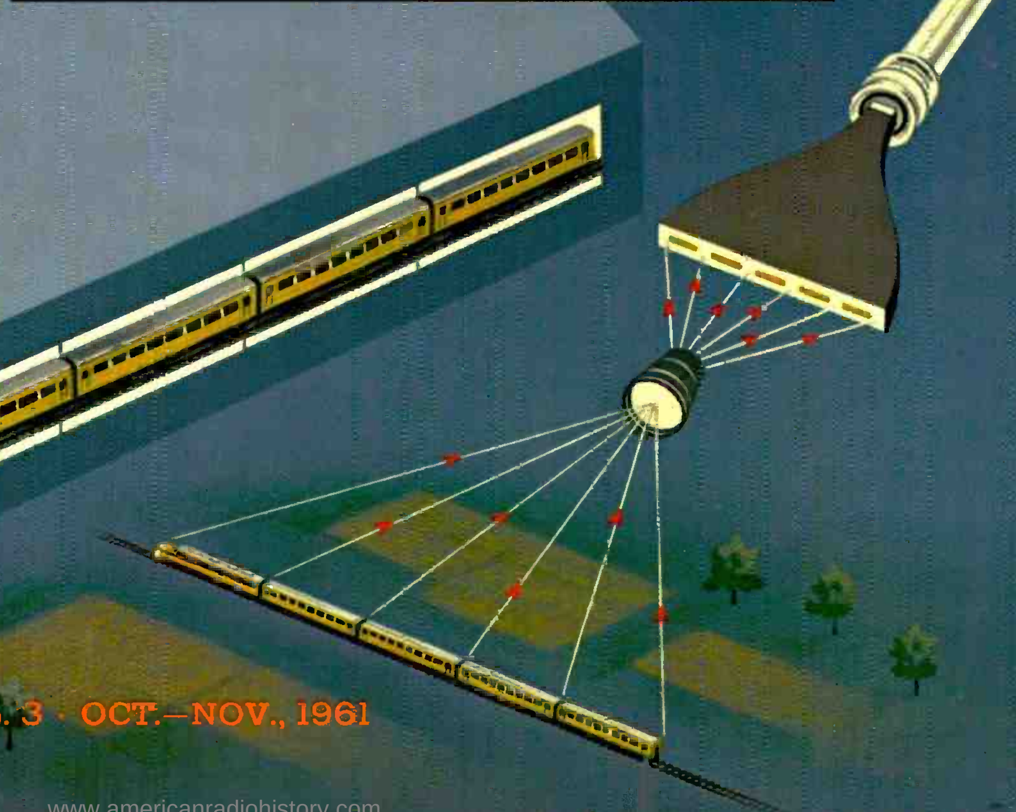
J. D. Callaghan 214-556

RCA ENGINEER



Vol. 7—No. 3 · OCT.—NOV., 1961

OBJECTIVES

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 engineering 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.

OUR COVER

... shows fiber optics at work. The artist's sketch in the lower right depicts a train being imaged onto the "line end" of a fiber-optics block converter for scanning by an image-orthicon camera tube. The enlarged view at left shows how the block converter rearranges this long image into a raster format. Shown in the inset photo discussing RCA's new fiber-optics tubes are Messrs. Judson Parker (right) and Paul Kaseman of Lancaster (holding a 2-inch image-orthicon tube) and Leo Krolak, Applied Research, Camden. The fiber-optics devices on the table (in front of Mr. Krolak) are two cathode-ray tubes, a block converter, and a 1-inch Vidicon camera tube.

The Professional Engineer—A Planner and Manager

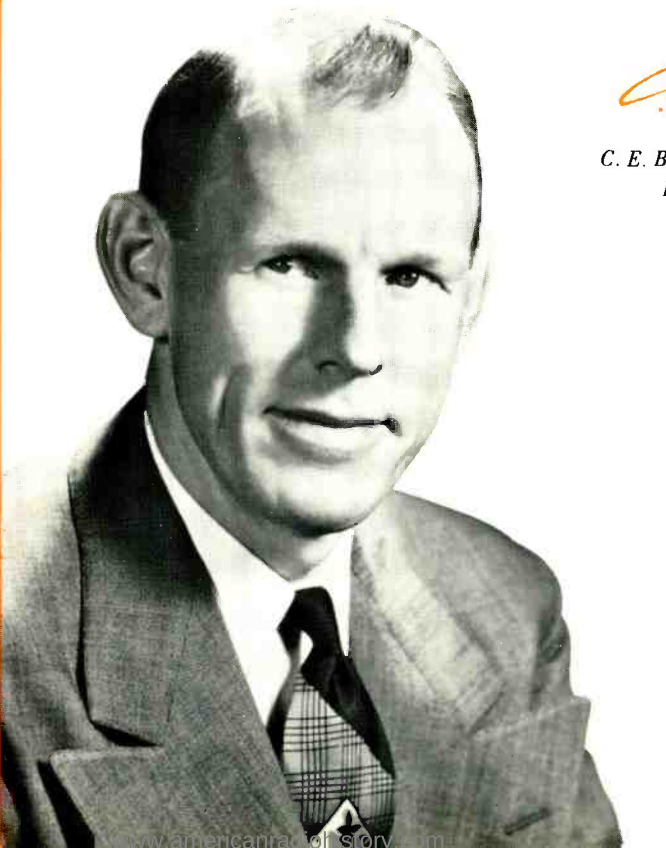
We at RCA are engaged in a highly competitive business which is filled with challenges at every turn. Since the engineer often finds himself at the focus of these demanding challenges, he must be an expert manager. Much of our corporate success hinges on his ability to plan and execute engineering projects.

Many times, the engineer is asked to prepare cost and job estimates either for budgets or for contract-bidding purposes. In doing so, his appraisal of the technical problems is critically important. His ingenuity and method of approach for proposed solutions often dictate the amount of the estimates. His assessments of the time, materials, and the kind and amount of manpower required are governing factors. His evaluations of the necessary allowances for technical difficulties or operating inefficiencies are just as critical as his estimates for success. If he is too pessimistic, we are not competitive; if he is too optimistic, we may lose heavily by over-runs.

Assuming that the engineer has been a good manager on estimating, his work has only begun. The performance of the job is a most demanding task. His ability to recognize and to separate key problems for priority of attack is a direct function of his managing skill. Clean-cut analyses on which to base conclusions are most essential. Success of a project will be governed by his skill as a manager in determining how to attack, how to appraise, and, when necessary, how to reattack the problems. A measure of his management skill lies in the degree of success he achieves in solving the problems of the project within the time and dollar limitations of the estimates. Perhaps the greatest single skill required of an engineer in his role as a manager is that needed to complete a job according to a competitively estimated, realistic plan.

Since the engineer is dependent on many service groups, he must also be a manager of the human factors in his program. In this case he must be able to appraise the abilities of these groups to deliver their commitments to him. Then too, he may have occasion to handle a project with other engineers when he must demonstrate again his ability to achieve success according to plan—by getting results through others. The engineer's imagination will certainly point out many other areas where managerial skills are extremely important.

Indeed, *our engineers must be expert managers.*



C E Burnett

C. E. Burnett, Division Vice President
Industrial Tube Products Dept.
Electron Tube Division
Radio Corporation of America

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THE SPACE AGE, WORLD COMPETITION, AND THE ENGINEER

by

T. A. SMITH, Executive Vice President

Electronic Data Processing, Cherry Hill, N. J.

THE HIGHEST REALIZATION of scientific research today is symbolized by the competitive project of putting a man on the moon. This is not without some justification. The President emphasized its importance in his message to Congress. It represents a challenge to man's ingenuity which everyone can understand.

And yet this project, costly and difficult as it may be, is but one of many manifestations of the Space Age—an era of intense competition on many fronts. For example, to bulwark the nation's economy at home and strengthen its competitive hand in world markets, the fruits of Space Age technology must be translated into new products more rapidly. Wider use of our technology is needed to win *three* major world-wide competitive contests: 1) the Cold War; 2) competition from lower-cost foreign goods, and 3) aid to newly created nations.

COMPETITIVE ENGINEERING AND THE "COLD WAR"

In a sense, our competitive efforts in cold-war satellites, in aircraft, in submarines, in missilery and in space also contribute to the betterment of mankind. World-wide engineering competition is producing a rich harvest of new materials, components, and techniques; this not only will help maintain U.S. weapon supremacy but could assure our economic future in commercial fields.

Back of the well-publicized trials of man-in-space or missile launchings lie enormous efforts to improve every element required for the success of the venture. Thus, we find intensive programs in control devices, in communications, in information handling, in propellants, in launching and guidance systems, in detection devices, and in many other broad fields. But more than this, in each of these areas are detailed programs keyed to the need for increased effectiveness. Thus, new metals and ceramics have been developed for high temperature use. Highly reliable and ultra-miniaturized components have evolved. New devices for generation of power from heat, radiant energy, and unconventional fuels are coming into use, and the list of other component programs is much too long to be recited. And this is not all. The techniques involved in designing, producing and delivering complex equipments and systems have had to evolve also. It has not been possible to take the time to do the job in the conventional manner. Now, computers can be used to lay out wiring runs or to test the feasibility of systems. We have new and simplified drawing techniques to cut down drafting time. There are photographically produced templates for drilling and punching, as well as automatic checkout devices to test the operability of complex systems.

Truly, this world-wide engineering contest has resulted in an improvement in the science of techniques—of engineering and production methods. Today's engineer has at his command materials and components totally unknown ten years ago. Enormous sums have been spent in development to make these and other new techniques possible.

In fiscal 1961, it is reported that more than $8 billion have been expended by the government for research and development. Large additional sums are also being spent on hardware projects which will contribute to technological progress. Stimulated by these programs, private industry itself will spend about half as much for research and development. With total expenditures of $11 to 12 billion classified as research, perhaps an additional $5 billion are spent by government and industry on efforts beneficial to techniques, product improvement, training methods, and the like. Adding these up, we find that a sum equal to about $100 for each man, woman, and child will be spent each year in this country on research, development, techniques, and methods, not including hardware. No other nation, with the possible exception of the Soviet Union, has ever spent such vast sums for these purposes.

The reader may say, "Granted that very large sums are being spent, what does this have to do with me as a product engineer?"

It has a great deal to do with product engineering and product engineers. As stated above, we are engaged in the three primary competitive contests. There are technological aspects to each of these contests, and unless we use all the resources at our command we will not be doing our jobs. It is obvious that defense engineering must get all it can from our total wealth of research and development, new techniques and methods, and anything else which will assure our technological supremacy. This is the primary job—to develop a position of strength which will prevent attack. But in the other areas, too, the product engineer has a real job to do.

FOREIGN COMPETITION

The second great contest concerns low-cost foreign commercial goods. For many years, competition in our domestic commercial market was generally limited to American firms. This is no longer so. The present trend is toward a reduction in American exports and an increase in imports of foreign-made articles. The intensive efforts of other nations to capture both foreign and domestic markets indicates that we must find new ways of capitalizing on the record investments in government and industrial research; new techniques are needed to produce better products at lower prices to combat foreign competition.

Not only is there competition between American companies, but there is added competition from foreign organizations who are exporting products. The competition is rough. With wages often but a fraction of ours, prices for some foreign products are substantially lower than ours. These foreign products are often built in factories equipped with machinery as modern or more modern than that in this country. Foreign products are designed by engineers with a low starting rate, in some cases as low as $1,600. They are capable engineers, too, who have proven their ability to do a first rate job.

Thus, it costs less to engineer products in many foreign countries and substantially less to produce them. The results—in 1960, 60 percent of all portable radios sold in the United States were made in Japan. In the past seven years, exports of American finished goods have increased only 8 percent but world trade in such products has increased nearly 40 percent. At the same time, our imports of finished products have increased about 250 percent. Reductions in American exports and increases, within certain classes of product, in imports of foreign-made articles into this country pose a serious threat to our economy.

Obviously, to continue to sustain our standard of living, productivity must be increased by every means at our command—by automation, by more efficient operations and by greater work output by labor—*or* our markets not only abroad, but here in the United States, will diminish.

But we have another way to combat the foreign cost problem. No foreign competitor—not Japan, nor England, nor Germany, nor Italy—has entered into the Space Age program as have we. Foreign research is first rate. It has expanded rapidly and industrial research, particularly in Japan, is excellent as shown by the development of sophisticated new devices. But there is, in our country, a broader vista of effort in a vast number of fields, coupled with experience in techniques not yet explored abroad, which should prove of value to us in competing with foreign-made products.

While today our greatest competition is with friendly nations, tomorrow we may be facing increased competition from the Soviets and their satellites for world trade. Russian products are even now being shown in world trade fairs. In countering this competition, engineers must evaluate new techniques fairly, visualize the applications of new principles for commercial uses, delve into new fields, and abandon the familiar when gains can be made. It is up to us to use our new techniques, to make our products better and more reliable, to adapt new materials and components to products so that they will be competitive with foreign products.

This is being done successfully in a number of fields. In computers and data processing, for example, no country can offer the variety of product or the performance of American equipment. It is interesting to note that the constructional details of the equipment, as well as the circuits, are more advanced than foreign-designed devices. This example clearly indicates that Space Age engineering can protect American products from low-cost foreign competition.

TECHNICAL AID TO NEW NATIONS

The third great contest is for the minds of men. The new nations of the undeveloped areas of the world are now choosing, or must choose within a few brief years, a free society or a controlled one. But in many of these nations there are great needs—needs for education, for training to use today's tools, for communications, and for industry to provide gainful employment. Without the means for a reasonable livelihood, men may turn to any seeming panacea which promises immediate benefits.

Here, too, the developments of the Space Age, if used wisely, can provide means for helping newly created nations almost immediately. The devices used to expedite teaching and training can shorten the gap to a stable economy. We have many such aids including television, audio-visual training devices, and teaching machines.

We have superior communications and transportation systems and many other needed ingredients to help people who have little. "Communications satellites" must be launched to provide unfiltered communications with the newly emerging nations. While technology is but one part of the problem, it is an important part in keying our efforts to help solve the problems of Africa, Asia, and other underdeveloped parts of the world.

The outcome of these three great contests can determine the future of all of us—the advances of the Space Age can help us win each one.

AN ENGINEERING CHALLENGE

There is sometimes a feeling among engineers that there are two worlds—a glamorous universe of missiles and satellites—and a fusty, unexciting world of commercial products. If this is so, and I do not believe that it is, we should rapidly make it one world. Commercial product engineers cannot afford to have the Space Age pass by any part of their technology.

Already, commercial engineers are planning satellite communications systems. Jet aircraft of the future will use materials developed for missiles to avoid heating at speeds above Mach 1. Other technical fields must similarly progress with developments of the Space Age or fall behind.

My plea is that we try to bridge the gap between the development of new concepts and their application in commercial products. If five years transpire before we apply the new developments, we may find that we have lost the advantage which should rightly be ours.

The product engineer can help us out of the dilemma in which we find ourselves—surrounded by the riches of research and development, yet not always using these riches to the extent possible. Efforts of the product engineer will support our economy in all three great competitive contests: by making our products more immune to foreign competition; by broadening our commercial base to provide the support we need in paying for the Cold War; and by assuring steady improvement in our national standard of living. And lastly, we need to use the new technology to aid us in competing for the understanding of the new and important nations of the world.

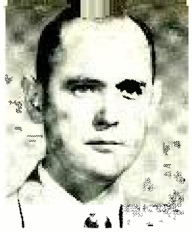
This is the challenge! *Will the product engineer measure up to the Space Age?*

THEODORE A. SMITH, after receiving his ME degree from Stevens Institute of Technology in 1925, joined RCA's Laboratories in New York City. Three years later, Mr. Smith took charge of television development and supervised the construction of RCA's pioneer Television Station W2XBS, New York. Mr. Smith entered commercial engineering in 1930 as district sales manager for RCA broadcast equipment. In 1938 he transferred to Camden where he held sales and engineering positions in the broadcast, scientific instruments and communications equipment activities, until his promotion to General Sales Manager of EPD. In 1951, Mr. Smith became Assistant Manager of the Engineering Products Department and was elected Vice President and General Manager in 1953. Later, Mr. Smith became Executive Vice President, RCA Defense Electronic Products; in 1957, he was named Executive Vice President, Industrial Electronic Products. In September 1961, Mr. Smith was named Executive Vice President in charge of Electronic Data Processing. Mr. Smith is a Member of the American Society of Naval Engineers and the Armed Forces Communications Association, and was a senior member of the IRE until being elected IRE Fellow in 1961 "for contributions in many fields of radio engineering." He has been Chairman of the Military Products Division of RETMA, chairman of the IRE, Philadelphia Section, and has been active in committee work of the National Security Industrial Association.

P. W. Kaseman
Electron Tube Division
(see p-5)

L. J. Krolak
DEP Applied Research
(see p-8)

J. F. Parker
Electron Tube Division
(see p-5)



K. C. Hudson
DEP Applied Research
(see p-11)

THE DISPLAY ARTICLES IN THIS ISSUE

An Example of Engineering Cooperation ...A Key to Corporate Success

THE SCENE on the front cover of this issue of the RCA ENGINEER illustrates the thesis; that willing cooperation and efficient exchange of information can and indeed does exist between the various branches of a large, complex corporation such as ours.

FIBER-OPTICS DISPLAY DEVICES

As one example, refer to the companion articles on the following pages pertaining to development and use of fiber-optics principles. Here, we have a clear-cut illustration of the fruitful results of intra-corporate cooperative enterprises. Starting with the *P. W. Kaseman* and *J. F. Parker* discussion of "New Tubes for Use With Fiber-Optics Devices," we see the offspring of efforts which called for liaison and cooperation between *Camera Oscillograph and Storage Tube Engineering* located at Lancaster, Pa., and the *Conversion Devices Laboratory* located at Princeton, New Jersey. Moreover, the latter group under the direction of *Dr. G. A. Morton* was able to draw on the wealth of information and experience at the RCA Laboratories in Princeton where basic research is conducted.

The oscillograph and camera tubes, with fiber optics built into the faceplates, developed by these groups are used in complete electro-optical systems such as those being developed by Defense Electronic Products for military purposes. The need for cooperation between the members of the *Conversion Tube Operation* of the Electron Tube Division and the members of *Dr. H. J. Woll's Applied Research Department* of DEP becomes quite obvious when we peruse *L. J. Krolak's* article, "Fiber Optics for High-Resolution-Displays and Pickup Systems".

ELECTROLUMINESCENT-PHOTOCONDUCTIVE DISPLAYS

Still another example of useful engineering interchange of information is apparent in the group of articles devoted to the subject of electroluminescent-photoconductive displays. Conversion Tube Operations in Lancaster is in the forefront of development and applications work in these areas; its *Photocell Enginering Group* in Mountaintop, Pa., directed by *Dr. C. P. Hadley*, has been active in the photoconductive cell field for many years, and is responsible for the advanced development and design of the solid-state photosensitive devices produced by RCA. See *Dr. Hadley's* article, "Electroluminescent-Photoconductive Micromodular Logic Elements" for a description of a new approach to EL-PC fabrication techniques. This new approach was suggested to Dr. Hadley by *L. E. Haining* of the *Data Systems Division*, Van Nuys, Cal., Defense Electronic Products, whose article, "A New Solid-State Alphanumeric Display" appears in this issue. Here again we have an excellent example of a mutually satisfying and highly profitable interchange of ideas which results in the application of devices and techniques.

Basic research is supplied again by the Princeton groups.

At Lancaster the *Chemical and Physical Laboratory*, under *R. H. Zachariason*, is working closely with several groups in the development of phosphors, and the *Electro-luminescent Engineering Group*, led by *G. E. Crosby*, has contributed to the application of phosphor materials to the electroluminescent sheets used to display images in color. Other applications are described in this issue of the RCA ENGINEER by *H. B. Law*, of RCA Laboratories, in his article, "A Review of Some Flat Display Devices." Another offshoot of the work on electroluminescence is shown by *M. Cooperman*, of RCA Victor Home Instruments, in his article on "Ferroelectric Scanning of EL Displays"; this work is in conjunction with video circuits for industrial TV.

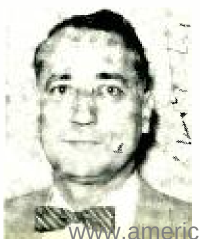
The use of photoconductive techniques in conjunction with thermoplastic film provides further large-area display applications as illustrated by *K. Hudson's* article "Large-Area Displays By Electrophotography and Magnetic Thin Films"; this work represents still another example where basic research work by RCA Laboratories in Princeton contributes to DEP's applied research program.

CONCLUSION

The cooperative research and development work being performed by DEP, Electron Tube Division, RCA Laboratories, and Home Instruments Division, described in this issue of the RCA ENGINEER, is vitally important to the success of many government and commercial applications of interest to RCA. Therefore, it is of the utmost significance that the engineers involved in these programs have demonstrated the ability to work cooperatively and productively with other RCA groups. In the highly competitive electronics industry, such coordinated effort assures the most efficient utilization of skills and development of new scientific fields, new products, and new services for RCA.

Dr. C. P. Hadley
Electron Tube Division
(see p-14)

L. E. Haining
DEP Data Systems Division
(see p-16)



M. Cooperman
RCA Victor Home Instruments
(see p-24)

Dr. H. B. Law
RCA Laboratories
(see p-20)

NEW TUBES FOR USE WITH FIBER-OPTICS DEVICES

by **P. W. KASEMAN and J. F. PARKER**
Camera Oscillograph and Storage Tube Engineering
Electron Tube Division
Lancaster, Pa.

THE RAPID GROWTH of fiber-optics technology and applications during the past three years has led to the development of a new line of cathode-ray and camera tubes in which light-transmitting fibers are in direct contact with the active element of the tube. These tubes form components of complete electro-optical systems which have many desirable features. Because fiber optics are built into the faceplate, light efficiency is improved, vibration isolation of the tube from the lens system is possible, and complex fiber-optics transducers may be brought into close register with the electron scanning beam. In addition, the fiber-optics cathode-ray tube permits direct contact printing.

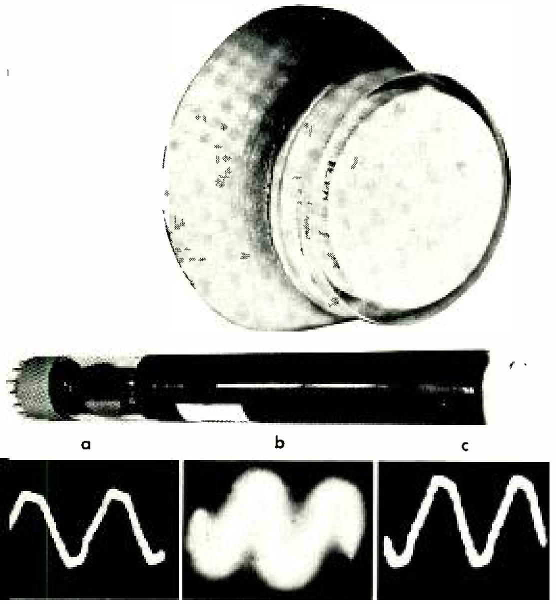


Fig. 1—Experimental cathode-ray tube with fiber-optics faceplate used to determine light efficiency: a) optically projected; b) contact-printed; c) contact-printed using neutral-density filter.

Theoretical calculations have shown that the optical efficiency of an early fiber-optics faceplate compared to a conventional lens system working at f/8 is of the order of 46:1. This efficiency ratio has been demonstrated with an experimental cathode-ray tube having a small (1-inch-diameter) tube face. Except for the face, the tube shown in Fig. 1 is a conventional electrostatic-deflection type of cathode-ray tube. However, the tube face contains approximately 100,000 fibers, 0.003 inch in diameter.

