON),** Sheraton Park Hotel, Washington, D.C. **Deadline info (four copies, 500-to-1000 word paper) 5/2/70 to:** Technical Program Chairman, Dr. Richard Marsten, NASA Headquarters, Code SC, Washington, D.C. 20546 or Program Vice Chairman, Dr. Harold Braham, General Electric Company, P.O. Box 8555, Philadelphia, Pa. 19101.

OCT. 27-30, 1970: **Electronics Division Fall Meeting Concurrently With 23rd Pacific Coast Regional Meeting,** St. Francis Hotel, San Francisco, California, The American Ceramic Society, Inc. **Deadline info (150 word abst) 6/15/70 to:** James R. Floyd, Program Chairman, Electronics Division, The American Ceramic Society, Inc., 4055 North High Street, Columbus, Ohio 43214.

NOV. 1970: **G-MTT Transactions is planning a special issue on Microwave Circuit Aspects of Avalanche Diode and Transferred Electron Devices, IEEE. Deadline info (complete ms) three copies of each 4/15/70 to:** Guest Editor, Mr. A. H. Solomon, Sylvania Electric Products, Inc., 100 Sylvan Road, Woburn, Mass. 01801.

NOV. 4-6, 1970: **Northeast Electronics Research & Engineering Meeting (NEREM),** Sheraton Boston Hotel & War Mem. Aud., Boston, Mass., New England Sections. **Deadline info: (abst) 5/29/70 (papers) 7/3/70 to:** IEEE Boston Office, 31 Channing St., Newton, Mass. 02158.

NOV. 15-19, 1970: **Engineering in Medicine & Biology Conference,** Washington Hilton Hotel, Washington, D.C., AEMB, G-EMB. **Deadline info (abst) 6/1/70 to:** Richard Johns, 522 Traylor Bldg., Johns Hopkins School of Med., Baltimore, Md. 21205.

NOV. 17-19, 1970: **1970 Fall Joint Computer Conference,** AstroHall, Houston, Texas, IEEE. **Deadline info (100-150 word abst; 6 copies complete draft ms) 4/10/70 to:** L. E. Axsom, Chairman, Technical Program Committee, 1970 Fall Joint Computer Conference, P.O. Box 61449, Houston, Texas 77061.

DEC. 2-4, 1970: **1970 IEEE Conference on Vehicular Technology,** Statler-Hilton Hotel, Washington, D.C. **Deadline info (six copies of 800 to 1,000 word sum) 6/15/70 to:** Dr. Peter M. Kelly, Kelly Scientific Corporation, 3900 Wisconsin Avenue, N.W., Washington, D.C. 20016.

DEC. 7-9, 1970: 1970 (9th) **IEEE Symposium on Adaptive Processes: Decision and Control,** University of Texas; Austin, Texas. **Deadline info (short papers—700 word sum) 8/1/70; (reg. papers) 5/1/70 five copies each to:** Prof. D. G. Lainiotis, Program Chairman, IEEE 1970 Symposium on Adaptive Processes, Department of Electrical Engineering, Engineering Science Building 502, University of Texas at Austin, Austin, Texas 78712.

DEC. 9-11, 1970: **Conference on Applications of Simulation,** Waldorf-Astoria, New York, New York, IEEE, ACM, AIIE, SHARE, SCI, TIMS. **Deadline info (three copies of 50-100 abst) 3/31/70 (five copies paper) 7/6/70 (ms) 9/30/70 to:** Michel Araten, Program Committee Chairman, Celanese Chemical Company, 245 Park Avenue, New York, New York 10017.

DEC. 14-16, 1970: **International Symposium on Circuit Theory,** Sheraton-Biltmore Hotel, Atlanta, Georgia, IEEE. **Deadline info: (two copies abst—100-to-250 words) 6/1/70; (four copies reg/short papers) 7/1/70 to:** Mr. I. T. Frisch, Network Analysis Corporation, Beechwood, Old Tappan Road, Glen Cove, New York 11542.

JAN. 12-14, 1971: **Reliability Symposium,** Sheraton Park Hotel, Washington, D.C., G-R, ASQC, ASNT, IES. **Deadline info: (abst) 5/1/70 to:** J. W. Thomas, Vitro Labs., 14000 Georgia Ave., Silver Spring, Maryland 20910.