A set of photographs was made to demonstrate the relative optical efficiency of the fiber-optics tube: the first photograph, shown in Fig. 1a, was made at unit magnification by a conventional f/2 camera lens having a 58-millimeter focal length; the photograph shown in Fig. 1b was made by direct printing against the tube face; and the final photograph shown in Fig. 1c was made by printing through a compensating 1.70 neutral-density filter placed between the tube face and the film at a 50:1 reduction in exposure. In all cases, film, exposure time, processing, and trace intensity were the same. Fig. 1b was overexposed as a result of the high optical efficiency of contact printing through the fiber-optics faceplate. Even though the fiber-optics tube was also used with the first exposure (through the conventional lens), the gain in optical efficiency shown in Fig. 1c is still at least 40 times that of the f/2 lens when used in this manner. Camera tubes show the same improvement in light transmission when the image is coupled directly from the system fiber bundle to the fiber bundle of the tube face.

This significant improvement in light transmission is equivalent to a substantial gain in the sensitivity of the camera tube, or a similar gain in light output of the cathode-ray tube. Both cathode-ray and camera tubes having fiber-optics faceplates have been developed to take advantage of this gain.

CATHODE-RAY TUBES

The use of optical fibers which pass through the faceplate effectively increases both the brightness and resolution of conventional cathode-ray tubes. Each phosphor particle in the screen of a cathode-ray tube becomes, upon excitation, a point source of light, radiating in all directions. When this light passes through the relatively thick conventional faceplate, the rays from different parts of the screen cross and the image is blurred. Such blurring precludes the possibility of photographic contact printing. Any practical lens system focused on the plane of the phosphor intercepts only a small fraction of the emitted light. However, a fiber-optics faceplate makes available a bright focused image on the exterior surface of the bulb envelope for such applications as contact printing and flying-spot scanning, as shown in Fig. 3.

In the fabrication of fiber-optics cathode-ray tubes, techniques which are at least quantitatively different from the conventional are necessary. For example, the construction of the tube envelope requires a special glass-to-glass seal at the faceplate and the thermal sensitivity of the fiber optics requires a very high degree of control during processing. Other problems, such as the real and virtual leaks in the fiber interstices, affect not only the vacuum properties but also the screen quality of the finished tube.

Any cathode-ray tube, including picture tubes and storage devices, can be manufactured with optical fibers in the faceplate. RCA tubes have been made with diameters of two and five inches, as shown in Fig. 2. The improved efficiency of devices using fiber optics often permits improved resolution because the tube can be operated at reduced beam currents.

THE VIDICON

The first vidicon having a fiber-optics faceplate was made by RCA several years ago. The developement was rela-

Fig. 2—Developmental cathode-ray tubes with fiber-optics faceplates.

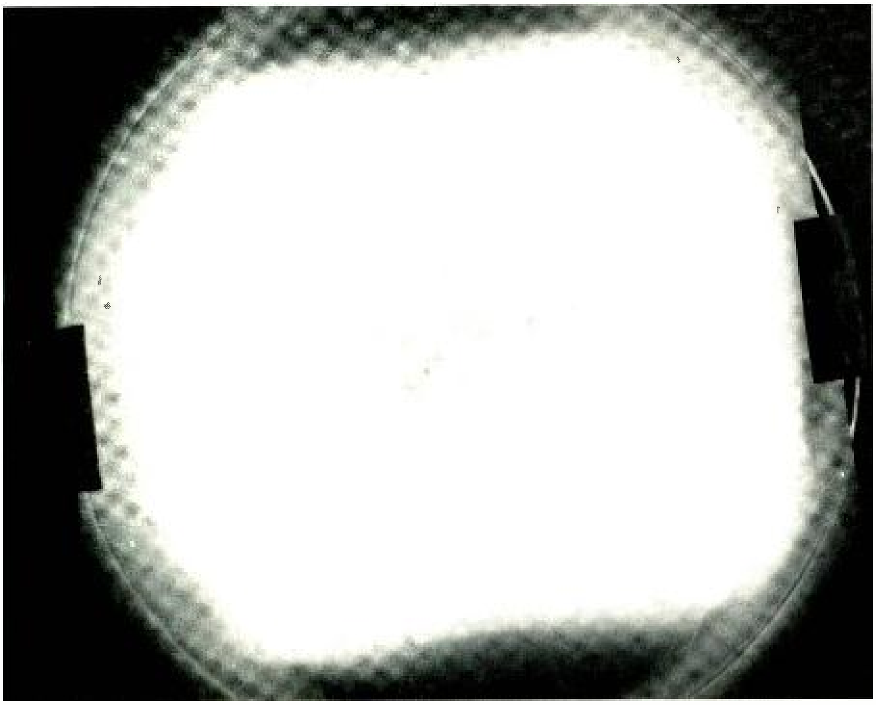


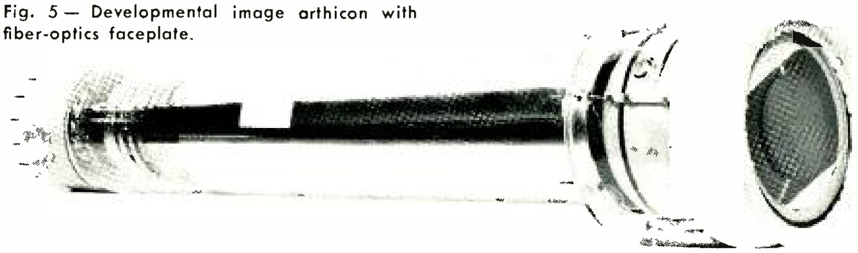
Fig. 3—Operation of fiber-optics cathode-ray tube simulating contact printing. Translucent paper against the faceplate displays the image, which is in focus only in the central rectangle containing the fibers.

tively straightforward because assembly techniques for the RCA-7038 vidicon were used. The faceplate-sealing technique for this tube permits fused quartz, hard glass, soft glass, or certain glassy ceramics to be sealed to the bulb with little regard to the expansion mismatch between the faceplate material and the bulb. Moreover, because the sealing process is performed at relatively low temperatures and the faceplate glass is not melted in the process, there is no danger of distortion or damage to the fiber bundle.

Some of the early vidicon faceplates were designed to have a ⅝-inch-diameter bundle of fibers centered in a faceplate made of the same glass as the fibers. In later tubes, the fiber-optics bundles covered the entire face of the tube. The faceplate was made somewhat thicker than in conventional tubes to insure adequate strength.

The most difficult problem in the fabrication of the tube was the development of a technique for placing a transparent coating on the high-lead glass without damaging the glass or fiber structure. The first vidicon made with the technique evolved had a fiber bundle of 0.003-inch-diameter glass fibers. The resolution of this tube was limited to about 120 TV-lines by the fiber structure. Later developmental tubes shown in Fig. 4 had 0.0006-inch fibers. These tubes could resolve about 600 TV-lines, a value close to the resolving capabilities of the tube itself. These vidicon tubes are most effectively used for fiber-optics applications in which the available illumination is at least 0.5 foot-candle on the tube face. For applications in which the light level is considerably less than 0.5 foot-candle, the more-sensitive image orthicon must be used.

Fig. 5 — Developmental image orthicon with fiber-optics faceplate.



THE IMAGE ORTHICON

The image-orthicon tube having fiber optics can operate with as little illumination as 0.02 foot-candle on the tube face. In special applications, when some loss of resolution may be tolerated, the tube may be operated at much lower light levels. Although these tubes are still in the developmental stage, image orthicons using 0.003-inch glass fibers in bundles 2 inches in diameter surrounded by a glass ring for sealing to the tube envelope have resolved 550 TV lines. This figure will be further improved when smaller fibers are used in the faceplate.

The development of the image orthicon was not nearly as straight-forward as the vidicon. Many problems had to be solved, some similar to those of the vidicon and cathode-ray tubes, others unique to the image orthicon.

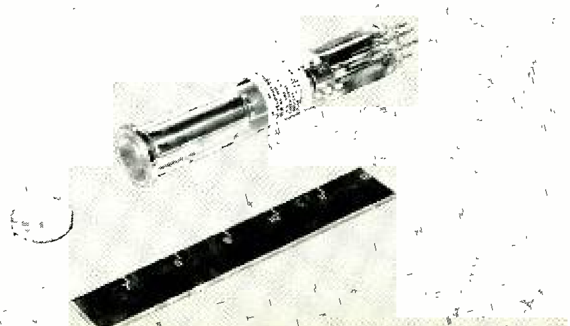
Obtaining a large-area vacuum-tight fiber-optics bundle was a major problem because any substance which could effectively stop leakage also left too heavy a film on the surface. However, new optics fabrication techniques have produced some good vacuum-tight faceplates.

The difference in the coefficients of expansion of the fiber-optics face and the envelope of the image orthicon was overcome by sealing the faceplate to a metal ring of similar expansion. This ring, in turn, was heliarc-welded to a metal flange sealed to the image bulb of the tube. Sealing of the fiber faceplate to the metal ring required the development of special sealing techniques because of the unusual expansion characteristics of the nonhomogeneous fiber-optics bundle

Another major problem was finding a protective coating which would prevent interaction between the alkalis of the photocathode and the lead glass of the fibers and, at the same time, provide a suitable substrate for the photocathode. A coating was satisfactorily developed which provides no appreciable loss in transmission of the fiber bundle.

Fig. 5 shows one of the developmental image orthicons. The metal parts of the tube are covered with an insulating film. Fig. 6 shows pictures produced by this tube. Although distortions resulted from misalignment of the fibers in this early fiber-optics bundle, fiber-optics bundles are now being produced which provide greatly improved quality.

Fig. 4—Vidicon with fiber-optics faceplate. Fibers have diameters of 0.0006 inch.



SUMMARY

The special vidicons, image orthicons, and cathode-ray tubes described in this paper are only the beginning of a large family of special tubes designed for close coupling of fiber-optics systems to electronic devices. Phototubes, multiplier phototubes, image intensifiers, storage tubes, and many other special types using fiber-optics coupling will be used in many applications in new electro-optical systems when the supply of fiber-optics bundles becomes more plentiful.

The application of fiber optics to vidicons, image orthicons, and cathode-ray tubes described in this paper is of the simplest type; other more sophisticated applications of complex fiber-optics bundles for use both inside and as adjunct parts of the tube are being developed.

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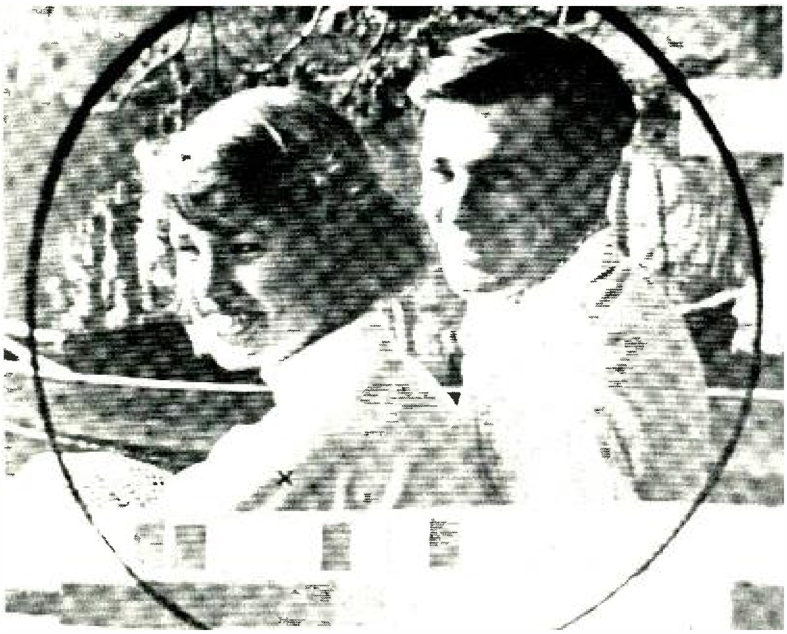


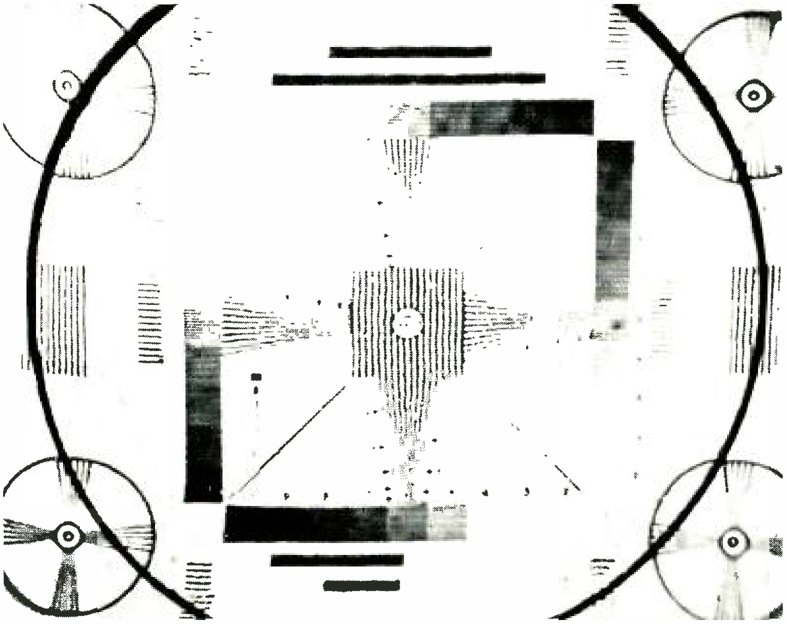


Fig. 6—Photographs made with a fiber-optics image orthicon. Fiber-optics bundle is contained inside the dark circle.

P. W. Kaseman, left, and J. F. Parker.

JUDSON F. PARKER received the B.S. degree in Physics from the University of Illinois in 1960. The same year, he joined the Oscillograph and Storage-Tube Engineering activity of the RCA Electron Tube Division in Lancaster, Pa., where he had previously worked while an undergraduate. He was assigned to the advanced development of oscillograph tubes, and has been concerned with the application of analog and digital techniques to problems in electron optics, as well as with the development of fiber-optics cathode-ray tubes.

PAUL W. KASEMAN received the B.S. degree in Electrical Engineering from the Pennsylvania State University in 1950. He joined the Electron Tube Division of RCA at Lancaster, Pa., the same year as a manufacturing engineer in the Camera Tube activity. In 1954, he transferred to the Camera, Oscillograph, and Storage-Tube Development activity as a design engineer; in this activity he worked on the development of high-resolution black-and-white television picture tubes and small projection kinescopes. Since 1956 he has been engaged in the design and development of several new types of image orthicons, and has done basic work on new types of photocathodes and precision-field-mesh tubes for color cameras. Mr. Kaseman is a member of Sigma Tau Honor Society, an Associate Member of the American Institute of Electrical Engineers, and a Member of the Institute of Radio Engineers.

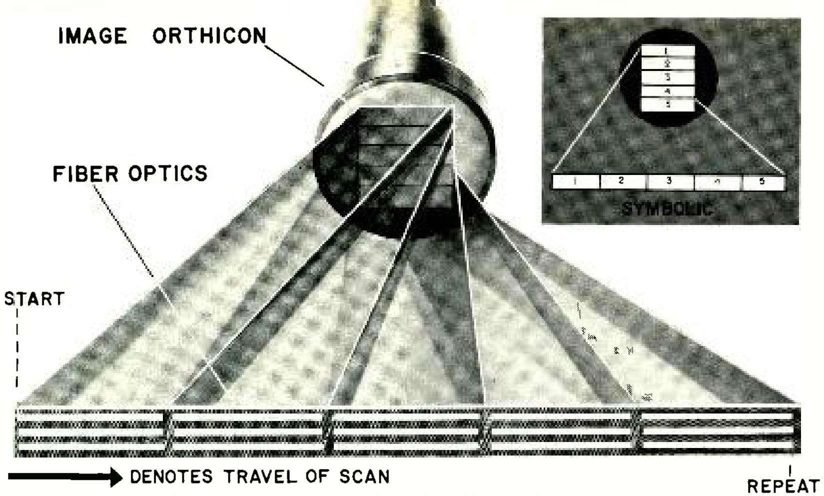


Fig. 1—Scan sequence through a fiber-optics converter

FIBER OPTICS FOR HIGH-RESOLUTION DISPLAYS AND PICKUP SYSTEMS

by **LEO J. KROLAK, Ldr.**
Applied Physics Group
Applied Research
DEP, Camden, N. J.

High-resolution display of technical data grows increasingly important in centralized control centers, both military and industrial. Displays run the gamut from print-out on film or paper to the presentation of instantaneously changing data on TV monitors or large wall panels. Many techniques and systems have been demonstrated while others are still in the conceptual stage.

The role of fiber optics for high-resolution displays and pickup systems can be three-fold:

1) The fiber-optics technique increases resolution capabilities.
2) It improves photometric efficiency of display systems over that obtainable with a lens system.
3) It enhances the details of the display through magnification.

When used with RCA's high-sensitivity television camera tubes, fiber optics can increase the resolution capabilities by rearranging the image format to take maximum advantage of the total number of resolution elements on the face of the tube. When used as a rear-projection screen material, fiber optics improves resolution by eliminating diffusion or scattering problems. When replacing a simple lens system to transfer light from one plane to another, fiber optics can increase the photometric efficiency of the optical system by a factor of as much as 100:1. With a simple lens system, less than 1 percent of the available light may be imaged without magnification; in contrast, a fiber-optics bundle will transfer most of the light directly. Magnification can be effected by tapered fibers; this feature, combined with the flexibility of arranging fibers in desired paths, makes possible unique image magnifiers.

FIBER-OPTICS INPUT-OUTPUT DEVICES

Television techniques offer the greatest flexibility in displaying rapidly changing data. However, many situations in the past have nullified the use of high-sensitivity electro-optical devices such as the image orthicon and the cathode-ray tube in data acquisition and display systems. Sophisticated information-handling and display systems of today need the sensitivity provided by these electron tube devices; however, modern display systems also demand higher resolution than that available in a single scan-line of these tubes.

The display data frequently forms a long narrow block, e.g., a line of text or details of a drawing (Video File[1]) or a narrow strip of a portion of the earth's surface comparable to that viewed in a slit camera (aerial reconnaissance[2]). To image these long lines onto the faceplate of an image orthicon would result in image degradation because of the small number of resolution elements across the tube diameter. Ordinarily, only a fraction of the total number of resolution elements of the whole faceplate would be utilized.

Fiber optics — the technology[3,4] of transmitting element-by-element, a light image from one point to another — has augmented television techniques to make these new display system applications not only feasible but practical. The underlying techniques have been demonstrated in the DEP Applied Research Optics Laboratory.

Fiber Optics Increases Resolution

An important feature of fiber optics, the ability to rearrange an image into any desired format, provides a relatively simple way to increase resolution capability of the image orthicon for line-scanning operations. Electron optics place severe restrictions on any latitude a designer may wish to take in changing the size and shape of the faceplate of an image orthicon; optimum scanning is obtained with a nearly square format. A long, thin rectangular faceplate, such as that needed for the display systems under discussion, is impractical.

Fiber-Optics Converter

A fiber-optics block converter can divide a long-line image into a number of short segments and stack these short segments one atop the other to provide a raster format at the faceplate of the image orthicon. This rearrangement by fiber optics is depicted by the artist's drawing shown on the front cover of this issue. In the lower right, a lens images a train onto the *line end* of a fiber-optics block converter which is butted against the fiber-optics faceplate of an image orthicon. The schematic at the left in the front cover shows an enlarged view of the train on the line-end of the fiber-optics block converter. At the other end, or *tube side*, of the block converter, the cars comprising the train appear stacked.

Fig. 1 illustrates the sequence of picture scanning referenced to the entrance end of the fiber-optics converter; a conventional scan from the top to the bottom of the camera tube results in a systematic scan of all portions of the long, narrow image synthesized by the fiber-optics converter.

The fiber-optics converter itself is shown in the front color cover; in addition to furnishing the necessary geometric rearrangement to give high resolution and high angular coverage, the converter achieves excellent conservation of incident light. Almost all the light is conveyed by total internal reflections from converter *entrance face* to the *exit face*—and then through the image-orthicon fiber-optics faceplate to the photocathode camera tube.

Each block of the converter corresponds to the length of a scan line on the faceplate of the image orthicon. The improvement in resolution capability of the camera tube is directly proportional to the number of blocks in the fiber-optics converter. The block converter (see cover) converts a line image 15 inches long by 0.083 inch high into a raster format that is 1 inch high by 1¼ inches long. The converter contains twelve fiber-optics blocks, each 1¼ inch long by 0.083 inch high. Thus, the resolution elements utilized on the faceplate of the image orthicon are twelve times the number used when a simple lens images the line directly onto the faceplate. The resolution is also increased by a factor of 12 for the fiber-optics block-converter system.

LEO J. KROLAK received his B.S. Degree in Optics from the Institute of Optics of the University of Rochester in 1949. He joined the Atomic Energy Project of the University of Rochester and while there received his M.S. degree in Optics. In 1956, Mr. Krolak joined RCA, and became leader of the Optics Group of DEP's Engineering Development Section in 1957. He is now Leader, Applied Physics Group, DEP Applied Research. His group designs, tests and evaluates optical systems; studies and fabricates special fiber optics systems; developes evaporating techniques for thin films for integrated electronic circuits and magnetic recording heads; investigates the phenomenon of superconductivity and devices utilizing superconductivity; and investigates the electrophotographic process of Electrofax. Mr. Krolak is a member of the Optical Society of America.

Fiber-Optics Faceplates

The fiber-optics block converter was said to be butted against a fiber-optics faceplate in the image orthicon; the use of the fiber-optics faceplate assures the highest possible photometric efficiency[1] and minimum loss of detail[2] in transferring the rearranged image at the raster end of the converter to the photoconductive surface on the inside of the faceplate. The use of a lens to image the raster end of the converter onto the photoconductive surface would nullify some of the advantages of high-sensitivity image-orthicon camera tubes in aerial reconnaissance applications where scene brightness may be low.

Now, consider the output end of the TV system. Information transmitted from the fiber-optics sensor (an image orthicon combined with a fiber-optics converter) must be displayed in its original format *as an unbroken line*, not as a raster in which it was scanned by the image orthicon. In many applications the information is recorded on film; hence, another block converter must be used in conjunction with a cathode-ray tube containing a fiber-optics faceplate. Again, the fiber-optics faceplate assures maximum photometric efficiency in transferring the light generated in the phosphor coating of the CRT to the raster end of the converter. The block converter is essentially the same as the one used at the input end. Printout is usually on a continuously moving film or Electrofax paper. In order to compensate for film motion while the first converter block is exposing the film, the second block is staggered a slight amount in the direction of film motion. Similarly, each succeeding block is displaced with respect to the preceding one, as shown in Fig. 2.

Thus, fiber-optics block converters, when combined with image-orthicon and cathode-ray tubes fitted with fiber-optics faceplates, make television techniques practical tools for the high-resolution display of technical data. The block converter increases the resolution capabilities of the image orthicon, and the fiber-optics faceplate assures that maximum advantage can be taken of the camera tube high-sensitivity characteristic. DEP Applied Research has combined these components in a breadboard to demonstrate the basic principles described above.

FIBER-OPTICS CRT FOR HIGH-SPEED PRINTING

The five-inch cathode-ray tube (CRT) with a fiber-optics insert in the faceplate (see color cover and Fig. 2 of Kaseman and Parker article) was developed to demonstrate the feasibility of an on-line printout device for high-speed computers. Normally, the mechanically operated off-line printout devices require a buffer store because the speed of mechanical impact printing cannot approach the usual computer character rates.

The heart of the DEP Applied Research in-line high-speed printer is the five-inch CRT butted against a fiber-optics converter containing four 3½-inch-long blocks; this system rearranges the four-block raster into a 14-inch line. Thus, fiber optics make it possible to print a "fanned-out" 14-inch picture by means of a five-inch CRT. A most important feature of the block converter is its ability to increase the combined resolution capability of the CRT and its fiber-optics faceplate insert; thus, maximum photometric efficiency is assured in transferring the image from the phosphor faceplate surface to the Electrofax paper.

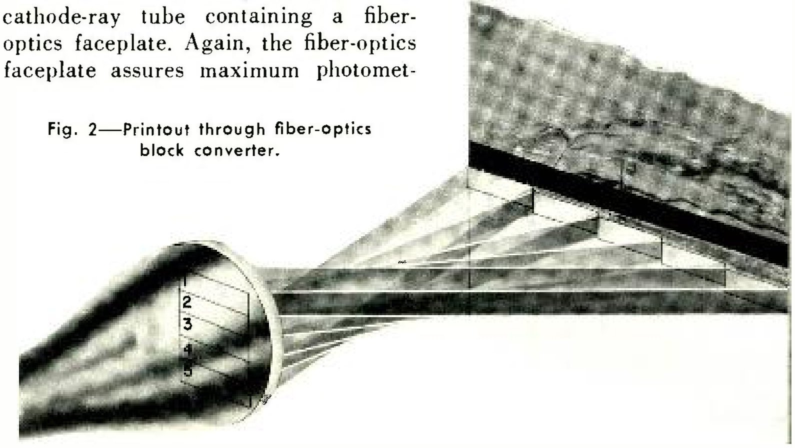


Fig. 2—Printout through fiber-optics block converter.

Another typical use of the CRT with a fiber-optics faceplate is in the recording of information on an Electrofax medium for transfer to a thermoplastic tape, as illustrated in Fig. 3 of K. Hudson's article, "Large-Area Displays by Electrophotography and Magnetic Thin Films."

FIBER-OPTICS LARGE-AREA DISPLAY MEDIA

In many military control centers, operational data displayed on large screens must meet the following rigid requirements: 1) details must be uniformly bright from all angles of view, and 2) observers must be able to examine the detail at close range without intercepting any part of the light delivered to the screen by the projector. The second requirement dictates the use of transmission type screens, i.e., the projector is behind the screen.

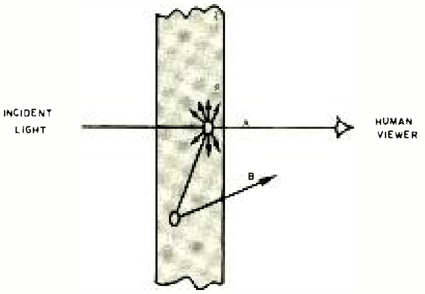


Fig. 3—Element-to-element scatter of transmission type screen

Problems with Commercial Screens

To display high-resolution information for recognition by a human observer requires that the display medium (the screen) must not degrade the image. In fact, the resolution capability of the display medium must go well beyond that of the unaided eye; a human viewer should be able to use a magnifying glass to study specific details of an image. Interacting with the need for greater resolution is the additional requirement that the screen be a good diffuser so that the same screen brightness is produced at any viewing angle.

When the surface of a transmission

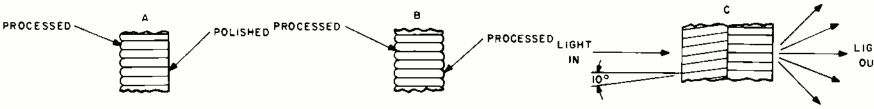


Fig. 4—Examples of fiber-optics screen materials

screen is treated with sandblasted aluminum, metallic paint, or tiny beads imbedded in a metallized surface, the diffusion properties are improved; however, there will be a great deal of backward and sidewise scattering of light caused by the surface preparation and the material of which the screen is made. This is depicted schematically in Fig. 3. The incident light ray strikes a scattering particle in element *A*; some of the scattered radiation passes to other elements such as *B* and gets reflected to the viewers eye. Sidewise scattering from element to element degrades the resolution, fine detail, and contrast of the display.

Fiber Optics as a Large-Area Screen Material

If there were some method of insulating the various elements of a screen from one another, the resolution capability of the display device would be limited by the size of the insulated element. Fiber optics techniques offer an excellent means of accomplishing this insulating effect. Under contract AF30(602)2238 with the Rome Air Development Center, DEP Applied Research investigated various arrays of fiber optics for use as rear projection screen materials. The type of arrays tested are shown in Figs. 4a and 4b; the fibers have been processed in such a way that lenticulas are formed at the fiber ends. This lenticulation diffuses the incident radiation and presents a relatively uniform high-resolution display to observers on the opposite side. Similar results are accomplished with the arrangement shown in Fig. 4c. The tilted fibers diffuse incident radiation into a cone whose axis is tilted to the incoming rays. The cone axis is again made nearly parallel to the original ray by the use of untilted fibers.

In the lenticulated versions, fiber diameters down to 0.00025 inch have been used; in spite of fine-diameter fibers, these screens do not have resolutions superior to those of certain special-purpose commercial screens. However, taking into account both the desirable diffusing properties and high resolution, the lenticulated screens are better than most commercial screens. The full potential resolution of the lenticulated screen has probably not been reached because of faulty lenticulation i.e., surface variations larger than the fiber diameters. Additionally, considerable cross talk occurs when the lenticulas extend above the insulating layer between fibers.

Further study of the potential of fiber optics for high-resolution screens is now being carried out in DEP Applied Research. One particular approach shows considerable promise; in this method, fiber-optics screens are subjected to a chemical process which etches the core of the fiber and not the lower-index cladding (a glass covering) shown in Fig. 5. The fiber-optics sample is rotated in a vacuum while metal is evaporated at grazing incidence. As a result, metal is deposited on the walls of the craters which are filled in with a diffusing material; the surface is then ground and polished. The chemical etching and filling process produces a surface that diffuses incoming radiation and eliminates any crosstalk between fibers.

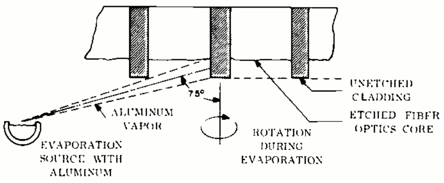
MAGNIFICATION TECHNIQUES USING FIBER OPTICS

Many situations exist, particularly on instrumentation panels, where it would be very helpful to enlarge the image and optically change the viewing angle of the display. Fiber-optics techniques again provide a possible solution by eliminating the bulky lens systems required for conducting light in any desired path. Also, desired magnification is provided by a bundle of fibers.

Any element of an image striking one end of a fiber is transmitted virually without loss to the other end. When the exit diameter of the fiber is larger than the entrance end, the image element is uniformly spread over the entire area of the exit end; it is thereby magnified. The ratio of magnification achieved is the same as the ratio between the fiber diameters at the exit and entrance ends.

Several techniques are available for making fiber-optics magnifiers. One of the first used by the American Optical Co. consists of making a fused, ordered bundle of cladded, parallel, cylindrical fibers; the whole group of fibers is drawn at an elevated temperature into the form of a bundle of tapered fibers (see Fig. 6).

Fig. 5—Chemically etched fiber optics structure



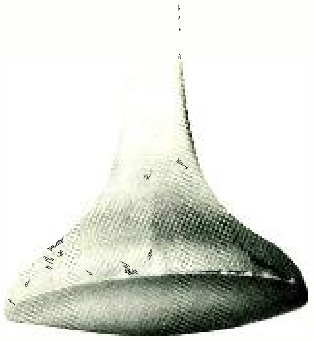


Fig. 6—Fiber-optics image magnifier. The diameter of the small end of the magnifier is about ⅜", and the large end about 2". Linear magnification is about 5.5X.

A second scheme is a splayed truncated magnifier, consisting of laying down a single layer of cladded, parallel fibers in a fused or bonded sheet. One end is cut and polished at a right angle to the fibers; the other end is truncated and polished at an acute angle to the fibers. Magnification is effected in both planes by stacking the bonded sheets so that the input ends meet, and the truncated output ends are spread apart, or splayed. To accomplish this magnification, the output must be in intimate contact with the diffusing surface or viewing screen layer. Such screens are necessary to produce the large viewing angles needed.

CONCLUDING REMARKS

Much progress has been made in demonstrating the value of fiber optics as an engineering tool for increasing the resolution of various display devices. In reviewing the initial article on fiber optics in the RCA ENGINEER[3] we find that most of the potentials outlined have been demonstrated. The basic techniques are now available; their applications are many. Continued cooperation by DEP Applied Research, the Electronic Tube Division, American Optical Company, and other suppliers of fiber optics will produce further advances in sophisticated systems using these techniques.

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LARGE-AREA DISPLAYS BY ELECTROPHOTOGRAPHY AND MAGNETIC THIN FILMS

by **K. C. HUDSON**
Electro-Mechanics Group
Applied Research
DEP, Camden, N. J.

The electrophotographic and large-screen projection techniques described may result in significantly improved large-area displays (10 x 10 feet). Such devices are in demand for the visual presentation of information from computers and video sources. Heretofore, systems relying on oil films in vacuum, ultrasonic light modulators, and mechanically complex rotating-mirror systems have not been satisfactory. In most cases, existing systems have been too complex, or lack reliability and versatility.

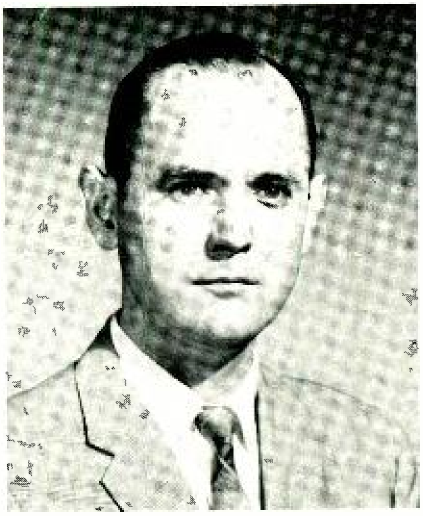
Recent work in DEP Applied Research on new materials and techniques may provide the answer to the demand for simple, reliable, and high-resolution display and pickup systems. In addition, some of these new techniques can be utilized for the temporary storage systems of displayed or recorded information. These advanced techniques presently under investigation are electrophotography and magnetic thin films.

ELECTROPHOTOGRAPHY

The basic technique of electrophotography using RCA *Electrofax*[1] was described briefly in "Electrofax — Today and Tomorrow", by D. J. Parker, (RCA Engineer Vol. 6, No. 3). A modification of this technique, which was developed by DEP Applied Research, makes use of RCA Electrofax and a transparent thermoplastic film in producing electrophotographic transparencies. These transparencies are similar to those obtained by W. E. Glenn[2] by electron beam recording on thermoplastic film. The advantages of this new Electrofax technique are that optical images can be recorded directly and no vacuum is required.

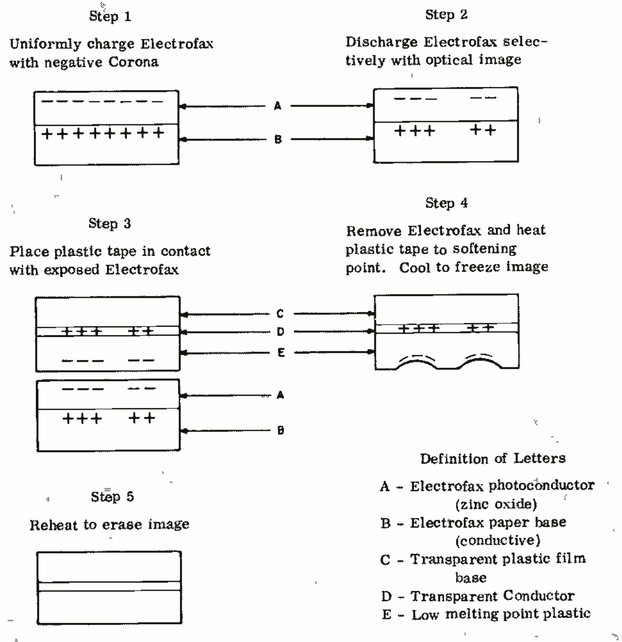
The technique for producing these transparencies (Fig. 1) consists of exposing a corona-charged Electrofax surface to an optical image such as the picture on the face of a kinescope. The resultant electrostatic image is transferred from the Electrofax paper to the surface of a thermoplastic film. The plastic film is then heated to its melting point so that a *mechanical image* is formed in the plastic by the presence of electrostatic forces. Comprised of plastic ripples, the image remains frozen in the film until it is erased by reheating the plastic film above its melting point. The image erase temperature is slightly higher than the developing temperature to assure that no residual charge will remain on the film and to provide the surface tension necessary for a smoothly erased plane surface.

Fig. 2 shows some of the projected images obtained by this thermoplastic film process. In Fig. 2a, a 2.5-mil black-and-white bar pattern is shown, as developed by standard Electrofax techniques. This image is not transparent and is shown for comparison purposes only. The corresponding transparent image formed by the above process on thermoplastic is shown in Fig. 2b. Schlieren projections (description to follow) of this same plastic image are shown in Figs. 2c and 2d at different magnification. In the latter photo it can be seen



K. C. HUDSON graduated with highest honors from Temple in 1952 with a bachelor's degree in physics, and received his master's degree in 1954. From 1952 to 1957, he did research and development on industrial instrumentation systems at Brown Instruments Division of Minneapolis Honeywell; he also served as project engineer on the development of ultrasonic instruments. Mr. Hudson joined RCA in 1957 in the Advanced Development Section of Commercial Electronic Products where he worked on the development of ultrasonic detection and measurement systems. In 1958 he joined DEP's Magnetic Head Advanced Development Group of applied Research; subsequent studies involved development of static reading heads, computer heads, audio and video *record* and *erase* heads; he discovered new methods for optical readout of magnetic tape and electrostatic recording of photographic and video information. Mr. Hudson has been granted two patents; one on a pressure-to-electric transducer and one on an electric flow meter for liquids; several more are pending. He is a member of Sigma Xi, Sigma Pi Sigma, the Accoustical Society of America, and the SMPTE.

Fig. 1—Thermoplastic recording process



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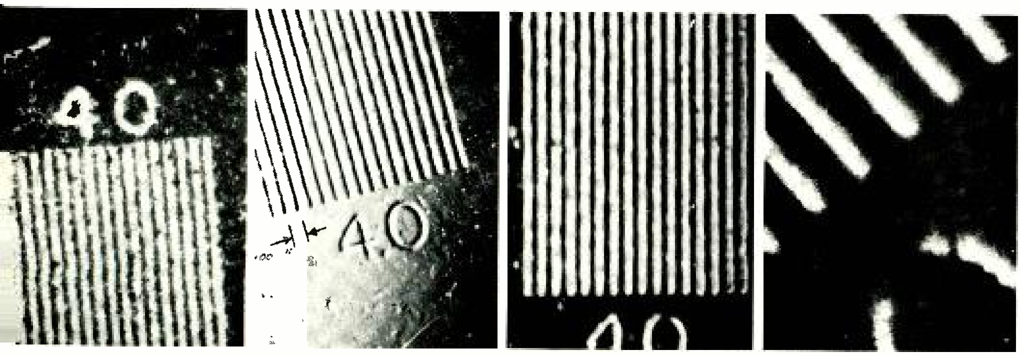

2(a) 2(b) 2(c) 2(d)

Fig. 2—Electrofax images on thermoplastic films

that limiting resolution has not been approached at the 400 lines/inch developed on the film.

A display system in which this technique can be used is shown in Fig. 3. In this system, the plastic film is used as a display medium for video or computer data. If recorded data must be stored for display at a later time, the plastic film can be stored on take-up reels, instead of the recirculating loop shown.

SCHLIEREN PROJECTION

In order to utilize the ultimate capabilities of thermoplastic recording film the projection system is of utmost importance. From DEP Applied Research's experience with these films it appears that schlieren projection is the best method of displaying information recorded on the film. In Fig. 4 a schlieren system is shown whose operation is briefly as follows:

1) An illuminated slit in an entrance stop is imaged by lens L_2 onto an exit stop so that no light reaches the screen when there are no ripples on the plastic in the schlieren field.
2) When the plastic is rippled by recording on it as discussed previously, light is then refracted by the ripples around the exit stop (see dashed line, Fig. 4).
3) The lens L_3 images these plastic ripples on the projection screen; the amount of light reaching the screen at a given image point is proportional to the slope of the plastic ripple at the corresponding object point on the plastic film. Because of this fact, it is possible to obtain a photographic gray scale by modulating the slope of the ripples.

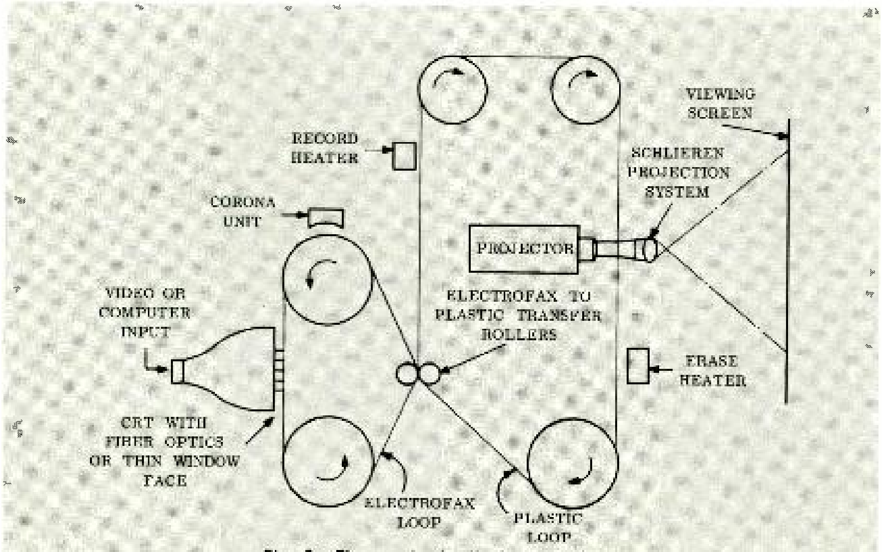

Fig. 3—Thermoplastic display technique

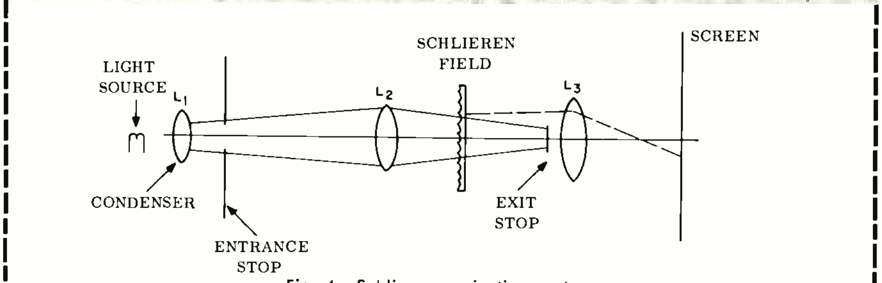

Fig. 4—Schlieren projection system

If the image to be impressed on the thermoplastic is "screened" the ripple profile shown in Fig. 5 will be obtained (a line screen consisting of very closed spaced opaque lines, is imaged on the plastic film simultaneously with the desired image to be photographed.) Thus, the photographic object, in effect, amplitude modulates the ripples formed by the screen. The large-amplitude ripples because of their increased slope refract more light around the exit stop than will the lower-amplitude ripples. The ripple structure in the schlieren image will not be seen if the sensing system (e.g., the eye) cannot resolve the fine structure. Then, only shades of gray corresponding to the original object will be seen.

The screening operation is not necessary when recording on the photoconductor is done with a cathode-ray tube, since the intensity of the moving phosphor spot can be varied by a high-frequency carrier. This carrier is amplitude modulated by the signal and when transferred will resut in a ripple profile on the thermoplastic similar to that in Fig. 5. When electrical playback of the data on the film is required, a pick-up tube can be used. The tubes scanning aperture will not resolve the fine structure in the image due to the carrier; thus, the need for demodulation is obviated.

THIN MAGNETIC FILM TECHNIQUES

DEP Applied Research has recently performed experimental work on thin magnetic films for visual displays and magnetic recording. These films, which are evaporated onto a transparent substrate as a single domain in thickness (600 to 2000 angstroms) can be switched at discrete points in a few nanoseconds (10^{-9} seconds) by an applied magnetic field. The resulting multi-domain patterns can then be viewed by reflected polarized light *(Kerr Effect)* or by transmitted polarized light *(Faraday Effect)* when the film thickness is less than 1000 angstroms.

To explain Kerr Effect read-out, it may be said that when plane polarized light is reflected from a magnetized film,

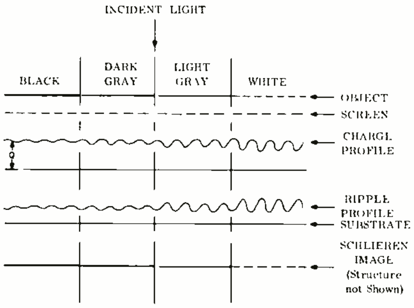

Fig. 5—Ripple profile of a gray-scale image

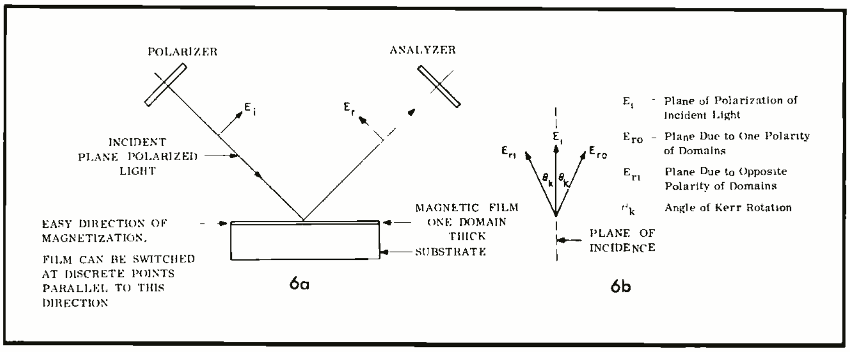

Fig. 6—Readout by Kerr Effect

the plane of polarization is rotated. The direction and magnitude of such rotation is dependent upon the orientation of the magnetic domains and the magnitude of the magnetization at the reflecting surface. This rotational effect can be used to visually read-out the polarity of a thin, single domain magnetic film by crossed polarizers. (Fig. 6) When domains in the plane of the film are switched to the left or right, rotation of the incident electric vector E_i will occur in a clockwise or counterclockwise direction (Fig. 6b). When the analyzer is set to extinguish one of these vectors, the other vector will produce a relatively bright region; in this way, antiparallel domains appear light and dark.

In Faraday-effect read-out, the plane-polarized light is transmitted through a very thin film about 600 to 1000 angstroms thick. Rotation of the plane of polarization takes place during transmission and is a function of domain polarity and thickness. A variation in transmitted light intensity is obtained with a polaroid analyzer as in the Kerr Effect. In both read-out methods, an angle of incidence of about 45° to 60° is required, since the magnetization vector for most thin films is in the plane of the film and this vector must have a component parallel to the direction of light propagation.

Examples of optical read-out of some magnetic thin films are shown in Fig. 7. In Fig. 7a, magnetic recording on a manganese bismuth alloy is displayed by reflected polarized light (Kerr Effect). This material has good contrast (exceeding 10 : 1), but is very difficult to make, even in small quantities. Fig. 7b shows Faraday read-out of permalloy film; this material is very easy to evaporate onto large areas, but contrast is less than 2 : 1 by reflection and about 3 : 1 by transmission. Means for obtaining increased contrast with permalloy have been studied, but have met with limited success. Fig. 7c shows Faraday read-out of recordings on iron-cobalt film. Iron-cobalt film, the most promising material to date, is easily made and contrast ratios of 5 : 1 have been measured with transmitted light.