Meetings

APRIL 26-MAY 1, 1970: **107th SMPTE Technical Conference and Equipment Exhibit,** Drake Hotel, Chicago, Ill. **Prog info:** Leonard F. Coleman, Eastman Kodak Co., Southwest Region, Motion Picture and Education Markets Div., 6300 Cedar Springs Rd., Dallas, Tx. 75235.

APRIL 27-30, 1970: **National Telemetering Conference,** Statler Hilton Hotel, Los Angeles, Calif., G-AES, G-Com Tech. **Prog info:** A. V. Balakrishnan, UCLA, Rm. 3531, 405 Hilgard Ave., Los Angeles, Calif. 90024.

MAY 2-7, 1970: **72nd Annual Meeting & Exposition,** Philadelphia Civic Center and Sheraton Hotel, Philadelphia, Pa., The American Ceramic Society, Inc. **Prog info:** ACS, 4055 North High Street, Columbus, Ohio 43214.

MAY 4-5, 1970: **Transducer Conference,** Governor's House, NBS, Gaithersburg, Maryland, G-IECI. **Prog info:** H. P. Kalmus, Harry Diamond Labs., Dept. of the Army, Wash., D.C. 20438.

MAY 4-6, 1970: **AIAA/Navy Marine Systems, Propulsion, and ASW Meeting,** Newport, R.I. **Prog info:** American Institute of Aeronautics and Astronautics, 1290 Sixth Avenue, New York, N.Y. 10019.

MAY 4-7, 1970: **Ind. & Comm. Power Sys. & Elec. Space Heating & Air Conditioning Jt. Technical Conference,** Jack Tar Hotel, San Francisco, Calif., G-IGA San Francisco Section. **Prog info:** D. B. Carson, Gen'l Elec. Co., 212 N. Vignes, L. A. Calif. 90012.

MAY 4-7, 1970: **4th Conference on Aerospace Meteorology,** Las Vegas, Nev., (AMS/AIAA). **Prog info:** American Institute of Aeronautics and Astronautics, 1290 Sixth Avenue, New York, N.Y. 10019.

MAY 5-6, 1970: **Appliance Technical Conference,** Leland Motor Hotel, Mansfield, Ohio, G-IGA, North Central Ohio Section. **Prog info:** J. G. Idle, Westinghouse Elec. Corp., 246 E. 4th St., Mansfield, Ohio 44902.

MAY 5-7, 1970: **Spring Joint Computer Conference,** Convention Hall, Atlantic City, New Jersey, G-C, AFIPS. **Prog info:** AFIPS Hdqs., 210 Summit Ave., Montvale, New Jersey 07645.

MAY 7-8, 1970: **Midwest Symposium on Circuit Theory,** Pick-Nicolet Hotel, Minneapolis, Minn., G-CT, Univ. of Minnesota. **Prog info:** B. A. Shenoi, EE Dept., Univ. of Minn., Minneapolis, Minn. 55455.

MAY 11-13, 1970: **Conference on Television Measuring Techniques,** Middlesex Hosp, Medical School, London, England, IERE, RTS, IEE, IEEE UKRI Sect. **Prog info:** IERE Office, 8/9 Bedford Sq., London W. C. 1, England.

MAY 11-14, 1970: **International Microwave Symposium,** Newporter Inn, Newport Beach, Calif., G-MTT. **Prog info:** R. H. DuHamel, Granger Assoc., 1601 Calif. Ave., Palo Alto, Calif. 94304.

MAY 13-15, 1970: **Electronic Components Technical Conference,** Statler Hilton Hotel, Washington, D.C., G-PMP, EIA. **Prog info:** Darnall Burks, Sprague Elec. Co., Marshall St., N. Adams, Mass. 01247.

MAY 13-15, 1970: **AIAA Atmospheric Flight Mechanics Conference,** Tullahoma, Tenn. **Prog info:** American Institute of Aeronautics and Astronautics, 1290 Sixth Avenue, New York, N.Y. 10019.

MAY 18-20, 1970: **Aerospace Electronics Conference (NAECON),** Sheraton Dayton Hotel, Dayton, Ohio, G-AES, Dayton Section. **Prog info:** IEEE Dayton Office, 124 E. Monument Ave., Dayton, Ohio 45402.