Methods for recording electrical data on these films includes the use of magnetic heads and X-Y switching matrices. The latter is the most promising for producing large area displays from computer and video outputs. A small section of thin-magnetic film screen with its X-Y switching conductors is shown in Fig. 8.

SUMMARY

A new recording technique, which has been developed by DEP Applied Research, utilizes Electrofax to transfer an electrostatic image to a transparent thermoplastic film. Photographic transparencies have been produced for large screen display by schlieren projection. The advantages of this technique over previous thermoplastic methods are that optical images can be recorded directly without the use of an electron beam and recording on the film does not have to be done in a vacuum. Means for further improvement of this technique are being investigated by DEP Applied Research.

In the area of thin magnetic films for recording and display we are investigating means for improvement of resolution, contrast and signal to noise. This includes an investigation of light sources, polarizers, and detectors in addition to a film materials investigation.

7a 7b 7c

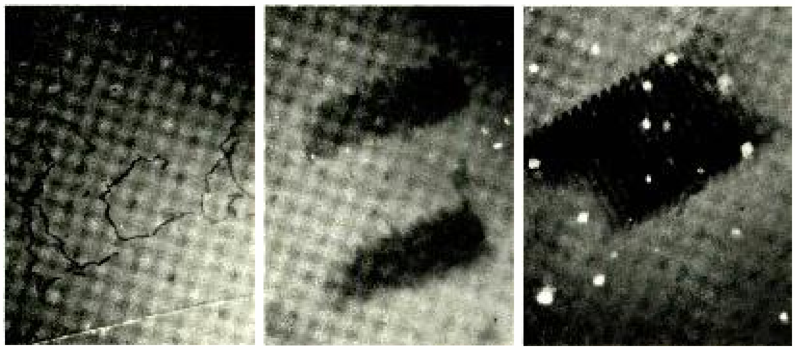

Fig. 7—Readout by Faraday Effect

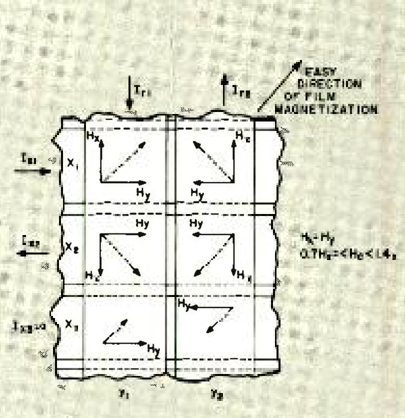

Fig. 8—X-Y switching conductors

Electroluminescent-Photoconductive MICROMODULAR LOGIC ELEMENTS

by **Dr. C. P. HADLEY, Mgr.**
Photocell Design Engineering
Electron Tube Division, Mountaintop, Pa.

In a new approach to the fabrication of electroluminescent-photoconductive logic circuitry, many micromodular building blocks called logic elements are stacked and interconnected to form the completed device (suggested by L. E. Haining, West Coast Missile and Surface Radar Division, DEP, Van Nuys, Calif.; see article, this issue.) Until recently, such devices were fabricated with both the photoconductor and the electroluminescent layer in panel form. Although this approach permits sophisticated electrode patterns and leads to a high active-element density, manufacturing processes must be closely controlled.

THE SIMPLE electroluminescent-photoconductive micromodular logic elements discussed in this paper use as a substrate the familiar 0.31-by-0.31-by-0.01-inch ceramic wafer shown in Fig. 1. On one side of the ceramic, a sintered cadmium sulfide photocell is formed by techniques which have been described by Hadley and Fischer.[1] On the other side of the ceramic, a "sandwich" is applied which consists of a transparent conducting electrode, a layer of electroluminescent phosphor, and a top metallic electrode. Because the ceramic is translucent, light from the electroluminescent layer can activate the photoconductor. More complicated electrode patterns can also be used, in which several photoconductive cells are formed on one side of the ceramic, and several electroluminescent lamps on the other.

The typical electroluminescent-photoconductive logic element is fundamentally a light amplifier in which optical as well as electrical coupling leads to extremely simple circuitry. Because the amplifier may have bi-stable properties, it can act as a storage element as well as a switch, and hence can perform most logic operations. The element is compact, flexible, and low in cost.

The speed of response of the logic element is limited by the properties of the photoconductor to the order of 0.1 second. Devices of this type promise to be useful, therefore, for applications in which human reaction time is the limiting factor rather than the speed of the device itself. An example of such an application is the switching and logic required in character display. Thus, the logic elements can readily be used as building blocks in circuitry for various devices discussed in this issue by Haining, Law, and Cooperman.

GENERAL CONSIDERATIONS

An electroluminescent (EL) lamp is a solid-state device which emits light when an alternating voltage is applied to it and acts in a circuit as if it were a lossy capacitor. The luminous output of a typical lamp made with a zinc sulfo-selenide phosphor is shown in Fig. 2. The brightness of the output increases with a high power of the applied voltage and is slightly less than linear with frequency.

A photoconductive (PC) cell is a light-sensitive solid-state device in which the electrical resistance decreases as the illumination incident on it increases. The conductance of a typical cadmium-sulfide photoconductive cell is shown in Fig. 3. Because the spectral sensitivity of the cadmium sulfide is close to that of the human eye, luminous photometric units may be analyzed as follows:

The typical EL-PC device is a combination of EL lamps and PC cells in which circuits are coupled by the action of light as well as electricity. Many of the EL-PC devices are combinations of two types, the series and bi-stable circuit.

In the series circuit shown in Fig. 4, a logic element (enclosed in dotted lines) is used as a light-controlled switch, while an external EL lamp, EL$_2$, acts as the load. Thus, PC$_1$ and EL$_2$ form the series circuit under consideration and act essentially as a light amplifier. The characteristic of such a circuit is shown in Fig. 5: the logarithm of the brightness of EL$_2$ is plotted as a function of the logarithm of the illumination incident on PC$_1$. The curve has a typical shape: one saturation region occurs at low values of illumination as a result of the dark conductance of the photoconductor, and another occurs at higher values of illumination for which the resistance of the photoconductor becomes negligible. One of the critical parameters, the shoulder of the curve, is shown in Fig. 5. The shoulder occurs at that value of illumination when the conductance of the photoconductive cell equals the susceptance of the EL load.

The cadmium-sulfide photoconductor does not respond instantaneously to light, but requires an appreciable time to reach its ultimate conductance after a change in illumination level. The speed of response increases with increasing illumination. The problem in designing the EL-PC series circuit is to optimize the conductance of the PC cell with respect to the susceptance of the EL load to permit maximum light output and minimum response time. In Fig. 5, the optimum condition occurs when the operating point is near the input illumination level determined by the shoulder of the curve. Usually, the PC cell is made more sensitive than the optimum condition by a considerable factor to compensate for spread in the sensitivity of photoconductors, spread in the output of the EL lamps, and degradation during life.

In the bi-stable circuit shown in Fig. 6, a single logic element, connected properly, can be used as a bi-stable element because the light which passes through the ceramic can serve as feedback illumination. The circuit has two stable conditions: *off* (the EL lamp is extinguished), and *on* (the EL lamp is lighted). The transition from the *off* to the *on* condition occurs when the photoconductor is exposed to a flash of light. The transition from the *on* to the *off* condition occurs when the applied voltage is removed momentarily.

In the design of both the bi-stable circuit, and series circuit, exactly the same criteria are important; solutions are also entirely the same. For all of the EL-PC devices mentioned above, a typical operating voltage is 250 volts, 420 cps.

APPLICATIONS

As examples of the applications of the EL-PC micromodular logic elements, several simple circuits are discussed below.

Fig. 7 shows a three-element *and* gate in which the circuit is completed only if all three inputs *A*, *B*, and *C* are present. No more than three logic elements are required to fabricate the gate. If, as is very frequently the case, the ultimate load is to be an EL lamp, the design considerations presented for the series circuit may be applied.

In the two-element *or* gate shown in Fig. 8, the output circuit is completed if either EL$_A$ or EL$_B$ is activated. By proper design, the complete gate can be fabricated on a single mircomodule.

A more complicated storage arrangement, called a flip-flop circuit[2] is shown in the center of Fig. 9. There are two conditions of equilibrium: one with EL$_1$ lighted, the other with EL$_2$ lighted. If EL$_2$ (or EL$_1$) is lighted, and it is desired to change to the other stable state, S_1 (or S_2) is momentarily closed. This circuit is regenerative in nature, and the switching is faster and more positive than for the simple bi-stable arrangement shown in Fig. 6. In addition to the main circuit, which can be made on a single micromodule as indicated by the central shaded area, an *on trigger* and an *erase trigger* are included, each on a separate micromodule. A separate load, normally an EL lamp, could be connected in parallel with EL$_2$.

As a final example, a display system is described which accepts a three-bit binary input, and decodes it in a manner to present the numerals 0 through 7 on an EL numeric panel. A similar system is described in the Haining article in this issue, in which the decoding is accomplished by an EL-PC panel device rather than by stacked logic elements. Because storage is incorporated in the device, the input signal need be applied only momentarily; the numeral may also be erased by a momentary signal.

In the schematic of the entire arrangement shown in Fig. 10, the photodecoder is shown on the left in diagram form; each cross represents a single logic element arranged as a switch. There are eight series-parallel circuits in the decoder, each of which leads to a flip-flop circuit of the type shown in Fig. 9. The load for each flip-flop is a segment of the 8-element pattern (see Haining article, Fig. 2). The characteristics of the system are as follows: power source, 250 volt, 420 cycles; trigger, 0.1-second pulse; erase, 0.1-second pulse; and output, 10 to 20 foot-lamberts, indefinite storage.

It can be seen that a total of 74 logic elements is needed to construct the system. These elements can easily be packed in a cylindrical container about ½ inch in diameter and 1½ inches in length. The numeric character can be made as small as ¼ by ⅜ inch, or as large as desired.

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2. T. B. Tomlinson, "Principles of the Light Amplifier and Allied Devices," *Journal of the British I.R.E.*, March 1957.

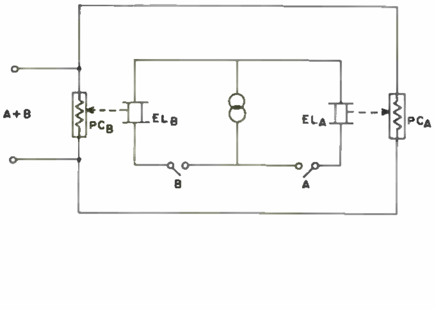

Fig. 8—Two-element *or* gate.

DR. HADLEY'S undergraduate and early graduate work was done in Physics at Dartmouth College prior to 1944. From 1944 to 1946 he served as Radar Officer in the U. S. Navy. From 1946 to 1950 he continued graduate work at Massachusetts Institute of Technology and received the degree of Ph.D. in 1950. His field of specialization was solid-state physics. Since 1950 he has been with the RCA Electron Tube Division, where his interest has been in thermionic emitters and in the energy-level structure of electronically active solids. He is a member of Sigma Pi Sigma, Phi Beta Kappa, and Sigma Xi. Dr. Hadley is Engineering Manager of Photocell Design.

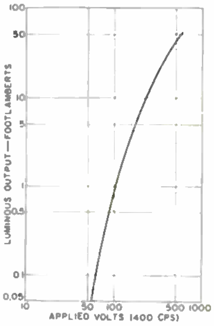

Fig. 2—Luminous output of an electroluminescent lamp.

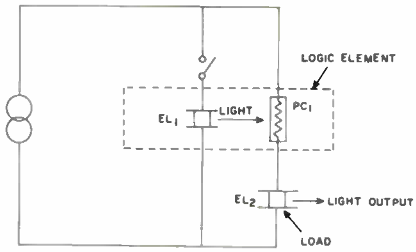

Fig. 4—Basic EL-PC series circuit.

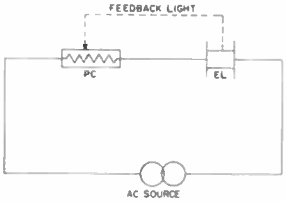

Fig. 6—The bi-stable circuit.

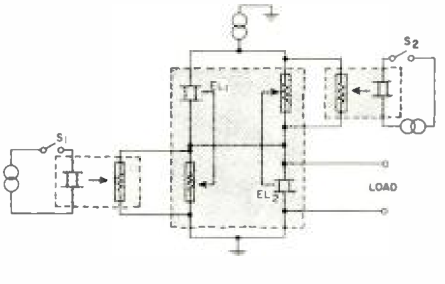

Fig. 9—Flip-flop circuit. The shaded areas represent the three logic elements discussed in the text.

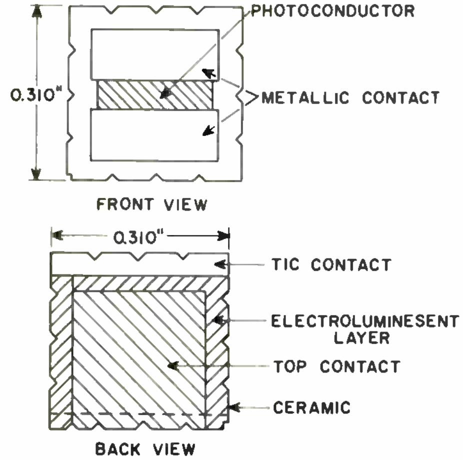

Fig. 1—EL-PC micromodular logic element.

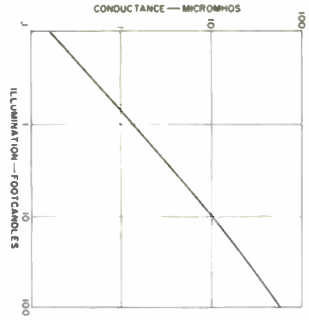

Fig. 3—Conductance of a cadmium sulfide photoconductive cell.

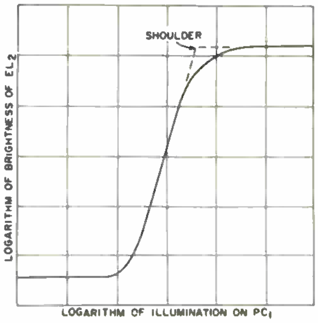

Fig. 5—Characteristic of the series circuit.

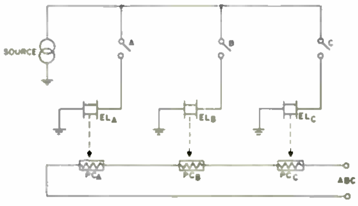

Fig. 7—Three-element *and* gate.

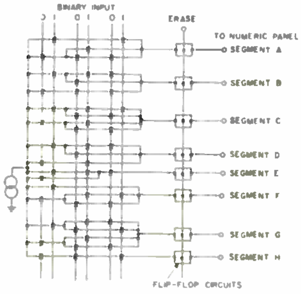

Fig. 10—Numeric display system: each cross represents a logic element in which the binary input lights the EL lamp, which in turn activates the photoconductor.

NEW SOLID-STATE ALPHANUMERIC DISPLAY

by **L. E. HAINING**
*Data Systems Division**
DEP, Van Nuys, Cal.

When we address computers and digital data-processing machines (insert information into them), the information must be put into a language the machine can use. And similarly, when machines must present processed information, display messages on status boards for military users, or on airline arrival-and-departure boards for travellers, the intelligence must be in a form familiar to those reading the messages; the users of such information are not expected to be specialists in decoding or in the use of such machines. The practical method of presenting the information, up to the present time, is to print out all the words or numbers involved on a display large enough for all to see it.

THE ELECTROLUMINESCENT STORAGE INDICATOR

A new device, ELSI *(Electroluminescent Storage Indicator)*, can display numerals or letters (Fig. 1) on thin glass panels; it promises to be a valuable component for use in numerous display applications. From a human-factors standpoint, it presents all characters or numerals on a flat surface so that there is no parallax; the essentially cosine distribution of light makes it appear equally bright from any direction. Any variety of colors of light can be used, permitting a wide choice for best viewing conditions. The ELSI power consumption is very low, resulting in cool operation. And finally, because it uses no vacuum and no filament, the possibility of catastrophic failure is minimized.

Electroluminescent display panels in the general form described here have been used for some time, but were limited in application because much complicated circuitry was needed to maintain voltages on the proper combination of display elements. The ELSI panel overcomes this difficulty by incorporating a "built-in storage" in each element. One encoding device can therefore turn on, or trigger, many different panels in succession; each one stays lighted until deliberately extinguished by momentarily interrupting the exciting voltage.

CONSTRUCTION DETAILS

The display portion of the ELSI panel consists of an array of electroluminescent elements, called line segments, arranged on a glass sheet in the pattern shown in Fig. 2. Lighting of the proper combinations of these line segments can provide displays for any of the 36 alphanumeric characters.

In this pattern there are 16 line segments, but since the top two are always lighted together and the bottom two are always lighted together, there are effectively 14 segments in all. This is the smallest number which can display all characters, and is the one presently used in the ELSI panels.

It has long been recognized that the shapes of some characters obtainable with the 14-line-segment array, or even with arrays using up to 20 line segments, are far from optimum. J. J. Belcher, of

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* Formerly named West Coast Missile and Surface Radar Division.

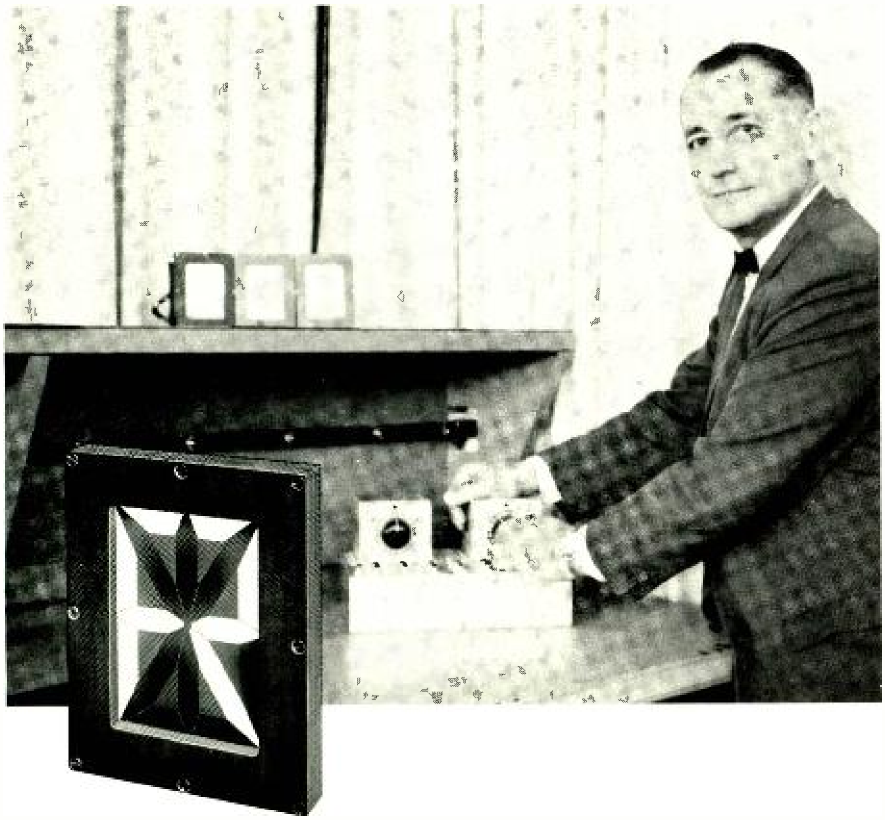


Fig. 1—Here the author is shown during engineering tests in his laboratory; the letters RCA are being displayed by electroluminescent light triggering to provide the desired contrasts (see the enlarged "R" panel inset).

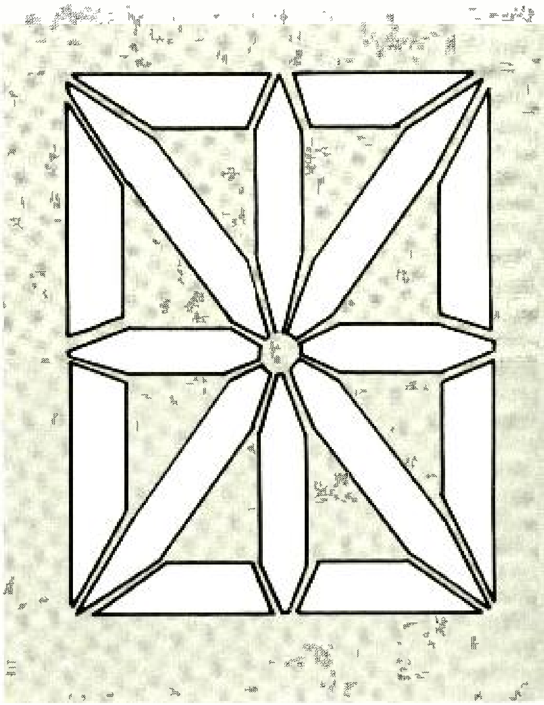


Fig. 2—The display panel portion of the Electroluminescent Storage Indicator (ELSI) contains 16 luminescent elements called "line segments" arranged as shown here.

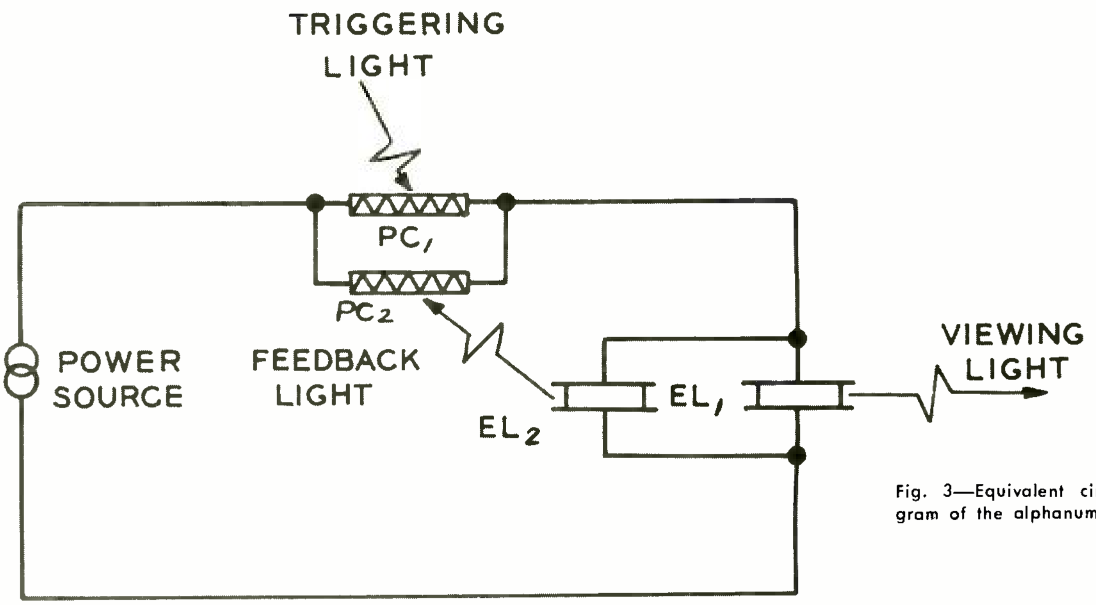


Fig. 3—Equivalent circuit diagram of the alphanumeric ELSI.

the Data Systems Division, Van Nuys, Cal., has studied the improvement possible by using arrays of more segments; he has worked out two combinations to provide greatly improved legibility—one uses 27 segments, and the other 38. This, of course, increases complexity of the code-translation equipment needed to select the proper segments, but new techniques have become available which make this back-up equipment compact and economical. One such technique is embodied in the photoconductive-electroluminescent *Photodecoder* described in this article; others are presently in development at the Data Systems Division, Van Nuys, Cal.

ELECTROLUMINESCENCE

The electroluminescence (EL) light source in the panels is a phenomenon involving light emission by the excitation of phosphor materials; in this case, the phosphor is excited by a varying electric field created by an alternating voltage. The electric fields are applied by utilizing the phosphor as a dielectric between two flat plates constituting a capacitor. One of the capacitor plates is a transparent conductor laid on top of a sheet of glass so that the light is visible; the conductor shape forms an outline of the desired line segment. The other capacitor electrode, consisting of aluminum deposited on the back of the phosphor material, not only applies the a-c field but also reflects the light forward.

Displays utilizing the line-segment array of Fig. 2 have been known for some time and are relatively simple to build. The basic problem has been the necessity of maintaining voltage on the proper combination of line segments. This has required, in effect, that an encoding device be provided for each character.

To avoid such complexity, several schemes have been tried for incorporating built-in storage in each segment. One approach consists of paralleling the capacitor of the unit with an inductor; thus, inductance values can be shifted to bring the circuit into or out of resonance. This, however, creates fabrication problems, since strict tolerances in capacitance and inductance must be held, and the circuit becomes very sensitive to exciting frequency.

Another approach, the method used in this project, employs a photoconductive (PC) element in series with each line segment, and an electroluminescent (EL) light electrically in parallel with the line segment. This arrangement illuminates the control photoconductor so that the segment is kept lighted indefinitely. Fabrication in compact, solid-state forms, relaxed tolerance requirements on uniformity, and operation over a wide range of exciting frequencies are among the advantages provided.

ELECTRICAL DESIGN

Electrically, the equivalent circuit for any segment is shown in Fig. 3. The PC elements are connected in parallel, as are two EL elements; the paralleled PC is then connected in series with the paralleled EL and an a-c voltage. Thus, EL_1 is the exposed line segment; the sustaining element (EL_2) and PC_2 are internal to the panel. Light feedback is from EL_2 to PC_2. Prior to triggering, PC_1 and PC_2 are not illuminated, and therefore, very little potential drop exists across the unlighted EL elements. When PC_1 is momentarily exposed to light, it becomes a low impedance, and EL_1 and EL_2 are excited and lighted. Then, PC_2 becomes a low impedance because of the light feedback from EL_2, and the triggering light may be removed. The panel is turned off by momentarily interrupting the supply voltage; in many applications, a PC cell is used to perform this function.

The proper combination of segments may be triggered on by lights, as described above, or by electrical switching. The "trigger-light" approach is used because of its versatility; the light used may be any one of several types, such as incandescent, neon, or other forms of electroluminescent lights. When transistors are used as the driving source, tiny incandescent lights are a logical coupling means; when the PC-EL Photodecoder, described in this article, is used, EL lights are employed because they match the output impedance of the Photodecoder.

Fig. 4 shows some of the parts of the experimental ELSI panel. On the left is the back of the panel, showing the triggering PC elements. Next is a front view showing the panel displaying the letter *R*. Second from the right is the ceramic sheet showing how the printed-on PC elements are arranged. On the right is one of the EL trigger-light panels.

The panels operate at about 15-foot-lambert brightness and require about 2 volt-amperes at 420 cycles for a character size of about 2 inches wide by 3 inches high. Small, inexpensive incandescent lights have also been used for triggering; panels can be turned on in about 1/20 second when operating at one-half rated voltages. The panels, as constructed and normally operated, require about ½ second to turn off, but experimental ones have been turned off in less than 1/10 second.

The ELSI panels are designed to achieve a decisive lock-on which will hold over a wide range of exciting frequency and voltage, and at the same time hold turn-off time to a minimum. This requires a close control of the characteristics of the PC elements in order to maintain reasonable uniformity. It also requires proper matching of the impedances of the PC and EL units. It might appear that the lighted impedance of

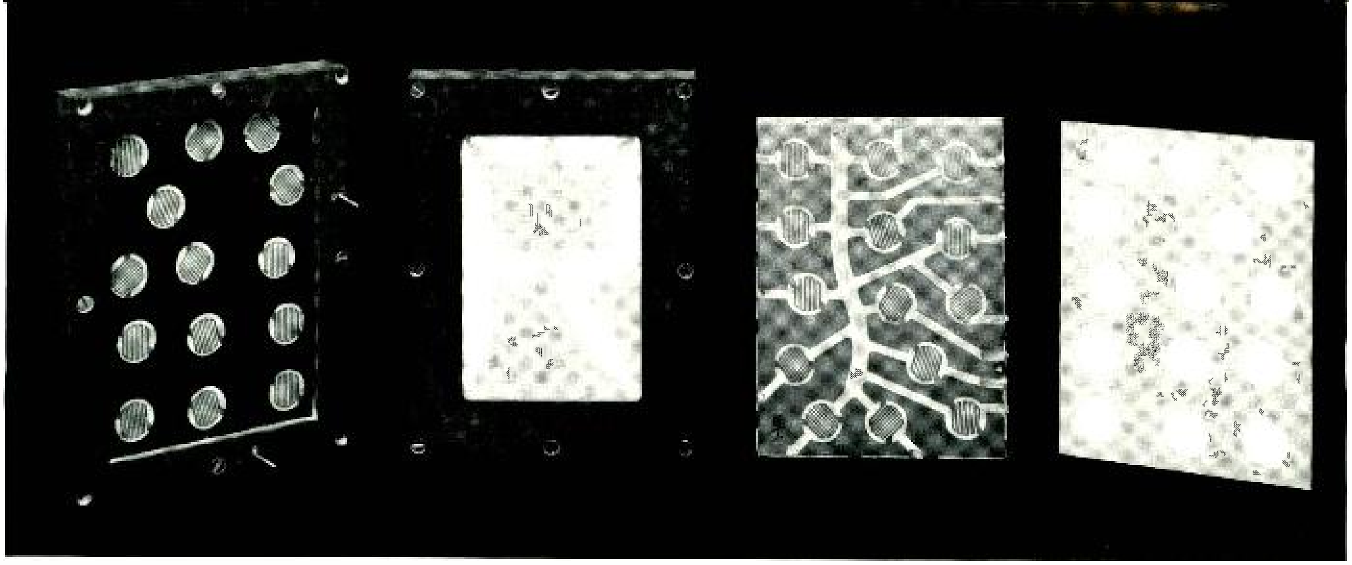


Fig. 4—Component parts of a typical ELSI panel (l. to r.): back of panel, front-panel view showing letter "R," ceramic sheet showing photoconductive elements, and electroluminescent trigger-light panel.

the PC elements should be as low as possible; however, too low an impedance can result in excessively long turn-off time.

CODE TRANSLATION AND ADDRESSING REQUIREMENTS

To make efficient use of such panels in display systems, circuitry must be available to select the proper combinations of segments and to select the proper panel from a large number which may comprise a complete display.

The most desirable form of decoding device will depend on the particular application. For many applications, the input to the display complex might well be the voltage on a specific conductor associated with each character, while voltage on another wire or cable selects the panel to be lighted. In other cases (probably most of those which involve large numbers of panels), separate codes would probably be needed for character identification and for location of the character in the display.

In any event, for the line-segment type display, addressing equipment must be available to 1) translate the voltage on a wire to specify a character, and 2) convert the character-specifying code into the proper selection of segments to create the character.

The actual component can vary from the simple multideck rotary switch used in the laboratory demonstrator to the transistor circuitry commonly found in digital computers. A more novel and versatile approach employs EL-PC combinations similar to those used to provide the ELSI storage capability; here, one method serves for both code translation and the routing of information and control of the panels. For the latter technique, EL and PC elements in the form of micromodule wafers are used to create multielement gates, flip-flops and counters (This subject is described by Dr. C. P. Hadley of the Electron Tube Division in a separate article in this issue.) For handling the code translation of line-segment selection, an EL-PC device accepts 6-bit parallel-input information and provides the proper selection of line segments for any alphanumeric character. The device is called a *Photodecoder* because it operates on the principle of using light as a coupling agent.

PHOTODECODER CIRCUITRY

To explain the operation of the Photodecoder, a simplified diagram is shown in Fig. 5. The Photodecoder accepts a four-bit input to address the segments of a seven-element numeric panel (Fig. 5). The principle of operation is exactly the same for a six-bit input, 14-segment alphanumeric; however, because of fewer elements, the former is easier to explain.

The decoder operates with a pair of EL strips corresponding to each input bit, arranged so that one strip is lighted when a *0* is present in that input bit position, and the companion strip is lighted when a *1* is present. These strips are shown in Fig. 5 as four pairs of shaded vertical strips; a *1* or *0* indicates which strip is lighted when a voltage is present or is not present in that particular position. The circuit at the top left of Fig. 5 turns on one of the left-hand pair of EL strips in accordance with the binary input signal. A similar circuit is used for each of the other EL strip-pair (bit) positions. When a binary input on line 1 is *0* (no voltage present), EL_2 is dark, and PC_2 and PC_3 are not illuminated. This prevents the line 1 strip of the decoder from being energized, and also leaves PC_2 in its high-resistance state. This permits EL_1 to be lighted and illuminates the line 0 decoder strip by lowering the resistance of PC_1. When a voltage is present on the input line 1, EL_2 is lighted, illuminating PC_3. Then, the line 1 decoder strip becomes energized and causes PC_2 to become a low-resistance shunt across EL_1; this respectively, turns off EL_1, and the line 0 decoder strip.

For the decoder proper, segment 1 of the numeric display should be lighted for the following designated numbers and for no others:

Arabic Number	*Binary Number*
0	0000
2	0010
3	0011
5	0101
7	0111
8	1000
9	1001

Display-panel operating voltage is applied through the printed wiring paths and PC "gaps" and coupled back through a common ground return. When an *arabic numeral zero* is indicated, the four line 0 EL strips are illuminated; conduction can take place through the four PC gaps (see dark black areas along wiring path at the top of the decoder of Fig. 5). When an *arabic numeral one* is selected, the line 1 strip in the fourth (right-hand) bit position is lighted. The conduction path is then complete through the first three bit positions, but is broken at the fourth where the line 1 strip is dark.

For *arabic two* (binary *0010*), conduction is complete on the upper path through the first two EL strip pairs. On this path, it will be noted that there are no PC gaps at either the binary *0* or *1* position for the fourth-bit pair. This is because segment number 1 must also be lighted for *arabic three* (binary *0011*), which is the same as *arabic two*, except for the fourth bit. Since conduction is desired for either a *0* or *1* in this position, no PC gap is necessary.

Similarly, conduction takes place for *arabic five* (*0101*) and *arabic seven* (*0111*) with no PC gaps required in the third-bit position because the segment must be lighted for either the *0* or *1* in that position. The same holds for the fourth-bit position on the fourth path; this is also the path for the *arabic eight* and *nine*. For any other binary code of the 16 available, no conduction is possible and the element remains dark.

The rest of the decoder, shown in Fig. 5, operates for segment 2, which must be lighted for arabic numbers 0, 1, 4, 5, 6, 8, and 9. Similar sections are required for the rest of the segments.

In the numeric system, it is possible to combine seven sections of the photodecoder into one, with some savings in the number of PC gaps. This would also be theoretically possible for the 14-section decoder for the alphanumeric version. In either case, however, it is necessary to insure that any lighted element is isolated from any other dark element by at least one unlighted PC gap. For the 7-element numeric system this is fairly simple to accomplish, but for the 14-element alphanumeric system it becomes a very difficult task. Furthermore, it is desirable from other standpoints to have the elements separated. With the method of construction used, the additional PC elements required are not difficult to provide. In the 14-segment model actually constructed, separate sections were used.

As shown in Fig. 5, EL$_3$ illuminates PC$_4$, which is in the return path for the decoder circuit. Thus, the output of one photodecoder may be connected to many panels in parallel, and any panel may be selected by lighting its own series PC cell. In actual practice, the seven PC elements are lighted by a single EL. However, the seven segment lines are controlled separately to prevent the sneak paths or matrixing problems occurring when several panels are used.

The Photodecoder for a six-bit code and a 14-line segment panel is considerably more complex, but works on exactly the same principle. Such a device was designed and built with the selections controlling the individual segments divided up into three groups and constructed on three sheets.

The resulting decoder is a compact and rugged solid-state construction. Its major disadvantage is in its relatively slow operating speed, a parameter limited by the characteristics of the PC material. In many applications where displays are controlled, high speed is not a serious requirement, since displays need only operate at a rate fast enough to satisfy those who must read the information.

CONCLUSIONS

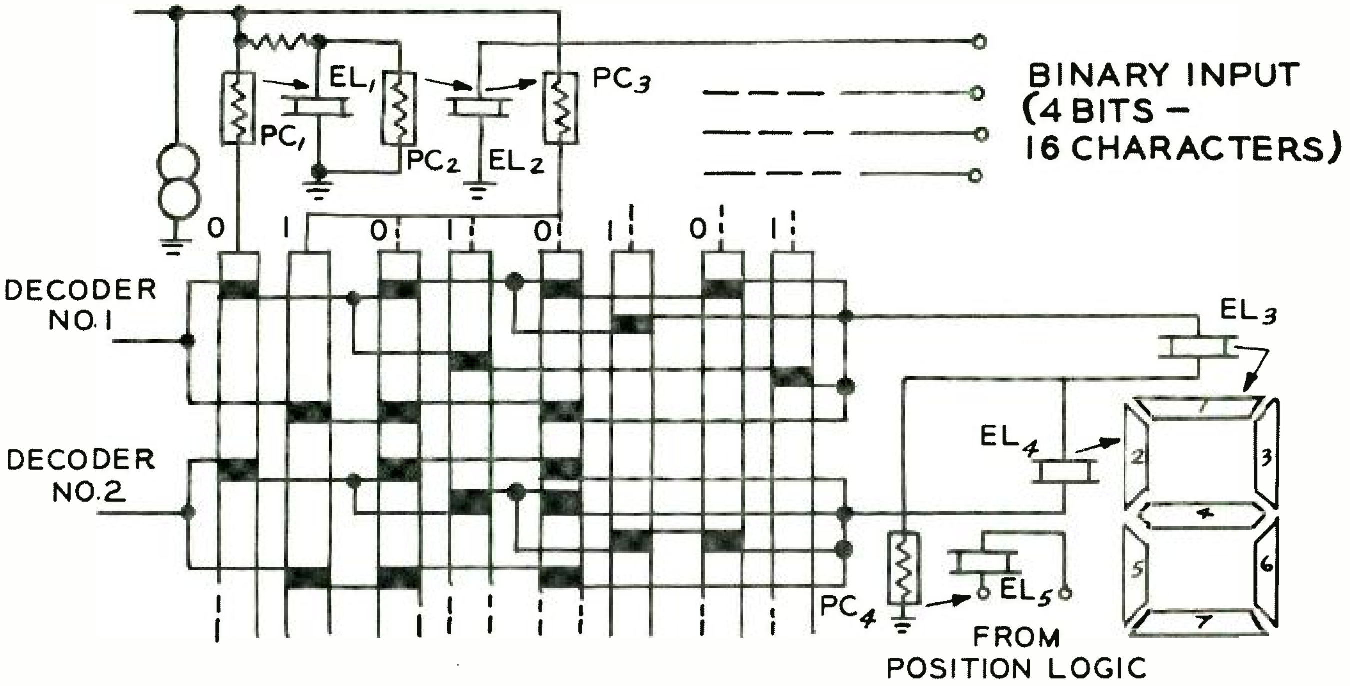
The addition of storage capability to the electroluminescent line-segment type panel results in a useful component for displays application which must present alphanumeric information. The further use of EL-PC circuitry for control and code translation functions can lead to complete display systems which are reliable, compact, cheap, and low in power requirements.

ACKNOWLEDGEMENTS

Acknowledgement is due to D. L. McLaughlin for early work on the panel, to Dr. C. P. Hadley and Dr. G. S. Briggs of the Electron Tube Division for actual construction of the devices, and to L. M. Seeberger and R. A. Davidson for guidance of the program of which this development was a part.

LESTER E. HAINING received the degree of B.S. in Electrical Engineering at the University of Nebraska in 1943. He served in the Armed Forces until 1946, first as a Radar Maintenance Officer in the Signal Corps, and later as Plans and Training Officer in the Radar School, Ft. Monmouth. When Mr. Haining joined RCA in 1946 his early work was on the Teleran project. Since then he has been concentrating largely in the field of displays; he has worked on a number of projects involving applications of radar and television techniques to various military problems. These projects include systems work on the Navy Project Cosmos, Air Force Advanced Reconnaissance System, and an RCA Air Traffic Control study. His most recent work has been applied research in the field of electroluminescent displays and electroluminescent-photoconductive logic elements. He is a member of the IRE, an associate member of the AIEE, and a member of Sigma Tau.

Fig. 5—Schematic diagram showing segments 1 and 2 of the numeric display of the "Photodecoder" which uses light as a coupling agent (see wiggly lines on sketch).



A REVIEW OF SOME FLAT DISPLAY DEVICES

by **Dr. H. B. LAW**
RCA Laboratories
Princeton, N. J.

On a recent trip, the author came across a small concern that has really done something about television-on-the-wall displays. An operating reproducer fastened to the wall at about eye level was observed. An excellent off-the-air picture was obtained which appeared to have about a 21-inch diagonal. The resolution and contrast were good and the brightness was quite adequate.

Before anyone gets the idea that television-on-the-wall has at last arrived, it should be pointed out that the concern was a motel, and that they had mounted a 21-inch table-model receiver on the wall using a crude bracket. Although the picture was good there was little else good about the arrangement of having a seemingly bulky receiver projecting out from the wall at eye level.

The placing of a table-model receiver on the wall may be symtomatic of the fact that many people believe picture-on-the-wall displays represent a kind of ultimate toward which engineers should work. Industrial concerns, educational institutions, and the military are all very much interested in a large, flat-display system. The potential market is exceedingly large — but, unfortunately, the problems are also large.

FLAT-DISPLAY APPROACHES

The approaches taken in the past to obtain a flat display have been quite varied. A recent review article[1] discusses flat-display devices under the following five headings:

1) evacuated displays or cathode-ray tubes of unconventional geometry;
2) displays using solid-state materials, in general matrix-type displays in which the input may be electrical or optical;
3) displays using liquids in which electrochemical changes are caused to take place;
4) gaseous displays making use of gas-discharge phenomena; and
5) mechanical displays such as those used for animation in connection with advertising.

In most of the above categories there are many devices—far too many to attempt a systematic review. Rather, it will be the purpose of this paper to select several devices from the solid-state category for discussion, since it appears that most of the effort today is in this area.

A primary consideration is the source of illumination to be used in producing the picture. Most often employed is an electroluminescent or EL phosphor.[2] The phosphor is imbedded in a dielectric, and the mixture sandwiched between two electrodes, at least one of which is transparent. An alternating potential applied between the electrodes causes the phosphor to emit light, the brightness of which is determined mainly by the strength of the electric field across the EL layer and the frequency of alternation. Large area-type light sources may be made that vary in brightness vs voltage across the EL layer for various frequencies as indicated in Fig. 1.

Fig. 1—Brightness of EL lamps as a function of voltage. The phosphor thickness is 0.004 inch.

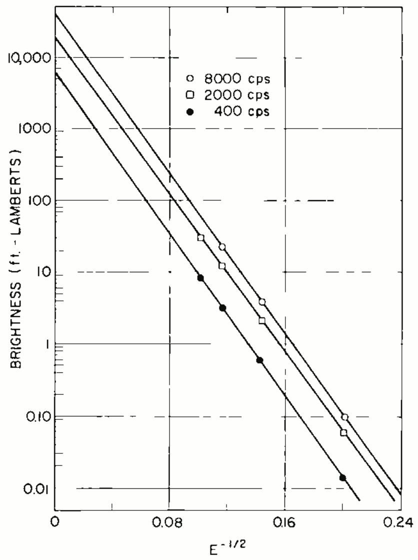
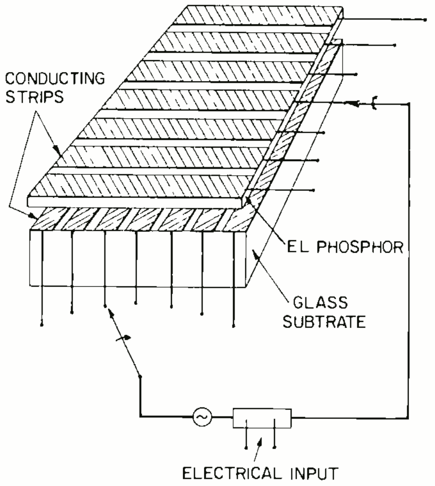


Fig. 2—Crossed-grid arrangement of electrodes. An a-c voltage applied between two crossed strips of the array excites the EL phosphor at the crossing, and also, to a lesser extent, the remaining phosphor under each strip to which voltage is applied.



Perhaps the simplest concept for using EL phosphor to produce a display, with only electrical signals as input, is a crossed-grid arrangement of electrodes between which is sandwiched the EL layer as shown in Fig. 2. Selecting one vertical and one horizontal strip, an alternating potential applied between the strips causes the phosphor at the intersection to emit light. However, not only the intersection but the entire EL area under each of the strips will also emit light because half voltage appears across the phosphor in these areas.[3] The effect is severe, since half voltage appears repeatedly where it is undesirable during the scan cycle and the light emitted integrates over a frame time. In a picture built up by application of signal to the strips in the simple arrangement described, the contrast obtainable is very poor when using the available EL phosphors.

The contrast is dependent on the nonlinearity of the voltage-light output characteristic of the phosphor. Improved operation results if a nonlinear resistive layer is placed between the EL phosphor and one of the sets of conducting strips to further increase the nonlinearity of the system. In one of the later publications on this subject[3] the use of SiC as the nonlinear resistor was described. A marked improvement in contrast was reported.

Assuming successful application of a nonlinear resistor to suppress unwanted light, another serious problem exists. The maximum light intensity obtainable in the picture is the peak light intensity of an individual element divided by the number of elements in the picture. A peak brightness orders-of-magnitude more than those shown in Fig. 1 would be needed to produce a satisfactory picture under this condition. Increasing the voltage or frequency of the excitation is not the answer to a brighter phosphor; increasing the voltage across the EL layer as well as increasing the frequency has the effect of reducing phosphor life. The requirements are quite severe. In the past, only by direct excitation of phosphor with an electron beam, as done in conventional cathode-ray tubes, has it been possible to obtain in a practical way sufficient brightness for picture reproduction with sequential element-by-element excitation. Longer decay time of cathodoluminescent phosphor over EL phosphors accounts for some of the increased light output potential.

If the time that a picture element remains on could be increased, the brightness of the picture would increase in direct proportion. In an ideal panel that would take full advantage of the brightness potential, there should be, *first*, a means to set and maintain (for a frame time) the signal level for each element, *second*, a way to energize the phosphor elements at that level, and *third*, a method of arriving at the signal level of each particular element by a simultaneous excitation of the appropriate horizontal and vertical strips without affecting the stored level of any other element.

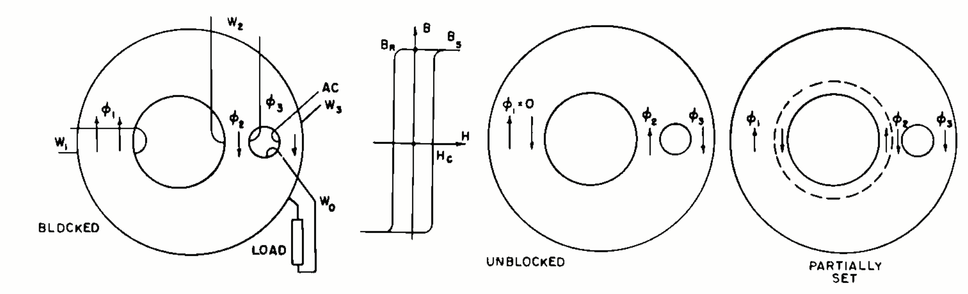


Fig. 3—Principle of two-apertured transfluxor.