MAY 18-20, 1970: **AIAA 5th Aerodynamic Testing Conference,** Tullahoma, Tenn. **Prog info:** American Institute of Aeronautics and Astronautics, 1290 Sixth Avenue, New York, N.Y. 10019.

MAY 18-22, 1970: **Air Force Materials Symposium—1970,** Miami Beach, Fla. **Prog info:** American Institute of Aeronautics and Astronautics, 1290 Sixth Avenue, New York, N.Y. 10019.

MAY 19-21, 1970: **Conference on Signal Processing Methods for Radio Telephony,** London, England, IEE, IERE, IEEE, UKRI Section. **Prog info:** IEE Office, Savoy Place, London W. C. 2 England.

MAY 25-27, 1970: **1970 Joint Conference on Fluids Engineering, Lubrication and Heat Transfer,** Statler-Hilton Hotel, Detroit, Michigan, the Cavitation Forum. **Prog info:** Albert G. Grindell, Chairman, 1970 Cavitation Forum, Reactor Division, Oak Ridge National Laboratory, Building 9201-3, Oak Ridge, Tennessee 37830.

MAY 26-28, 1970: **6th Region Conference,** Washington Plaza Hotel, Seattle, Washington, Region 6, Seattle Section. **Prog info:** P. R. Metz, Univ. of Wash., EE Dept., Seattle, Washington 98105.

Engineering News and Highlights

New Solid-State Division formed

Robert W. Sarnoff, Chairman and President of RCA, recently announced establishment of a new Solid-State Division. Mr. Sarnoff announced that **William C. Hittinger,** President of General Instrument Corporation, will join RCA, effective April 15, in the newly-created position of Vice President and General Manager, Solid-State Division. Mr. Hittinger will report directly to Mr. Sarnoff.

The new Division was formed through the consolidation of RCA's Integrated Circuit Technology Center of Research and Engineering and the solid-state operations of Electronic Components.

According to Mr. Sarnoff, "RCA intends to adopt a more aggressive program in order to participate more fully in the growth that lies ahead in the solid-state area. The centralization of our activities under one of the outstanding executives in the electronics industry represents a major step toward the fulfillment of that aim."

Dr. Brown made Fellow of British TV Society

Dr. George H. Brown, Executive Vice President, RCA Patents and Licensing, has been elected a Fellow of the British Royal Television Society.

The Royal Society is honoring Dr. Brown for his "very distinguished career in the field of television," according to T. H. Bridgewater, Membership Committee Chairman.

Dr. Brown, who has been associated with RCA since 1933, has made outstanding technical contributions to electronic communications and to modern television, particularly in antenna development and systems design. Among his major achievements is the conception of the trunstile antenna, which has become the standard broadcast antenna for television.

New consumer affairs activity to oversee quality and reliability

Creation of a major new corporate function—the office of Consumer Affairs—with far-reaching staff responsibility for the quality and reliability of RCA's full-range of products and services was announced recently by **Robert W. Sarnoff,** Chairman and President of RCA.

Mr. Sarnoff said **Herbert T. Brunn,** a veteran of almost 30 years executive service with various RCA divisions, has been selected for the newly-created post of Vice President, Consumer Affairs. In this capacity, he will be responsible for directing a company-wide program to insure that the rights and interests of the consumer public continue to receive the highest priority in all of RCA's diversified operations. In his new position, Mr. Brunn will report directly to Mr. Sarnoff. In announcing the new activity, Mr. Sarnoff said all of RCA's customers—institutions, Federal and local governments and private agencies as well as individuals—are equally entitled to the assurance of high quality and reliability in everything they buy from RCA.

Herold and Rosenthal promoted

Promotion of **Dr. Edward W. Herold** and **Howard Rosenthal** to newly created Director positions on RCA's Corporate Engineering Staff has been announced by **Dr. James Hillier,** Executive Vice President, Research and Engineering.

The two new Directors are responsible for coordinating the engineering activities of RCA's product divisions with the Corporate research and planning functions. In addition, they provide liaison between the divisional engineering organizations and Research and Engineering.