USE OF THE TRANSFLUXOR

Obviously the crossed array already discussed does not meet the specifications for an ideal panel. However, a system has been described[4] that comes very close to formally satisfying the requirements. In this system a special magnetic core called a transfluxor is associated with each EL phosphor element, the elements again being identified with the crossings of arrays of conductors. The principle of operation of the transfluxor in controlling a panel of EL cells is well described in the original article as follows:

"In the two-apertured transfluxor shown in Fig. 3, the apertures are of unequal diameter and form three legs, numbered 1, 2, and 3. The core is made of a magnetic material exhibiting a nearly rectangular hysteresis loop, usually ferrite. Assume that at first a current pulse is passed through winding W_1 of sufficient intensity to saturate legs 2 and 3 in the direction indicated for the blocked state. The two legs will remain effectively saturated after the termination of the pulse since remanent and saturated inductions are nearly equal in square-loop materials.

"Consider now the effect of a sine-wave alternating current in winding W_3 producing an oscillating magnetomotive force (mmf) along a path surrounding the smaller aperture. Depending upon its sense, this mmf tends to produce an increase in flux in either leg 2 or leg 3, but since neither increase is possible because these legs are saturated, there is no flux change. The transfluxor in this state is said to be "blocked" and little induced voltage appears across the output winding W_0.

"Consider now the effect of a 'setting' pulse of current having a polarity opposite to that of the blocking pulse. This current applied to winding W_1 tends to reverse the flux direction of leg 1 of the blocked core. The magnetic field H produced decreases radially with distance measured from the center of the larger aperture according to Ampere's law $Hl = 4\pi X$, where l is the circumference of the flux path and X the mmf. Because a critical value of H is required in square-loop materials to produce flux reversal, the flux will reverse from the radius of the aperture out to a critical radius only. The amplitude of the setting pulse determines this radius and can be prescribed so that any desired portion of the width of leg 2 will reverse its direction of saturation, while the rest of the leg, as well as the more distant leg 3, remains saturated in the original direction.

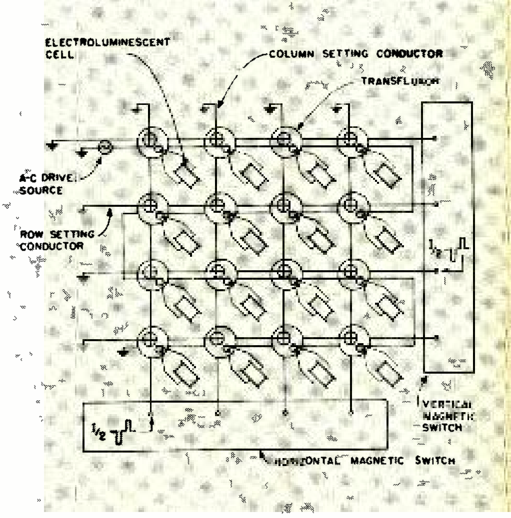
"After such a setting operation, the alternating current applied to winding W_3, at its first proper phase, will switch back the whole flux in leg 2 to its original direction of saturation and cause the flux in leg 3 to decrease by the amount that the flux in leg 2 increased, which is precisely equal to that initially 'set'. On the next phase of the alternating current, the flux of leg 3 will be switched back to its original direction and the amount of set flux will be transferred back to leg 2. On successive excursions the amount of flux set in will be transferred back and forth between legs 2 and 3, and a voltage will be induced in the output winding, the magnitude of which is proportional to the set flux and is therefore seen to be determined by the amplitude of the single setting pulse. Although the transfluxor is made of material which is always saturated in one or the other direction, continuous or 'halftone' control is possible because the output flux and voltage are determined by the critical radius, which can be varied continuously in a range.

"The simplest method of using a transfluxor to control an EL cell is to connect the cell directly to the a-c output of the transfluxor, using an output winding of a few turns to obtain sufficient voltage. An array of such transfluxor EL elements is shown schematically in Fig. 4. Each EL cell is connected separately to each transfluxor. The output apertures of all transfluxors are energized from a common a-c source.

"It is possible to set any transfluxor in an array independently of the others by using a coincident-current method of selection. To accomplish this, two setting windings are provided for each transfluxor. Shown in Fig. 4, these windings (indicated by single turn) are connected in series in two sets. One set is connected in series in the row direction and the other set in the column direction of the array. Current pulses of the correct amplitude applied simultaneously to one row and one column winding group will set only the one transfluxor at the intersection of the row and column lines, and leave all the others unaffected."

A 1200-element array containing 30 rows of 40 elements each was con-

Fig. 4—A simplified diagram of a display device made up of an array of two-apertured transfluxors driving electroluminescent cells. The driving power is supplied to all the transfluxors connected in series with a single source. Transfluxor setting currents are supplied in coincidence by magnetic switches.



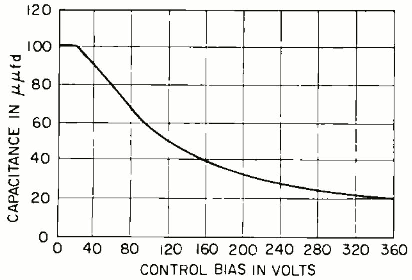


Fig. 5—Small signal capacitance of a ferroelectric capacitor as a function of control bias.

structed that measured 13 by 17 inches. To set the level of excitation of the elements, pulses of fixed amplitude were supplied to the column conductors and pulses of variable amplitude to the row conductors. Switching circuits were developed to scan the array in conventional television fashion using 15 frames/sec.

The display demonstrated the performance to be expected from the ideal signal storage at every element provided by the transfluxor. Outside of construction problems and onerous circuits, the main difficulty encountered was the mismatch between the relatively low impedance of the magnetic device and the relatively high impedance of the EL cells.

ELECTROLUMINESCENT FERROELECTRIC DISPLAYS

A much better impedance match was obtained in a different type of panel-display system known as ELF[5] (electroluminescent ferroelectric). In this system elemental capacitors provide high-impedance coupling to individual EL cells making up an array. The ferroelectric material used as dielectric has non-linear capacitance characteristics that permit the excitation applied to each EL cell of the panel to be determined by the charge on the associated ferroelectric coupling capacitor. The capacitance vs voltage characteristic of such a ferroelectric capacitor is shown in Fig. 5.

The operation of a single element in a panel using the simplest arrangement is described in the original article as follows:[1]

"An electroluminescent and a ferroelectric capacitor are connected in series with an a-c source which is called the light power supply, Fig. 6. Typically this source might be 200 volts-rms, 10,000 cps. In addition, provision is made for the introduction of a control potential. This is a unidirectional charge or voltage which, for purposes of explanation, might be supplied by a battery in series with an isolation resistance.

"Assume that the components in Fig. 6 are proportional so that with no control potential applied, the a-c potentials on the electroluminescent and ferroelectric cells are 150 and 50 volts, respectively. This corresponds to the "full-on" or bright condition for the element. If the control potential is now increased from zero, the capacitance of the ferroelectric body decreases. A larger fraction of the light power voltage appears across the ferroelectric and a smaller fraction across the electroluminescent cell. When the d-c control potential reaches 500 volts, the a-c voltage across the electroluminescent cell would be reduced, perhaps, 50 volts. This is the *off*, or dark, condition for the element. Dropping the excitation on a typical electroluminescent cell from 150 to 50 volts rms causes the brightness to diminish about a factor of 40 to 1.

"If, after a control potential is established on the capacitor, the control supply is disconnected, the control charge is trapped and causes the element to continue to emit at the pre-set brightness level. This is the storage feature of the screen. Storage time is primarily determined by ohmic leakage."

Microcircuit techniques have been developed[6] for constructing the combined ELF screen and signal distribution system, but instead of the simple circuit of Fig. 6, a bridge circuit is used to increase the control sensitivity. Screens as large as 8 inches by 4 inches have been constructed with a resolution of 256 elements per square inch. A brightness of 10 foot-lamberts with contrast ratios as high as 100 to 1 have been obtained. In one display system, information is distributed to the screen at a rate of 150 μsec per screen-line, with a frame storage time of 5 seconds.

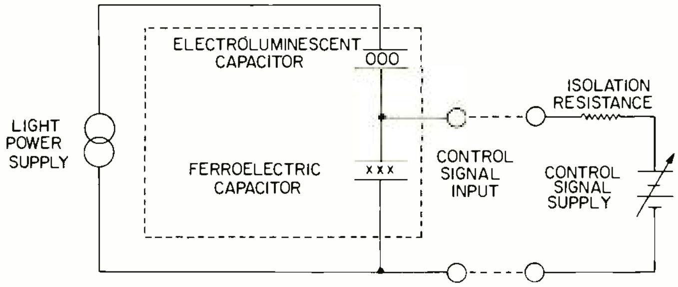


Fig. 6 — Equivalent circuit of the two component ELF element.

HAROLD B. LAW was born at Douds, Iowa, on September 7, 1911. He received the B.S. degree in liberal arts and the B.S. degree in education, both in 1934, from Kent State University, in Kent, Ohio. He received the M.S. and Ph.D. degrees in physics from the Ohio State University, Columbus in 1936 and 1941, respectively. In 1941, Dr. Law joined RCA at Camden, N.J., and in 1942 transferred to the David Sarnoff Research Center in Princeton, N.J. He has engaged in research on pickup tubes, and, more recently, on color kinescopes. Dr. Law was the joint recipient with Dr. E. G. Ramberg of the 1961 David Sarnoff Outstanding Team Award in Science for contributions to the science of electron optics. Dr. Law is a member of the American Physical Society, a Fellow of the IRE, and a Member of Sigma Xi.

Although much progress has been made with the ELF screen, realization of a practical display is made extremely difficult by problems associated with screen fabrication and feasible signal distribution. Essentially, the root of the problem is the attempt to control the input signals *at the screen* by means of electrical connections to the screen while utilizing a light source of very modest output compared to that of a cathodoluminescent phosphor source. Producing a picture in a nonvacuum device with this type of light source requires an ideal display, as defined earlier, or one in which every element emits light continuously at the level set by a scanning means until a new level is set. The attainment of a practical, nonvacuum, large-panel display with only a wire cable connection is beset with extremely difficult problems.

OPTICAL INPUTS AND PHOTOCONDUCTIVE CONTROL

Consider now what may be done if an optical input to the panel is allowed rather than requiring a cable connection to feed in an electrical input. One possibility is to make the large-panel display simply a projection screen on which the image from a particularly bright cathode-ray tube is projected. Severe requirements are placed on the cathode-ray tube in order to secure sufficient brightness at the screen. Special cathode-ray tubes are made for this purpose that operate with high voltage and efficient optical systems. Alternatively the Eidophor[8] projection system or storage type kinescopes[9] may be used. Another approach is to build a light-amplifying structure into the viewing screen itself.[7] The principle of operation of such a screen is illustrated in Fig. 7. A photoconductor (PC) is connected in series with an a-c voltage source and an EL cell. The a-c voltage applied to the EL cell, and therefore the cell brightness, depends on the relative impedance of the PC and EL cell. The PC impedance is lowered by the application of light. Modulation of the light falling on the PC, therefore, serves to modulate the brightness of the EL cell.

An efficient method of applying the PC-EL light amplifying principle to a panel display must take into account that in practice the PC material, usually CdS powder, strongly absorbs light, and that EL requires a-c voltage for operation while the PC performs best with a-c voltage. One of the best arrangements[10] is to groove the PC as indicated by the cross sectional diagram of a light amplifying screen shown in Fig. 8. Conducting lines on the grooved photoconductor are separated into two interdigital sets, each set being connected to one of the two bias supplies. If light strikes the photoconductive layer, as shown in Fig. 7, conductivity results on the surfaces of the grooves at the local area illuminated. The portions of the photoconductor and phosphor area corresponding to a single picture element are identified in Fig. 8 by the heavy lines. A very recent advance[11] is the application of these principles to a two-color-input, two-color-output, image-intensifier panel. The difference in spectral response of CdS and CdSe photoconductors is used in conjuction with two different color emitting electroluminescent phosphors. The PC and EL strips form essentially two interleaved and independent systems.

With proper spectral match to the photoconductor of the single-color amplifier, an integrated energy gain of about 200 is possible. However, the present CdS photoconductor has a decay time of the order of seconds. The highlight gains and long persistence of the present amplifier are potentially useful in slow TV and radar applications. For this purpose a bright, large amplified picture may be obtained by projecting a cathode-ray tube image on the amplifier.

The light amplifier is also sensitive in the near infrared (to about 900 millimicrons) and to X-rays. In both cases the amplifier can convert low-intensity radiation to the visible region to produce useful displays.

Sintered CdSe as the control element in a light amplifier would make possible improved gain and speed of response.[12]

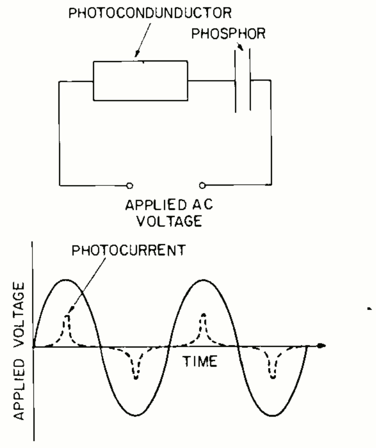


Fig. 7—A-C operation of single-element light amplifier.

Results on single elements show that moderate gains with high-output luminance are possible with speeds in a range suitable for moving pictures. Very high gains are possible if slow response can be tolerated. The problem is one of fabricating the sintered material in a form suitable for the amplifier.

A CHALLENGE

A property of the transfluxor and ferroelectric-controlled panels described earlier is that of retention or storage of an image when desired. A PC-EL panel may also be made to store by incorporation of feedback of light from the EL cell to its PC control. A limited amount of feedback can serve to increase the gain of the panel while under other conditions an element once excited by an input signal will remain on at full brightness.[7] In this latter case a problem is to devise a cell structure sufficiently "light-tight" to prevent adjacent elements from exciting each other to cause image spreading.

An excellent review of solid-state display panels with photoconductive control has recently been published[13] in which display panels representative of the present state of development are discussed. In this article it is also pointed out that ideally it would be desirable to be able to construct a solid-state panel that could satisfy the needs of a wide range of applications. For instance, if a display panel could amplify a light image, possess analog storage capabilities and be able to change its stored state rapidly, this single panel could answer essentially all the needs of a modern display device. However, it seems to the author, one should not lose sight of the ideal device as outlined in the beginning of this discussion. For that case a cable of wires leading to the large, flat-display panel would permit increased flexibility, in many installations, over a panel that required a projected optical input signal. The panel would, of course, need to be fast, bright and preferably capable of storage functions. Such a device still stands as a challenge today—a very difficult problem.

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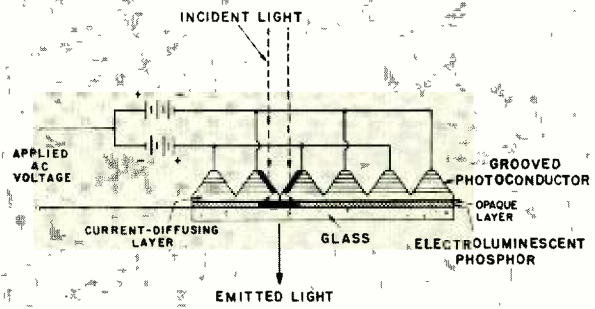
Fig. 8—Biased a-c operation of light amplifier.



FERROELECTRIC SCANNING OF ELECTROLUMINESCENT DISPLAYS

The basic element of this new scheme for scanning flat, electroluminescent display devices is a barium titanate ($BaTiO_3$) crystal. The crystal is activated to switch video information, lighting up the appropriate spot on the display device. To demonstrate the principle, an array of five lines, each having five elements, was addressed with this technique. The circuits, however, were capable of addressing an array consisting of 20 x 20 elements. Circuits are simple in construction, low in power consumption, and the number of elements can be further increased. Although this scheme looks promising, a number of problems will have to be solved before it can be utilized. The most important immediate challenge is to increase brightness of the display, especially those with increased numbers of picture elements.

by **MICHAEL COOPERMAN***
Advanced Development Engineering
RCA Victor Home Instruments Division

MICHAEL COOPERMAN received the B.E.E. degree from the City College of New York in June 1955. From 1955 to January 1961, he was with the Advanced Development Section of the RCA Home Instruments Division, Cherry Hill, N. J. His work has centered around the application of ferromagnetic and ferroelectric devices to television circuits and, more recently, the development of tunnel-diode circuitry and parametric amplifiers for operation at kilomegacycle frequencies. He is presently with the RCA Electronic Data Processing Division, Pennsauken, N. J. Mr. Cooperman is a member of the Institute of Radio Engineers, Tau Beta Pi, and Eta Kappa Nu.

In recent years RCA and others in the electronics industry have done a considerable amount of research aimed at developing solid-state display devices (See references 1-7, and articles by Haining, Hadley, and Law in this issue). Such devices might replace the cathode-ray tube for industrial-TV and military-display applications. Among the attractive features of a solid-state display are its small volume and its low weight for a given viewing area.

One of the most difficult problems encountered in the design of a flat display is to find a suitable means for scanning, i. e. distributing the video information at each instant to light up the appropriate spot on the panel. Schemes to accomplish this are usually complex, power consuming, and unsuitable for mass production.

It is the object of this paper to describe a scheme using ferroelectric materials for switching sequentially the video information to a flat electroluminescent panel. This scanning scheme is low in power consumption and suitable for mass production due to its simplicity. This paper also describes an experimental model employing this technique for scanning.

PRINCIPLE OF OPERATION

The basic circuit for using a ferroelectric material for sequential switching is shown in Fig. 1. The ferroelectric capacitor *(C_f)* uses a $BaTiO_3$ crystal for a dielectric. The characteristic of C_f is show in Fig. 2a by plotting the capacitor charge vs. applied voltage; this produces a hysteresis loop similar to that observed in magnetic materials. The hysteresis loop of Fig. 2a has been idealized in order to simplify the analysis of switching.

Let it be assumed, for the moment, that in Fig. 1, $E_b = 0$, and that C_f and R_f are proportioned so the sawtooth produces a negligible drop across R_f. Consequently, most of the sawtooth appears across C_f. The voltage drop across C_f produced by the sawtooth and the battery voltage is shown by curve 2 in Fig. 2b. As the sawtooth voltage goes through amplitudes *a,b,c,d,e,f*, and back to *a*, the hysteresis loop is traversed in the order *a,b,c,d,e,f,a*. As the hysteresis loop is traversed, the reactance of C_f is changed so that it is relatively high in the region *a* to *b* and *c* to *d* and relatively low from *b* to *c*. (The reactance is also changed in the region *d* to *a*, but this is of no interest here.) The ratio of high-to-low reactance can easily be made 100:1. The R_f and C_f are so proportioned that E_s sin ωt, whose frequency is high compared to that of the sawtooth fundamental and its harmonics, appears across R_f only during the time t_3 to t_4 corresponding to the interval b to c, when the reactance of C_f is low. It has been assumed in this analysis that the amplitude E_s is sufficiently small so that it swings over a small portion of the characteristic of Fig. 2a.

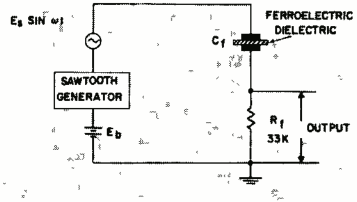


Fig. 1—Basic circuit for sequential switching.

When E_b is positive, the sawtooth voltage is shifted to the right as shown in curve 3 of Fig. 2b. This causes C_f to conduct earlier, namely from t_1 to t_2. When E_b is negative, the sawtooth voltage is shifted to the left, as shown in curve 1 of Fig. 2b. Under these conditions C_f conducts later, namely from t_5 to t_6. Thus the time of conduction relative to the sawtooth timing is a function of the d-c bias, E_b.

Actual photographs of the input and output waveforms of the circuit in Fig. 1 are shown in Fig. 3. The input consists of the sawtooth in series with E_s sin ωt. The output is a burst of E_s sin ωt. Photographs (a), (b), and (c) show the relative timing between the output burst and the sawtooth for positive, zero, and negative bias conditions. The negative spikes in the output waveforms are due to the conduction of C_f during the sawtooth retrace. The frequency of E_s would normally be made higher than shown in the photographs. Here the frequency was reduced so it could be observed cycle by cycle.

EXPERIMENTAL CIRCUITS

Line Scanning

An experimental circuit where this principle is used for sequential switching and scanning one line is shown in Fig. 4. This is essentially the same circuit as that of Fig. 1. Here, however, the sawtooth in series with E_s sin ωt is applied across five C_f-R_f combinations connected in parallel. These are biased so that the ferroelectric capacitors conduct in the sequence of the indicated num-

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*The author performed this engineering work during his employment by the Home Instruments Division, Cherry Hill, N.J.; he is presently with Electronic Data Processing Division, Pennsauken, N. J.

bers. Across each of the resistors is connected an electroluminescent cell, a device which lights up when an a-c voltage is applied. A typical brightness characteristic of an electroluminescent cell is shown in Fig. 5. As each C_f conducts, its corresponding electroluminescent cell lights up for the period of conduction. The five electroluminescent cells comprising a scanning line are triggered sequentially. If $E_s \sin \omega t$ is amplitude-modulated with video information, the brightness of each cell will be proportional to the instantaneous amplitude of E_s. Thus the information with which $E_s \sin \omega t$ is modulated is displayed as the line is scanned.

A more practical arrangement of the circuit of Fig. 4 is shown in Fig. 6. Here the individual ferroelectric capacitors are formed by using a single strip of ferroelectric material with one common connection. Each capacitor formed by the bottom connection and the common top conductor can be operated with essentially no interaction with the rest. In the actual experiment the bottom connections were spaced 1/16 inch apart from one another. The various bias voltages necessary for sequential switching are obtained from a bias distributor. The a-c impedance at the various taps of the bias distributor must be sufficiently low to prevent crosstalk between cells. This can be accomplished by making the resistors in the bias distributor small. The 4-k resistors used here were found to be quite satisfactory.

Horizontal and Vertical Scanning

Both horizontal and vertical scanning can be accomplished by using the circuit of Fig. 6 for horizontal scanning and another such circuit for vertical scanning. Such an arrangement is shown in Fig. 7. The H conductors are switched at a horizontal rate and the V conductors at a vertical rate.

Electroluminescent cells represented by equivalent capacitors are connected between sets of conductors. The voltage across each cell is the difference between the potentials of its intersecting H and V conductors.

For the purpose of illustration, it will be assumed that the ferroelectric strips are perfect switches, (i.e. when conduction takes place all of E_s is connected to the switched conductor.) If, for example, at a particular instant the H_3 and V_3 conductors are switched, then the potential across the cell connected between them is $2E_s = 80$ volts peak at that instant. The doubling of the voltage is due to E_s in the horizontal circuit being out of phase with E_s in the vertical circuit. At the same time all remaining cells connected to the H_3 conductor and V_3 conductor can have a maximum voltage across them of $E_s = +40$ volts peak and $-E_s = -40$ volts peak respectively. The electroluminescent cells have a typical brightness characteristic as shown in Fig. 5. It can be seen that a voltage change from 40- to 80-volt peak produces a brightness change of .32 to 7.5 foot-lambert. That is, a 2:1 change in voltage produces a 23:1 change in brightness which is sufficient to turn a cell on and off. With proper design, the cell between two switched conductors will light up and the remaining cells will appear dark.

Thus, as the H and V conductors are switched in sequence, scanning proceeds from left to right horizontally, and from top to bottom vertically. Information can be displayed by modulating E_s in the vertical scanning circuit, horizontal scanning circuit, or in both.