Priority for environmental pollution patents

The Commissioner of Patents recently announced that the Patent Office will speed up the examination of patent applications covering devices "which can aid in the curbing of environmental abuses". The priority will reduce processing time from the present average of about three years to a period of from six to eight months. Inventors who claim this privilege are required to indicate how their inventions relate to the "maintenance or restoration of one of the basic life-sustaining elements: air, water or soil." The new procedure will apply to existing and future patent applications. *Any RCA inventor who recognizes such an application for his invention should contact Patent Operations, Princeton, N.J.*

Errata

In the article, "Light scattering with laser sources," by Dr. G. Harbeke and Dr. E. Stegmeir (Vol. 15, No. 5, Feb-Mar 1970, pp. 82-85), the following corrections should be made:

p. 82, col 2, Eq. 2 should be:

$$\mathbf{P} = \alpha \mathbf{E} = (\alpha_o + \alpha_1 \cos 2\pi \nu_1 t)\, \mathbf{E}_o \cos 2\pi \nu t = \alpha_o \mathbf{E}_o \cos 2\pi \nu t + \tfrac{1}{2} \alpha_1 \mathbf{E}_o [\cos 2\pi (\nu + \nu_1) t + \cos 2\pi (\nu - \nu_1) t]$$

p. 82, col. 3, lines 12 and 13 should be:

excited state of energy $h\nu_1$ above the ground state. The emitted photon lacks

p. 83 col. 1, lines 1 and 2 should be:

the sum of the momenta of the scattered photon $h\mathbf{k}_s$ and the phonon

p. 83, col. 1, lines 19 and 20 should be:

located very close to $\mathbf{k}=0$ on the abcissa of Fig. 2 extending to $\mathbf{k}_{max}=2\pi/F_a$

p. 83, col. 2, lines 40 through 42 should be:

of phonon states is highest. Such critical points exist preferably at the Brillouin zone edges like at $|\mathbf{k}| \approx 2\pi/a$ in

p. 85, col. 3, References 1 through 7 should be:

1. Lord Rayleigh, *Philadelphia,* Vol. 47 (1899) p. 375.
2. Brillouin, L., *Ann. Phys.* (Paris) Vol. 17 (1922) p. 88.
3. Raman, C. V., *Indian J. Phys.* Vol. 2 (1928) p. 387.
4. Mooradian, A., "Light Scattering in Semiconductors", to be published in *Festkorperprobleme X,* Vieweg, Braunschweig.
5. Cummins, H. Z., Knable, N. and Yeh, Y., "Observation of Diffusion Broadening of Rayleigh Scattered Light," *Phys. Rev. Letters,* Vol. 12 (1964) p. 150.
6. Fatuzzo, E., Harbeke, G., Merz, W. J., Nitsche, R., Roetschi, H. and Ruppel, W., "Ferroelectricity in SbSI," *Phys. Rev.* Vol. 127 (1962) p. 2036.
7. Baltzer, P. K., Lehmann, H. W. and Robbins, M., "Insulating Ferromagnetic Spinels," *Phys. Rev. Letters* Vol. 15 (1965) p. 493.

Contents: March 1970 *RCA Review*
Volume 31 Number 1

The *RCA Review* is published quarterly. Copies are available in all RCA libraries. Subscription rates are as follows (rates are discounted 20% for RCA employees):

	DOMESTIC	FOREIGN
1-year	$4.00	$4.40
2-year	7.00	7.80
3-year	9.00	10.20

Degrees Granted

P. Joy, ATL, Camden ... MS, Mechanical Engineering, Drexel Institute of Tech.; 6/69
F. R. McGuirk, MTP, Cocoa Beach ...... BSEE, Florida Institute of Technology; 9/69
L. R. Dodd, MTP, Cocoa Beach .... BS, Mathematics, Florida Institutes of Tech.; 9/69
S. A. Farra, MTP, Cocoa Beach .... BS, Physics, Florida Institute of Tech.; 9/69
P. L. Beem, MTP, Cocoa Beach ..... BS, Mathematics, Florida Institute of Tech.; 9/69
A. J. Fandozzi, CES, Meadow Lands .... MSEE, University of Pittsburgh; 8/69
R. S. Mezrich, Labs., Princeton ... PhD, Electrical Engineering, Polytechnic Institute of Brooklyn; 2/70
R. C. Brauder, EC, Lancaster .... Master of Engineering Science, Penn State U.; 12/69
J. Elko, AED, Pr. .... MSEE, Stevens Institute of Technology; 1/70

Promotions

Electromagnetic and Aviation Systems Division

M. Masse from Principle Member Engineering Staff to Leader, Navigation Systems (R. P. Crow, Van Nuys, Calif.)
J. B. Harrison from Staff Engineering Scientist, Van Nuys to Manager, Mechanical Engineering (G. A. Lucchi, Van Nuys, Calif.)

Commercial Electronic Systems

A. T. Montemuro from Class A Eng. to Ldr., Des. & Dev. Engrs. (R. J. Smith, Camden)

J. Shelton from Engineer, Audio Visual to Leader, Broadcast Audio (R. S. Putnam, Meadowlands)

Television Picture Tube Division

J. J. Moscony from Sr. Engineer, Product Development to Engineering Leader, Product Development (R. H. Zachariason, Lancaster, Pa.)

A. C. Porath from Sr. Engineer, Product Development to Engineering Leader, Product Development (R. H. Zachariason, Lancaster, Pa.)

K. D. Scearce from Engineer, Equipment Development to Engineering Leader, Equipment Development (J. F. Stewart, Lancaster, Pa.)

R. E. Salveter from Engineering Leader, Product Development to Manager, Chemical and Physical Laboratory (D. J. Ransom, Marion)

Industrial Tube Division

J. J. Florek, Superintendent, Tube Assembly and Finishing to Manager, Tube and Parts Preparation, Production Engineering (C. A. Hear, Harrison)

Computer Systems Division

C. D. Hughes from Engineer to Ldr., Design & Development Engrs. (J. K. Mulligan, Camden)

T. D. Floyd from Sr. Mbr., D&D Engrg. Staff to Leader, Technical Staff (H. N. Morris, West Palm Beach)

RCA Service Company

J. L. Alexander from Associate Engr. to Mgr., Navigation Data Handling (M. J. VanBrunt, Cocoa, Florida)

J. E. Connaway from Systems Service Engineer to Ldr. (D. Botticello, Springfield, Va.)

J. T. Herbert from Engineer to Mgr., Ship Instrumentation (S. L. Candler, Andros Island)

R. F. Schneider from Engineer to Mgr., Acoustics Range (L. R. Whitehead, Andros Island)

E. D. Stone from Engineer to Mgr., Data Acquisition (L. R. Whitehead, Andros Island)

R. H. Tuten from Ldr., Engineers to Mgr., Ship Pulse Radar (K. F. Wenz, Cocoa, Florida)

T. D. Hummer from Associate Engineer to Ldr., Trinidad Operations—Shift (J. Brady, Trinidad Instrumentation Station)

Astro Electronics Division

Herbert Berkowitz from Senior Engineer to Manager (Specialty) Engineering (J. F. Baumunk, Hightstown)

Stephen C. Blum from Engineer to Manager (Specialty) Engineering (J. F. Baumunk, Hightstown)

L. A. Freedman from Manager, Project to Manager (Specialty) Engineering (G. Barna, Hightstown)

Jack A. Frobieter from Engineer to Manager (Specialty) Engineering (G. Corrington, Hightstown)

John C. Graebner from Senior Engineer to Manager (Specialty) Engineer (J. F. Baumunk, Hightstown)

L. T. McCloskey from Engineer to Administrator, Customer Relations (H. D. Bradbury, Hightstown)

Robert Miller from Senior Engineer to Manager Project (C. K. Hume, Hightstown)

Anthony R. Pontoriero from Leader Project Administration to Manager Business Operations (L. V. Fox, Hightstown)