A more practical arrangement of the interconnection between H and V conductors and electroluminescent cells of Fig. 7, is shown in Fig. 8. It consists of a glass plate having a set of transparent V conductors printed on it. Next comes a layer of electroluminescent phosphor which is then covered by a set of H conductors. When an a-c voltage is applied between an H and V conductor, the phosphor at their interaction lights up. Due to the high resistivity of the electroluminescent phosphor, only the area sandwiched between the two intersecting conductors lights up. Such panels are available commercially.

PROPOSED CIRCUITS

Line Scanning

An alternate display arrangement using ferroelectric switching in conjunction with electroluminescence is shown in Fig. 9. A strip of glass is covered with a transparent conductor, a layer of electroluminescent phosphor, a layer of ferroelectric material, and a coating of resistive paint. At each end of the resistive coating is a conductor for contact with terminals a and c. This arrangement can provide continuous scanning of one line. The equivalent circuit of this arrangement is shown in Fig. 10. The principle of operation is the same as that of Fig. 6. Resistors R_t which represent the resistive coating provide the d-c potential distribution for sequential switching. These resistors are sufficiently small so that there is negligible a-c potential difference between the top terminals of C_f. The term C_f represents the ferroelectric capacitance, while R_f and R_2 represent the resistivity of the electroluminescent phosphor. The inductors L prevent the sawtooth and the a-c signal from shorting to ground.

The capacitor C prevents the d-c bias

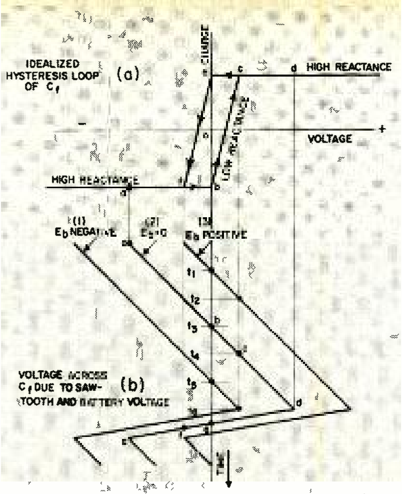
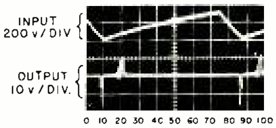
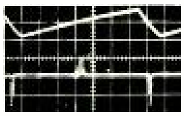


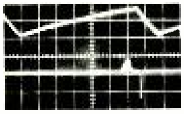
Fig. 2—Graphical analysis of sequential switching.



(a). BIAS $E_b = +100$ VOLTS



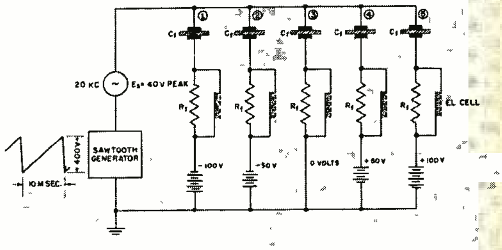
(b). BIAS $E_b = 0$ VOLTS



(c). BIAS $E_b = -100$ VOLTS

Fig. 3—Photographs of input and sequentially switched output waveforms of Fig. 1.

Fig. 4—Experimental circuit for a five-element scanning line.



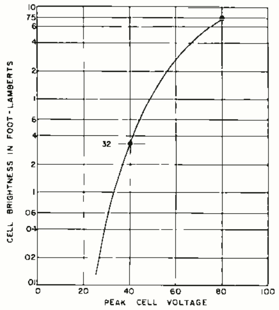


Fig. 5—20-kc sinusoidal excitation of electroluminescent cell.

from being shorted to ground. Thus the bias distributor circuit and the scanning circuit do not interfere with each other's functions. If, for the moment, R_2 is considered infinite, then the remainder of the circuit and its function becomes identical to that of Fig. 6. As the ferroelectric capacitors are switched, the a-c signal appears across their corresponding resistances R_f and continuous scanning of the strip results. The presence of R_3 does not alter the principle of operation, it merely provides some interaction between adjacent R_f resistors, thus limiting the resolution.

Horizontal and Vertical Scanning

A configuration for horizontal and vertical scanning is shown in Fig. 11. The horizontal strips with terminals *a*, *b*, and *c* are identical to those described in Fig. 9. The horizontal sawtooth and biasing are applied to each strip in the same manner. Terminals *b* are connected to a vertical scanner. This consists of a ferroelectric switch similar in construction and operation to that described in Fig. 6. The vertical sawtooth switches E_s to each R_f and corresponding scanning line in succession. The horizontal sawtooth switches all lines at the same time. However, only the line which receives E_s from the vertical scanner produces a visible scan. Here again information is displayed by amplitude-modulating E_s.

BRIGHTNESS LIMITATION

With presently available electroluminescent materials, about 60 volts-peak of continuous excitation is required to light up a cell. This voltage is in the order of magnitude obtainable with the scanning technique described. In order to produce a larger output, the thickness of the ferroelectric material and the amplitude of the sawtooth would have to be increased.

However, for a given excitation amplitude, the brightness is also a function of the portion of time during which a cell is excited. If five elements are scanned, then each element is excited for about one fifth of the time. For ten elements this time is about one tenth, etc. Consequently, as the number of elements is increased, the brightness for a given excitation voltage is reduced.

One method of increasing brightness is to have some external circuitry which would maintain the excitation of each cell once it has been briefly excited[5-7].

As electroluminescent materials with more brightness are made available, this problem will become less serious.

ACKNOWLEDGMENT

The author wishes to express his gratitude to his colleagues at Indianapolis, Princeton, and Lancaster for their support and cooperation. Particular thanks are due C. M. Sinnett and G. L. Grundmann, under whose supervision this work was done.

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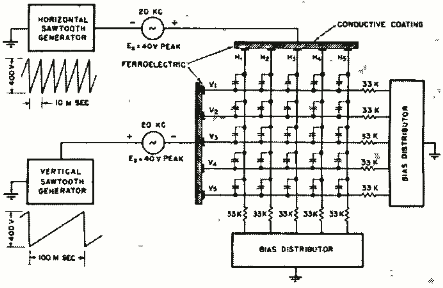

Fig. 7—Experimental circuit for horizontal and vertical scanning.

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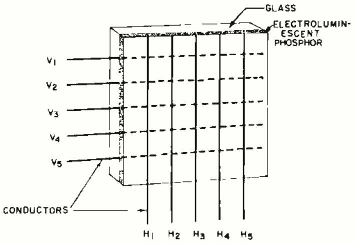


Fig. 8—Commercial electroluminescent panel for horizontal and vertical scanning.

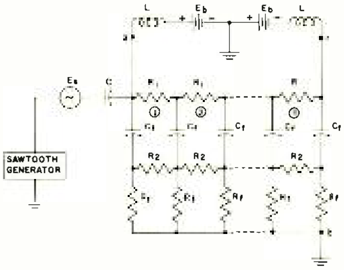


Fig. 10—Equivalent circuit for Fig. 9.

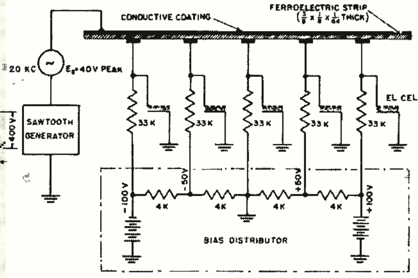


Fig. 6—Experimental circuit for a five-element scanning line.

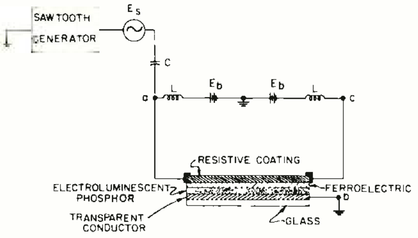


Fig. 9—Suggested construction for single-line continuous scanning.

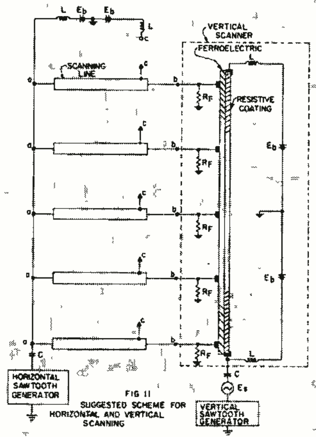


Fig. 11—Suggested scheme for horizontal and vertical scanning.

NEW THREE DIMENSIONAL SPATIAL DISPLAY

This three-dimensional display presents multiple targets in their true spatial relationships. It is completely independent of illusionary or two-dimensional stereovision techniques and may be viewed by observers from any position around the display. It has many applications in space navigation, satellite and missile displays, air-traffic control, and under-sea warfare and navigation.

by **M. J. CAMPANELLA, J. F. DELANY, and S. S. TOW**

Advanced Techniques Development Group
Missile and Surface Radar Division
DEP, Moorestown, N. J.

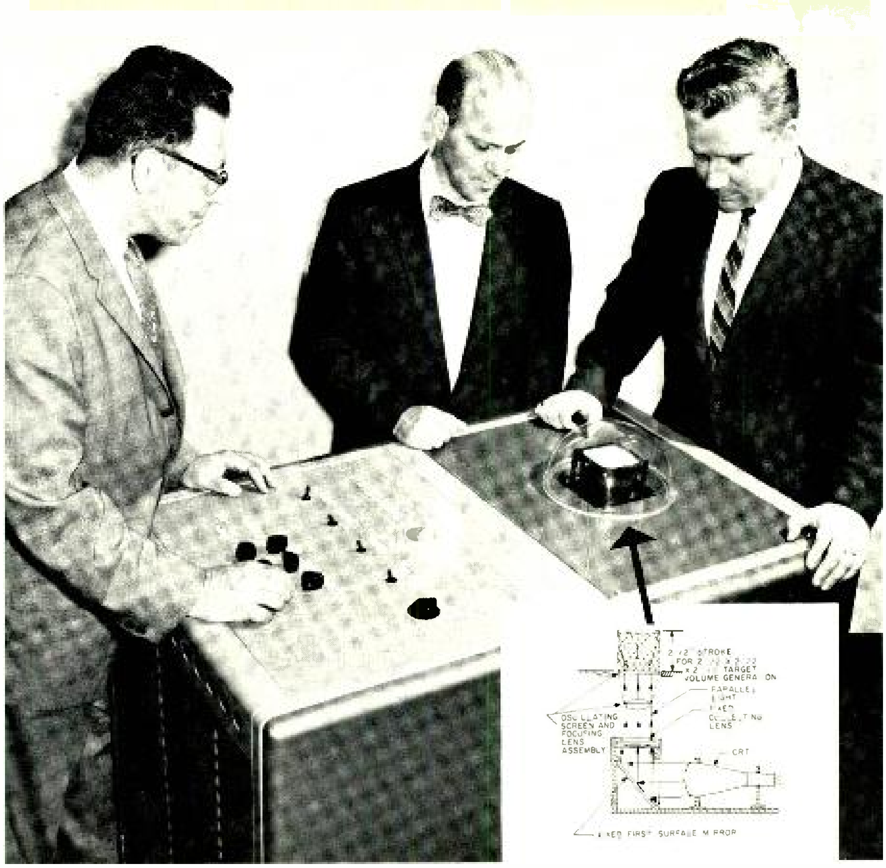


Fig. 1—The laboratory model of the 3-D display is demonstrated by engineer Seymour Tow (left), inventor of the balanced hypocycloid drive, to the co-authors, M. J. Campanella and J. F. Delany (far right) of the Advanced Technique Development Group. This display holds promise for air traffic control, undersea warfare, and space surveillance and navigation.

THE ADVENT of advanced target locating systems plus complex target situations has created a standing need for a means of spatially displaying target data in *true three dimensions*. Previous efforts usually encompassed a stereo technique whereby the observer is "fooled" into the illusion of three-dimensional space from a two-dimensional display. A recent RCA development, utilizing known principles other than stereo, demonstrated very effectively a technique for producing a true three-dimensional display.

An evaluation model (See Fig. 1), built to display targets in a space $2\frac{1}{4} \times 2\frac{1}{4} \times 2\frac{1}{2}$ inches, demonstrates to an observer, in a startling manner, the advantages of such a display. Spots of light representing targets may be positioned in space and made to move throughout the spatial volume of the display. The targets are visible, *without the aid of special glasses or other devices*, from any direction in a hemisphere above the horizontal.

The basic techniques, proven with the laboratory model, can be readily extended to create a larger display and color may be added to permit target sorting or grouping. Spatial reference patterns were included in the laboratory-model display through the use of fluorescent overlays, which were illuminated by an ultraviolet light source (not shown

J. F. DELANY received the BS Degree in M.E. from the Catholic University of America in 1951. Prior to graduation he was an engineer at the National Bureau of Standards, Wash., D.C. After graduation, he continued at the Bureau as senior mechanical engineer in the Main Instrument Division. In 1954, he entered active duty as a project engineer in the research and development program for the Periscopic Range Finder T-44. In 1956, he joined the Antenna and Radiation System Laboratory of Melpar, Inc., and was made Project Engineer in charge of the Electromechanical Antenna group; this work included such projects as design and development of a subsystem of the huge surface complex AN/GLR-1, design and development of beacon and telemetry antenna systems for the Project Mercury capsule, and TITAN ATLAS, and THOR re-entry nosecones Mr. Delany joined RCA in 1960 as Leader, Electromechanical Sub-Unit of Advanced Techniques Development, Moorestown Missile and Surface Radar. Here his activities have been concerned with implementation of a magnetohydronamics laboratory, development of correlation techniques and the development of the 3-D Radar Display. He is a Senior Member of the IRE and a Member of the American Ordnance Association.

S. S. TOW received the BME degree from the CCNY in 1941, and has done graduate work at Brooklyn Polytechnical Institute and Drexel where he is a candidate for the MSEE degree. In 1940, Mr. Tow was an engineer in the Ordnance Design Section, New York Navy Yard. He joined the Empire Designing Corp. in 1945, as a project engineer responsible for the design of automatic machinery, and worked with Greer Hydraulics Corp. as project design engineer. In 1949, Mr. Tow headed up the mechanical design of an automatic submarine depth-control system at Bendix Aviation Corp.; later, he had mechanical responsibilities at Reeves Instrument Corp. for the design of trailer and antenna elevator for the AN/MSQ-1A Mobile Radar System. In 1958, Mr. Tow joined RCA Missile and Surface Radar at Moorestown where he has worked on inplementation and coordination of the launch and checkout system for the Atlas Missile and Ground Hydraulic Checkout System. In 1960, he joined Advanced Technique Development as a senior member of the Electromechanical Sub-unit of the Applied Physics Unit; he has been responsible for the overall mechanical design of the laboratory model of the 3-D display and has applied for a patent on a novel balancing feature. Mr. Tow holds a Professional Engineer's License in New York State.

M. J. CAMPANELLA received a BSEE in 1949 from the University of Notre Dame and an MS in Applied Physics in 1950 from Harvard University. Upon graduation from Harvard, he joined the General Electric Co., Advanced Engineering Program to work on selected rotating engineering assignments. In 1951, he joined RCA where he has worked on many design and development aspects of radar and weapon-control systems. One of the major efforts of this period concerned advanced development of circuits for use with the RCA Radechon electrostatic storage tube and the development of an Aero Moving Target Indicator using electrostatic storage tubes. In 1954, Mr. Campanella moved into the area of digital data processing as applied to radar systems; he supervised the design and development of the digital data processing equipment used in Tracking Radar. He joined Advanced Technique Development in 1960, where he is Leader, Digital Handling and Processing; he is concerned with advanced control and data techniques. Since 1956, Mr. Campanella has been attending the University of Pennsylvania, taking graduate courses leading to a PhD degree. He is a Member of the IRE and AIEE, and a Registered Professional Engineer in New Jersey.

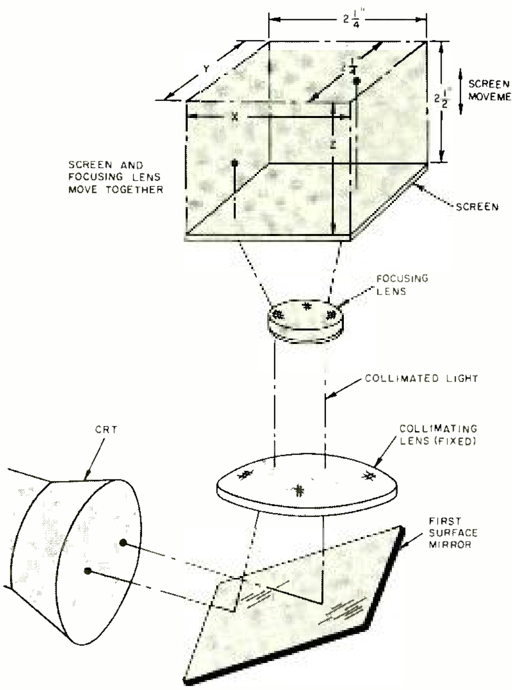


Fig. 2—Sketch of 3-D display showing principle of operation.

in Fig. 1). Additional reference points, lines, paths, or planes can be generated electronically, as the application or end item usage requirements dictate.

PRINCIPLE OF OPERATION

The technique developed for three-dimensional spatial projection utilizes the retentive ability of the eye to fix an image in space, when the image is rapidly and repetitively flashed at the same point in space. This principle of retinal persistence is used in television and motion pictures to create a similar effect in two-dimensional presentations.

In this technique, spots of light, positionable in X and Y, are generated using a cathode-ray tube (See Fig. 2). These spots are then projected through an optical system onto a translucent focal screen, which is oscillating rapidly in a direction perpendicular to its plane at a rate which may be varied from 10 to 20 cps. When the spots of light are "keyed-on" for a short duration in synchronism with the vertical motion of the screen, the spots appear to be fixed in space.

In Fig. 2, the optical image (the keyed spots on the face of the tube) is reflected by a mirror onto a fixed collimating lens. The collimated light is then focused, by the focusing lens, onto the screen. Since the focusing lens and the screen move together, the focal distance is constant. Thus both focus and magnification are maintained fixed for the length of travel of the focal screen.

DYNAMICALLY BALANCED HYPOCYCLOID DRIVE

A novel adaptation of a dual hypocycloid drive coupled with a unique, balancing system is used for the drive mechanism of oscillating lens and focusing screen. The mechanism, which is the basic mechanical element of the three-dimensional display, was designed to meet the following requirements:

1) Provide realistic velocity and acceleration characteristics for the screen and lens combination — to minimize peak torques and forces as well as to avoid shock.
2) Provide dynamic balancing throughout the operating range of 10 to 20 cps—to minimize vibration levels and to lower attendant noise.
3) Create a basically simple drive system—to minimize the extraneous elements required, to minimize the input power necessary to overcome friction and inertial forces, and to provide a mechanism which occupies a small volume for a given stroke.
4) Provide a symmetrical oscillating motion—to simplify the data input to the display.

The hypocycloid drive offers the best approach over many other types investigated, since it most nearly meets the established requirements. The method of balancing allows the driving elements to rotate continuously in one direction even though the focal screen oscillates.

The reciprocating motion is pure harmonic (sinusoidal). Theoretically perfect torque and force balancing are possible on a "rigid-body" basis, and in practice the operation very nearly approaches the values established in the detailed study. Another inherent advantage of the mechanism is that the drive motor sees a constant inertial load. A negligible amount of power is dissipated due to very low friction losses in the guides, bearings and gear train. The net result of the balancing system is that inertial torques are very nearly balanced out and the input power required to operate the mechanism is quite low (1/15 hp for the laboratory model). The over-all dimension of the mechanism in the direction of travel is only slightly larger than its stroke, which results in a quite compact package.

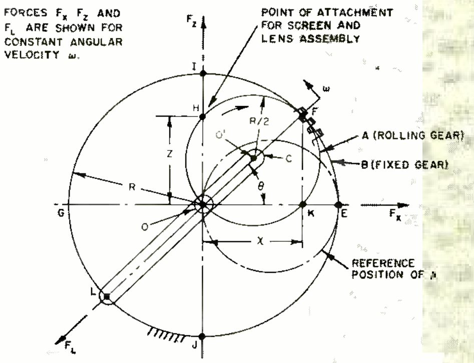
Fig. 3 illustrates a schematic representation of the drive mechanism. A planetary gear of pitch radius $R/2$ is driven by crank C so that it may be considered as rolling within a fixed internal gear of pitch radius R. It can be shown that any point on the pitch circle of A travels in a straight line but its X and Y position is sinusoidally related to θ. Only the fundamental frequency is generated, since the motion is pure harmonic. A very low noise level, which was barely audible to the human ear, resulted when the mechanism was operated at 20 cps. The gear teeth and bearings produce noise at higher harmonics but actual operation has shown that these higher order frequencies are still quite low in amplitude and not at all objectionable. However, this already-low noise level can be further reduced, if so required, by the application of conventional sound-absorbing materials.

The dashed circle in Fig. 3 indicates an initial reference position of the pitch circle A with reference to the pitch circle of B. Point E designates a common position on the pitch circle of A and B at the reference position. Point K represents a projection of point F on the horizontal line GE. Point K travels harmonically in a horizontal line between points G and E. Similarly, a point H on the circle will travel along the vertical line IJ.

The dynamics of the motion are such that the vector sum of the vertical force F_z and the horizontal force F_x is instantaneously counter balanced by the resultant vector F_L when suitable masses are attached to the points H, K, and L. The force F_z results from the screen-lens assembly attached at point H, and is counteracted by the reactive forces of masses located at points K and L. If the masses at K and L are made equal to the screen-lens assembly, the vector sum of F_x, F_z, and F_L becomes zero. Despite the fact that F_z and F_x vary sinusoidally as a function of time, the net force effect at point O is always zero. The mass force system is dynamically balanced throughout its complete cycle so the system is independent of the operating frequency selected.

The drive mechanism developed re-

Fig. 3—Balanced hypocycloid drive schematic.



CRANK "C" DRIVES GEAR "A". ANY POINT ON PITCH ◉ OF "A" (SUCH AS "H") TRAVELS IN A STRAIGHT LINE. "H" TRAVELS BETWEEN POINTS "I" AND "J".

sults in a very compact mechanism for any specified stroke or excursion. The oscillating assembly is dynamically balanced through a variable-frequency range; vibration and noise are minimal, and power requirements are very low.

DATA HANDLING

Many 3-D display data-handling problems encountered are independent of the type of sensor used. For purposes of discussion it is assumed that the data is obtained from a radar sensor. A block diagram of how the display would be used with a three-dimensional radar is shown in Fig. 4. Reference to this figure will facilitate understanding the comments which follow.

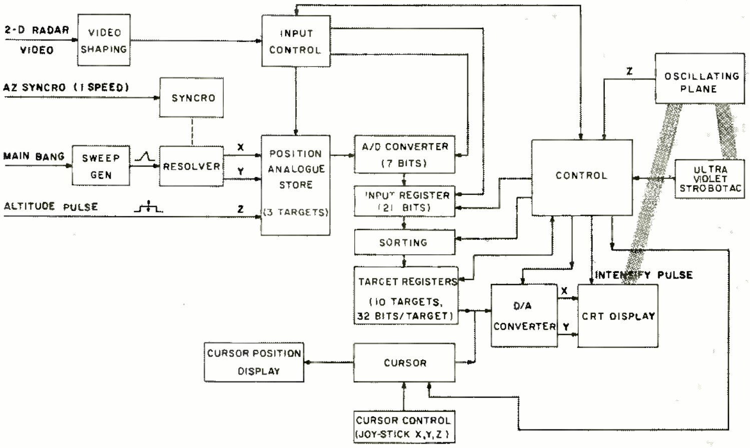


Fig. 4—Block diagram of 3-D radar display for an air height surveillance radar.

To obtain the effect of persistence of vision, the targets must be displayed on the oscillating plane at a rate much higher than that of incoming raw radar data. Oscillating rates of 10 to 20 cps (600 to 1200 cpm) are used in the display, whereas most radar scan rates are in the order of 3 to 60 rpm (or 1/400 to 1/10 as fast). Consequently, the electronics within the over-all display must provide storage for the data and must simultaneously but independently synchronize to the two actions: 1) the acceptance of incoming raw radar data; and 2) the provision of radar data to the display proper. This dual synchronization is accomplished by means of a memory in which the coordinates of each target, along with a time tag, are stored.