E. W. Schlieben from Administrator, Long Range Planning to Manager, Oceanographic Programs (W. T. Manger, Hightstown)

J. R. Staniszewski from Mgr., Specialty Engineering to Mgr., Projects (C. R. Hume, Hightstown)

E. J. Vallas from Engineer to Mgr., Specialty Engineering (J. Staniszewski, Hightstown)

Missile and Surface Radar Division

W. J. Beck from Engineer to Ldr., Des. & Dev. (W. S. Perecinic, Moorestown)

B. J. Matulis from Engineer to Ldr., Des. & Dev. (W. S. Perecinic, Moorestown)

Defense Communications Systems Division

O. E. Bassette from A Engineer to Ldr., Design & Development Engineers (J. D. Rittenhouse, Camden)

W. Blackman from Engineer to Ldr., Des. & Dev. (J. B. Howe, Camden)

D. J. D'Andrea from Engineer to Ldr., Des. & Dev. (J. B. Howe, Camden)

G. Galanek from Engineer to Ldr., Des. & Dev. (J. D. Rittenhouse, Camden)

J. S. Griffin from Ldr., Des. & Dev. to Mgr., Rec. Equip. Projects (J. D. Rittenhouse, Camden)

W. A. Hatsell from Class A Eng. to Adm., Design Integration (L. Iby, Camden)

M. Rosenblatt from Ldr., Des. & Dev. Eng. to Mgr., Comm. Eqp. Projects (J. B. Howe, Camden)

C. R. Thompson from Ldr., Des. & Dev. to Mgr., Rec. Equip. Projects (J. D. Rittenhouse, Camden)

R. M. Zieve from Engineer to Ldr., Des. & Dev. (J. B. Howe, Camden)

Advanced Technology Laboratories

W. A. Clapp from A Engineer to Ldr., Design & Development Engineers(H. S. Zieper, Camden)

K. R. Keller from Sr. Member Tech. Staff to Ldr., Technical Staff (H. Borkan, Camden)

P. Schnitzler from Sr. Member Technical Staff to Ldr., Technical Staff (L. West, Camden)

Memory Products Division

J. J. Cosgrove from Leader to Manager, Core Engineering (Dr. H. P. Lemaire, Needham, Mass.)

P. C. March from Leader to Manager, Mechanical Production and Services (Dr. H. P. Lemaire, Needham, Mass.)

Graphic Systems Division

C. R. Corson, Senior Project Member, Tech. Staff to Leader, Tech. Staff (D. S. Sikora, Dayton, N.J.)

I. Finn from Technical Staff to Leader, Digital Engineering (D. S. Sikora, Dayton, N.J.)

R. S. Eiferd, Ldr. Font Devel. to Mgr. Font Develop. (G. O. Walter, Dayton, N.J.)

Defense Microelectronics

K. R. Keller from Member Technical Staff to Leader (Harold Borkan, DEP, Somerville)

P. Schnitzler from Sr. Member Technical Staff to Leader (Laurice West, DEP, Somerville)

Solid-State Division

D. Curry from Engineer Manufacturing to Manager Quality and Assurance and High-Reliability Programs (H. Hansen, Somerville)

H. Donnell from Engineer Leader to Manager Manufacturing and Production Engineering (Liege, Belgium, Archer Moore)

William Allen from Engineer Manufacturing to Manager Design and Reproduction (Evan Zlock, Somerville)

R. Espiano from Engineer Product Development to Engineer Leader (J. Hilibrand, Somerville)

Professional Engineers

D. B. Dobson, ASD, Burlington, PE #22852, Massachusetts
E. J. Sass, DCSD, Camden, PE #17217. New Jersey

Awards

Missile and Surface Radar Division

The following engineers were cited for the Technical Excellence of their performances during the second and third quarters of 1969: **A. Gorski** for his outstanding technical and timely accomplishment in developing a high-voltage, high-speed, solid-state modulator for the AN/MPS-36 radar transmitter; **H. Halpern** for originality in developing the concept of the signal processor for the CAMEL Reentry Radar and for presenting this concept to the customer in a manner that was a major factor in the award of this system contract to RCA in a competition with fifteen other companies; **F. Palmer** for the development of the Product Detector for the AN/FPS-95 Receiver; **W. Sheppard** for the direction of RCA's AMFAR, in-house, development and the R&D effort which resulted in a 128-element S-band subarray complete with phase shifter and beam steering equipment; and **D. Wawrzyniak** for major contribution to the system design of the computer-display control system for the AN/TPQ-27.

Aerospace Systems Division

Barry A. Bendel of Automatic Test Equipment Engineering was selected as Engineer of the Month for November for his contribution to the DIMATE Program.

The team of **C. G. Badstübner, R. J. Bosselaers, J. S. Brodie, N. M. Clark, W. J. Goldwasser, H. P. Hatch, A. J. Krisciunas, B. Norlund, K. D. Pigney, P. M. Pollara,** and **N. B. Wamsley** from Automatic Test Equipment Engineering has received a Team Award for November. The award recognizes the outstanding work of the team on the programmable RF-signal system for DIMATE III and IV.

Astro-Electronics Division

Y. C. Brill received the Engineering Excellence Award for the month of January, 1970 and **P. Brandt** received the Engineering Excellence Award for February. **E. W. Schieben** received the Tiger award for February for development of SKAMP (Station Keeping and Mobile Platform).

Television Picture Tube Division

S. T. Villanyi received the 1969 Engineering Achievement Award for outstanding engineering achievements in the development of a variety of new computer programs and numerically controlled machining techniques which created an in-house capability to produce facilities to make critical tube parts with a high degree of precision.

The team of **Harry R. Frey, Edith E. Mayaud (Mrs.), Theodore A. Saultner,** and **Bradford K. Smith** have received a 1969 Engineering Achievement Team Award for unique and outstanding technical contributions in the development of the RCA Hi-Lite Matrix Shadow Mask Color Picture Tube which, when operated in the RCA solid-state receiver, provides 2.4 times increased brightness and a 20% contrast improvement at the same highlight resolution and with improved low light picture sharpness.

Industrial Tube Division

The team of **Paul W. Kaserman, George S. Briggs, Thomas W. Edwards,** and **William N. Henry** have received the 1969 Engineering Achievement Team Award for significant engineering contributions to the development of a novel camera tube.

Robert V. Eggemann has been selected for an Engineering Recognition Award for 1969. His technical achievements include the development of methods for zone leveling high silicon content silicon-germanium alloys with predictable and reproducible properties. He conceived techniques and redesigned equipment to prepare thermoelectric materials in a diversity of designs.

Reinhard Otto Schlaefli has been selected for an Engineering Recognition Award 1969 because of the outstanding technical competence he demonstrated in the design of the RCA SS2104 C-band Solid State TR Switch. His ingenuity in design resulted in a device that was both smaller than, and superior in performance to, the comparable X-band device. He also developed and used a computer program which facilitates the rapid design of ferrite limiters.

RCA Laboratories

Sixty-seven scientists on the staff of the David Sarnoff Research Center in Princeton have received RCA Laboratories Achievement Awards for outstanding contributions to electronics research and engineering during 1969. Recipients of the awards and brief descriptions of the work for which they were honored are:

Arthur H. Firester for pioneering theoretical analysis and experimental demonstration of high-resolution parametric conversion of infrared to visible images.

James A. Goodman for continued contribution to the development of interactive editing languages and a series of file-editing programs to mechanize them.

Ivan Ladany for research leading to the preparation of practical high-efficiency electroluminescent diodes.

Shing-Gong Liu for the development of techniques for the reproducible fabrication of high-power silicon avalanche diodes and for development of 1-kilowatt oscillators using such diodes.

Reuben S. Mezrich for the development of an erasable optical storage medium.

Kazuo Miyatani for experimental investigation of critical phenomena in magnetic materials.

Herbert I. Moss for research leading to advances in pressure-sintering techniques which led to improvements in ferrite and metal-alloy videotape recording heads.

Robert J. Ryan for devising new adhesive materials for use in novel printed-circuit boards.

Harold B. Shukovsky for fundamental investigations of multilayer electrodeposited magnetic films for plated wire memories.

P. David Southgate for studies of electroluminescence in III-V compounds and for the first demonstration of bulk electroluminescent laser action.

Ross Stander for research leading to the successful employment of stripline resonators in UHF tuners.

Alan Sussman for contributions to the understanding of the failure mechanism of liquid-crystal devices.

Barry N. Taylor for a new determination of the fundamental constant e/h, using macroscopic phase coherence in superconductors.

C. C. Wang for advancements made in the synthesis of lead oxide photoconductive thin films for application in the Vistacon camera tube.

Cheng P. Wen for the invention of novel transmission systems including nonreciprocal and reciprocal circuits compatible with microwave integration and active solid-state devices.

Malcolm E. White for the conception, development, and implementation of numerical control languages for the RCA Spectra 70 computer.

Aline Akselrad, Istvan Gorog, and **William Phillips** for contributions to a team effort in the synthesis of cathodochromic materials and their imagination exploitation in cathodochromic devices.

Henry M. Bach, G. Theodore Nygreen, and **Sherwood Skillman** for contributions to a team effort in the research, development, design, and implementation of an advanced practical Management Information System for Patents and Licensing.

William H. Barkow, Philip Kuznetzoff, and **Dalton H. Pritchard** for contributions to a team effort in the development of a novel thin television color kinescope.

Robert A. Bartolini, Joseph R. Frattarola, Edward A. James, and **Charles H. Morris** for contributions to a team effort in developing techniques for plating masters and replicating vinyl holographic tapes.

Stanley Bloom and **W. Michael Yim** for contributions to a team effort in the epitaxial synthesis and the characterization of II-VI compounds and quaternary semiconducting alloys.

Edwad J. Boleky, III, Glenn W. Cullen, John E. Meyer, Jr., and **Joseph H. Scott, Jr.,** for contributions to a team effort in the conception, analysis, and realization of high-performance silicon-on-sapphire integrated circuits.

Charles J. Busanovich and **Robert M. Moore** for contributions to a team effort in the conception and development of a novel thin-film heterojunction-diode strain sensor.

Victor Christiano and **John A. van Raalte** for contributions to a team effort in producing new large-area television light-valve display.

Roger L. Crane, Ralph W. Klopfenstein, Angelo Pelios, and **Franz W. Schneider** for contributions to a team effort in the conception, implementation, and publication of a sophisticated scientific subroutine library compatible with FORTRAN IV and FORTRAN PI.

Michael T. Duffy, Alvin M. Goodman, Edward C. Ross, and **Joseph H. Scott, Jr.,** for contributions to a team effort in optimizing the device and material parameters of MNOS memory transistors.

Robert J. Farquharson, Steven L. Haas, Lawrence A. Rempert, Edward P. Helpert and **Fred W. Scheline** for contributions to a team effort in the development and reduction to practice of specialized production equipment for integrated circuits.

James R. Fendley and **Karl G. Hernqvist** for contributions to a team effort in the development of the helium-cadmium gas laser

William H. Fonger and **Charles W. Struck** for contributions to a team effort in providing improved understanding of the radiative efficiency of red phosphors.

Larry J. French, James C. Miller, Hans F. Schnitzler and **Alfred H. Teger** for contributions to a team effort in the development of an interactive graphic system for computer-aided design.

William J. Hannan, Dainis Karlsons and **Michael J. Lurie** for contributions to a team effort in the development of techniques to improve the signal-to-noise ratio and scratch immunity of holographic video tapes.

Gunther Harbeke and **Edgar F. Steigmeier** for contributions to a team effort in outstanding research in studying materials through observation of Raman spectra.

John G. N. Henderson and **Henry Tan** for contributions to a team effort in research leading to an all-electronic, all-channel television tuning system.

Hernqvist and Pankove named Fellows

Dr. Karl G. Hernqvist, Materials Research Laboratory, and **Dr. Jacques I. Pankove,** Semiconductor Device Research Laboratory, have been named Fellows of the Technical Staff of RCA Laboratories.

In announcing the honors, **Dr. William M. Webster,** Vice President, RCA Laboratories, said the Fellow designation is comparable to the same title used by universities and technical societies. It is given by RCA in recognition of a record of sustained technical contributions in the past and of anticipated continued technical contributions in the future.

Index to RCA Engineer volume 15

This index covers Vol. 15-1 (June-July 1969), 15-2 (Aug.-Sept. 1969), 15-3 (Oct.-Nov. 1969), 15-4 (Dec. 1969-Jan. 1970), 15-5 (Feb.-Mar. 1970), and the present issue, 15-6 (April-May 1970). Since *RCA Engineer* articles are also available as reprints, the reprint number (PE-000) is noted throughout. *RCA Engineer* papers are also indexed along with all other papers written by the RCA technical staff in the annual *Index to RCA Technical Papers.*

Subject Index

Titles of papers are permuted where necessary to bring significant keyword(s) to the left for easier scanning. Authors' division appears parenthetically after his name.

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