The position of the oscillating plane is continuously monitored using a position-to-digital encoder. As the plane reaches each elevation level, the *X-Y* positions of all targets at that level are sequentially but very rapidly sent from the memory to the deflection plates of the cathode-ray tube, via digital-to-analog converters. An intensifying pulse is applied to the cathode of the cathode-ray tube for each target, following the decoding of its *X-Y* position in the converters. As a result, a spot of light is generated corresponding to the *X*, *Y*, and *Z* coordinates of the target. By displaying the spot repeatedly and rapidly persistence of vision makes the spot appear in space.

In retrieving targets from the memory (target registers), a check is made of their time tag. If it exceeds a pre-set level, the target is rejected (not displayed and not perpetuated in the memory). Otherwise the target position is passed along to the cathode-ray tube and displayed. By varying the preset time level, the target position from several previous scans of the radar may be displayed and in this way easily produce a "target trail."

Targets are read into the memory whenever it is not engaged in sending targets to the cathode-ray tube. The position of each observed target is encoded using the data received from the radar at a pulse repetition frequency. As the memory becomes available, the target positions are read in. A time tag is assigned at the time of read-in, which later is used to indicate the "age" of the particular target position.

Since many returns will be received from one target during one scan of the radar antenna, it is necessary that a sorting be done before storing a specific target in the memory to ascertain if the target is already there. In the display illustrated by Fig. 4, the sorting is accomplished by comparing an incoming target with the coordinates of targets already in the memory. If an agreement is found, the incoming target is placed in that particular memory location; otherwise the incoming target is given a new location.

An electronic cursor may be included in the display if desired. When included, it permits the positioning in *X* and *Y* of a vertical reference line whose height (*Z*) is adjustable. With it, quantitative readout of the position of any target may be easily obtained by an operator. The cursor may be controlled with knobs or a "joy stick."

REFERENCE PATTERNS

Extremely bright, colored reference grids, and/or other special patterns are obtained in the laboratory display by means of special transparent ultraviolet overlays attached to the oscillating focal plane. The desired pattern is painted on the overlay using fluorescent paint. As the focal plane oscillates, an ultraviolet lamp is strobed at specified heights which causes the paint to fluoresce. The effect gives patterns in space which may be used as references for the targets being displayed.

APPLICATIONS

The three-dimensional display described in this article can be used to display any situation where information from sensors covers three spatial dimensions. In particular, it is especially attractive for 3-D radar systems, especially those used for area (volume) surveillance.

Many radar surveillance systems used for control of both military and commercial air traffic have height data available in addition to planar *X-Y* position information. Ground-control intercept systems also have height data as part of their output. The use of a 3-D display can greatly aid the human operator problems of air-traffic control and air intercept control.

Certain single-target systems (such as tracking radars) can also use the display to great advantage when spatial references are included as part of the display. An example is the availability in real time, and with operator ease, of the spatial position of missiles and rockets during flight.

Another application of the single-target display is its use in an aircraft cockpit as a pilot aid. The inputs to such a display could be from the aircraft's various navigational position inputs. Reference information showing various air routes, approach patterns, and glide paths in three dimensions could be shown on the display. A similar application would be the display of a spacecraft's position in three dimensions, using the earth and other planets as references. The display might also be used on the earth to show the position of one or several space craft or satellites in space.

THE TR-22
. . . RCA's Transistorized TV Tape Recorder

by **A. H. LIND, Mgr.**

Electronic Recording Products Engineering
Broadcast and TV Equipment Division
IEP, Camden, New Jersey

THE ELECTRONIC ART during the past decade experienced a revolution as solid-state components were first applied in military and data processing equipment and later in other branches of the wide electronic field. Today, long-established product lines are affected by the new devices. Broadcasting networks, for example, are now clamoring for solid-state equipments and, in some cases, have stated their intention of switching to completely transistorized broadcasting systems. Thus, it is not really too surprising that RCA recently announced a transistorized TV tape recorder, only three years after introduction of its electron tube model.[1] Although the experience gained in these first three years of TV tape recording has been invaluable, nevertheless, the new transistorized version, the TR-22, represents a departure from conventional broadcasting equipment in both appearance and engineering design.

NEW DESIGN BASED ON HUMAN ENGINEERING

By contrast with previous recorders, the TR-22 is a striking machine. In addition to the achievement of a new level in performance, some of its salient characteristics are: smaller size; single-package machine; lighter weight; power consumption substantially reduced and easier to operate than previous recorders. As shown in Fig. 1, the tape transport is centered in the recorder package and arranged with the supply and take-up reels horizontally oriented. The transport is mounted in a plane 45° from the vertical. This orientation was selected after an extensive study of the human engineering elements involved in operating tape recorders. There are two control panels, one mounted on each side of the transport; the left one the *record control panel*, the right one (Fig. 2) the *playback control panel*. Both panels contain the necessary pushbuttons for the respective operation, i.e., *record* and *playback*. Associated control amplifiers likewise are placed on their respective sides under the control panels to add to operating convenience. The only control common to both panels is the *stop* pushbutton. As may be seen in Fig. 1, the picture, sound and video waveform-monitoring facilities are mounted in the housing at the top of the recorder. All monitoring for operational purposes, and a large portion of the monitoring convenient for testing and troubleshooting, are provided by the high-quality 14-inch picture monitor, the waveform monitor, the volume indicator and the loudspeaker sound monitor. The row of pushbuttons along the lower edge provides input switches for each of the monitor units; it is thus possible to check very quickly a multitude of signal points to reassure an operator of proper operation.

The monitoring cabinet can be removed from the basic recorder if desired and either mounted elsewhere as a unit, or the individual components may be mounted in the manner of the user's choice. A number of indicator lights are visible at the top of the transport panel immediately below the monitor cabinet. These indicators serve two purposes: those on the right indicate the mode of operation of the machine, and those on the left are warning lights that indicate malfunction of the associated part of the machine. Information displayed by these indicator lights clearly reduces the possibility of operator error and is an aid in quickly localizing malfunctions should they occur.

The lower part of the recorder houses the majority of the transistor circuits, as well as the power supplies, air blowers, and pumps. Keyed, modularized construction of the transistor circuits has been provided to allow easy servicing, with module extenders and test points available in either operative mode. A bank of the transistorized modules with the required set-up adjustments is shown in Fig. 3.

The video headwheel panel assembly (Fig. 4), as in the late tube models[2], uses air-film bearings. This technique of air lubrication makes it possible to achieve very smooth rotation of the video headwheel.

OPERATION OF THE TR-22

The TR-22 Recorder, as most other TV tape recorders presently in use around the world, uses transverse-track recording. The basic functions of such a TV tape recorder are shown in Fig. 5. Only the block labeled *monitoring facilities* uses vacuum tubes. The *video record* and *video playback* blocks include FM and r-f circuits, as well as video circuits, since the signal recorded on the tape is a frequency-modulated radio-frequency carrier. Because four video heads are used, portions of this circuitry are present in quadruplicate. The *audio record* and *playback* circuits perform functions very similar to those well-known for audio tape recorders. The three servomechanisms which control the headwheel speed of rotation, the vacuum guide positioning and the capstan speed and phase are associated in application and performance. Of the three servos, the headwheel servo is the most demanding in performance. Elaborate interlocked control circuits are required to perform the many functions required for operation modes, while the requirements for power supplies are conventional for the broadcast class of electronic equipment. Picture and waveform monitoring of the video signal on the 14-inch monitor and sound monitoring by appropriate metering circuits and loudspeaker reproducers is conventional and typical.

Electrical signals occur in the recorder over a wide range of frequencies and power levels. Frequency ranges from d-c to 55 megacycles. The signal levels range from microvolts, in the case of the video playback-head output, to approximately 60 watts, the power output capability of the motor drive amplifiers.

SERVOMECHANISM CIRCUITS

There are many new, interesting circuits in the TR-22. It is not practical to attempt detailed descriptions of any of them here, but it is feasible to discuss the approach to the new servomechanism circuits. A functional block diagram of the headwheel and capstan servos in the *playback* mode is shown in Fig. 6. In the *record* mode of operation, the two servos control the speed and phasing of the

A. H. LIND received a BSEE in 1946 and an MSEE in 1949 both from the University of Wisconsin. He joined the Broadcast Studio Engineering staff of RCA in 1946. Except for the academic year 1948-1949 which he spent at the University of Wisconsin on an RCA Fellowship, he has worked in the field of studio television and audio equipment. In 1953, he became Manager of Audio and Mechanical Devices Engineering, RCA Broadcast Studio Engineering Section. In 1960, Mr. Lind was appointed Engineering Manager, Electronic Recording Products, IEP Broadcast and TV Division. Mr. Lind is a member of Eta Kappa Nu, Tau Beta Pi, Franklin Institute, IRE, and SMPTE.

headwheel so as to properly record the video information, and also control the longitudinal speed of the tape by the capstan so as to record the video and associated longitudinal tracks at a uniform rate. To accomplish this, the headwheel motor is locked in phase and speed by comparison of the 240-cycle tonewheel pulse, which is derived from a magnetic tone-wheel on the motor shaft, with a 60-cycle field rate pulse which is phased with respect to the vertical interval of the input signal to cause vertical sync to be recorded at the center of the video track during which it occurs. The capstan motor is driven synchronously with a 60-cycle signal that is derived from the 240-cycle tone-wheel pulse generated by the headwheel shaft rotation; thus a very close lock occurs between the headwheel motor rotation and the capstan rotation during *record*.

The functions of the servos during *playback* are more complex. The ultimate objective is to deliver a video signal at the output of the recorder which is exactly synchronous with the sync signal from a local synchronizing signal generator. In addition to establishing proper tracking of the video heads on the recorded video tracks in playback, the capstan servo must function to select the proper video track for the video head to play back the vertical sync signal at approximately the right time with respect to the local sync signal. Once this is accomplished, the headwheel servo must phase the wheel to precisely synchronize the tape vertical sync signal to the local vertical sync signal.

The capstan servo is shown in the lower third of the diagram. It has three input signals:

1) The control track signal, which is a 240-cycle signal, from the tape.
2) A frame pulse, which is a 30-cycle signal, generated from an externally supplied local sync signal.
3) A tape-signal frame pulse, which is a 30-cycle signal, obtained from the tape video-playback circuits.

The philosophy of operation of the capstan servo is quite different from that followed in earlier recorders. While a 240-cycle sine wave is recorded on the tape control track, as is standard for transverse video recording, the error detection is accomplished at a 30-cycle or frame rate. Since the response of the capstan servo is relatively slow, a 30-

Fig. 1—The author A. H. Lind, threading tape through the headwheel assembly of the new television tape recorder, TR-22.

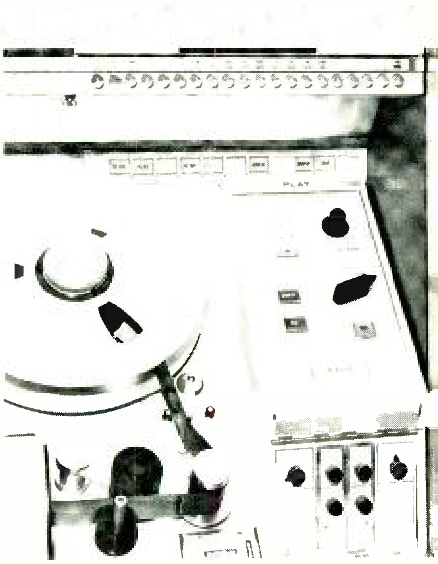


Fig. 2—Closeup of the *playback* controls on the right-hand side of the TR-22 recorder; similar controls are provided on the opposite side of the recorder for the *record* mode.

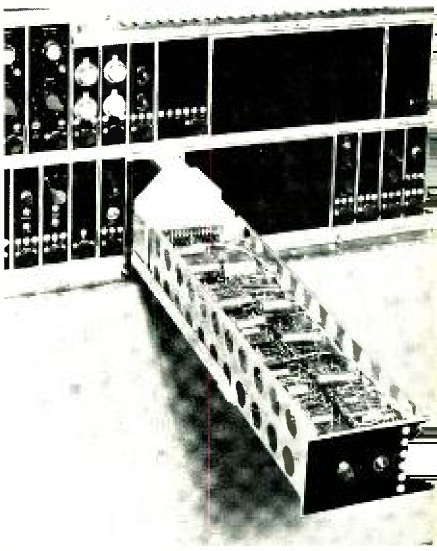


Fig. 3—Modularized transistor circuits.

cycle sampling rate is more than adequate. Further, it has been found that the 30-cycle error-detection circuits permit lock-in and hold-in performance over a wider frequency range than is possible at 240-cycle rates. The 240-cycle control-track signal from the tape is first divided by suitable binary counters to a rate of 30 cycles per second. This 30-cycle pulse is compared with a 30-cycle frame pulse which is derived from the local sync signal. The error signal resulting from the comparison is used to frequency modulate a 120-cycle oscillator. The output of this oscillator is divided by two and, in the process, two 60-cycle waves are generated which are 90° apart in phase. These two quadrature 60-cycle signals are then amplified in power amplifiers to drive the two-phase synchronous capstan motor. The lock-up between the control-track signal and the 30-cycle frame pulse is accomplished very quickly and prior to the time the vacuum guide is energized to cause video head contact with the tape. After this much of the servo has locked, the locked-in status is sensed by the lock-in sensor circuit. This sensor circuit causes a gate circuit to permit a 30-cycle frame pulse to pass. This frame pulse is derived from the tape-playback vertical-sync signal and is present after the vacuum guide closes if a signal is present on the video tracks. The tape-signal-derived frame pulse causes the eight-to-one frequency divider to be reset to its pulse-counting start condition. If the capstan servo is phased such that the video track containing vertical sync is occurring at the same time as the local frame pulse, the reset action coincides in timing with the normal eight-to-one divider operation and the servo continues to function with no disturbance from the tape frame pulse. If this condition does not exist, the 30-cycle pulse output from the eight-to-one divider is shifted in phase following the reset action of the tape frame pulse. The resulting error from the phase detector will cause the modulated oscillator to feed speed change information to the capstan motor. At the same time, the lock-in sensor circuit will close the gate, thus preventing further reset action from the tape derived frame pulse. This gating effectively keeps noise from resetting the eight-to-one divider. The speed change of the capstan will cause "slipping" of video tracks until a tracking lock-up is again achieved. When the servo is again locked, the lock-in sensor opens the gate and a comparison is once again made between the tape frame pulse and the local frame pulse. In the event the two pulses do not coincide, the cycle of resetting the eight-to-one divider and the consequent action will be repeated. In general, only one measurement is required to achieve proper phasing of the capstan servo.

Fig. 4—Headwheel assembly of the TR-22.

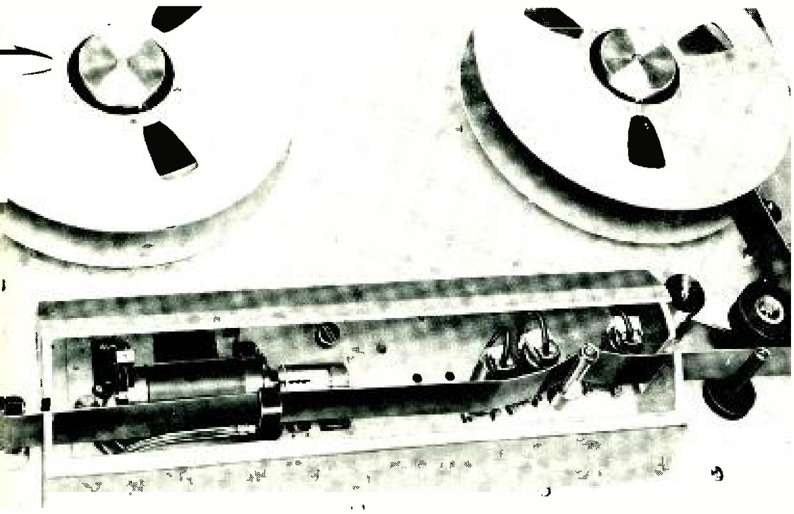
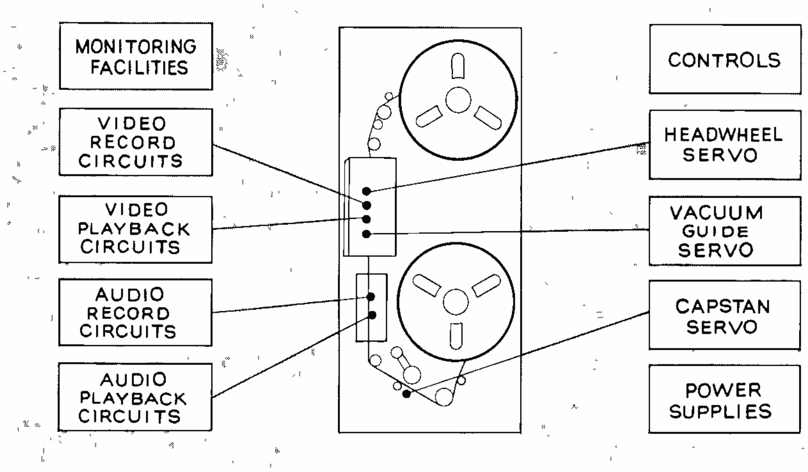


Fig. 5—Transverse-track TV tape recorder.



Once the capstan servo phasing is established, a more precise phasing between the local sync signal and the tape sync signal is accomplished in the headwheel servo, which has five input signals:

1) The tone-wheel signal, which is a 240-cycle signal generated by a magnetic tone-wheel on the shaft of the headwheel motor.
2) A field pulse, which is a 60-cycle signal, generated from an externally supplied local sync signal.
3) A horizontal-drive pulse, which is a 15,750-cycle line-rate signal, generated from an externally supplied local sync signal.
4) A tape-signal field pulse, which is a 60-cycle signal, obtained from the tape video playback circuits.
5) A tape-signal horizontal-drive pulse, which is a 15,750-cycle line rate signal, obtained from the tape video playback circuits.

When the recorder is started in the playback mode, the headwheel servo is connected so that the "tone-wheel" loop is operative. In this mode the tone-wheel signal is compared with the field pulse which is derived from the local sync signal. The headwheel motor is driven by power amplifiers which are supplied a 480-cycle signal that is amplitude modulated to control the motor speed. When the motor reaches a speed of 240 rps, the output of the phase detector circuit (that compares the tone-wheel pulse to the reference 60-cycle signal) reaches a stabilized condition. This loop of the servo brings the headwheel motor to the correct nominal speed. A supplementary loop, the *tape vertical alignment* (TVA) loop, contains a second phase detector that compares the tape sync vertical signal with the 60-cycle reference signal. The output of this phase detector controls a pulse delay circuit (TVA) which establishes the timing of the 60-cycle reference pulse that reaches the first phase detector. The action accomplished in this supplementary loop is that of causing the tape vertical signal to be aligned with the local sync vertical signal. The accuracy with which this is accomplished is to bring the tape vertical signal to within less than one TV line of precise coincidence with the local vertical sync signal. At this point the lock-in sensor associated with the TVA phase detector recognizes a working lock of the TVA loop. It then switches to a second mode of operation in which the horizontal sync signal being played back from tape is compared to the horizontal sync from the local synchronizing signal source. This precision phase-detection loop then controls the headwheel motor to maintain a precise relationship which is the reference. The tight servo control that results has been named the *Pix-Lock* system.

RECORDER CONTROL CIRCUITS

The recorder control circuits utilize transistors and semiconductor diodes for almost all of the logic and memory functions. A simplified diagram of the recorder control circuits is shown in Fig. 7. The blocks labeled *wind*, *standby*, *play*, *set-up*, *cue-record*, *audio-record* and *master-record* represent transistor bistable flip-flop circuits. These circuits are used to "remember" the mode of operation selected after the manually operated momentary-contact pushbuttons are released. When a pushbutton such as the *wind* button is depressed, a trigger signal is passed to the *wind* flip-flop memory to cause the *wind* flip-flop to be turned *on*. It will stay in this condition until one of the other pushbuttons is depressed or power is removed from the machine. In the *on* condition, the bus at the lower right of the block is energized and supplies a sensing signal to the interlock circuits shown in the block at the right of the diagram. In the event that any pushbutton other than *stop* is depressed, so that a second memory flip-flop is triggered, the signal on the sense bus is increased to the point where the interlock circuits will send a release signal back to all memory flip-flops, thus restoring them to the *off* condition. This clearing action occurs in a matter of microseconds. Thus the memory flip-flop associated with the depressed pushbutton will restore itself to the *on* condition before the button is released. Once the *wind* memory flip-flop is in the *on* condition, its output bus will energize the diode logic matrix shown in the lower areas of the diagram. In this case the *reel motors wind* circuit and the *reel brake solenoids* will be energized. Since it is desirable to make it necessary to push the *stop* pushbutton switch prior to selecting any other mode of operation, inhibit circuits are used. These circuits are shown in the block at the left of the diagram. The *wind* output bus will energize inhibit circuits that in turn will prevent any other memory flip-flop from being triggered until the *stop* switch is depressed to restore all memory flip-flops to the *off* condition. As a further guard against possible damage, should several pushbuttons be depressed simultaneously, the power to the pushbutton switches is connected in series with the normally closed side of the switches. Thus, the lowest-ranking mode will always take precedence.

The output busses from the diode logic matrix energize transistor driver circuits in cases where solenoids are used to perform the mechanical control function. In other cases, the output busses energize relays that are located within the circuit modules or near the associated motors.

CONCLUSION

The extensive use of transistors in the TR-22 TV Tape Recorder circuit design has resulted in increased performance and reliability at a 50-percent reduction in power and a 50-percent reduction in floor space and weight, thus increasing mobility in field use, while also enhancing studio installations.

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Fig. 6—Headwheel and capstan servos, the "Pix-Lock" system.

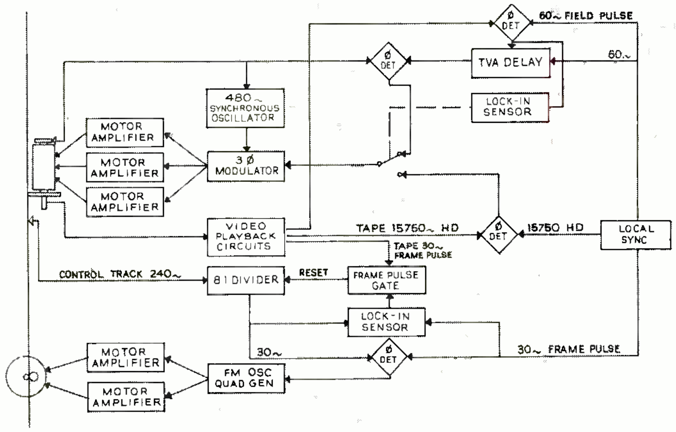

Fig. 7—Basic recorder control circuits.

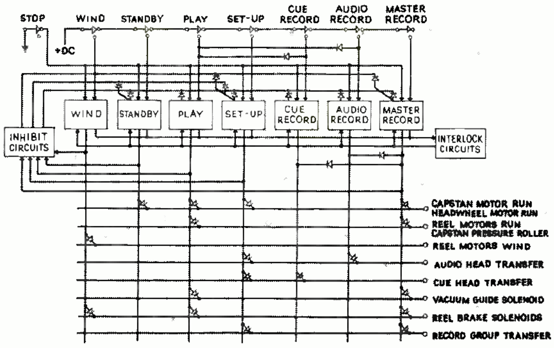

Fig. 1—EDP engineering and production, Natick, Mass.

Fig. 2—EDP engineering and production, Palm Beach Gardens, Fla.

A LOOK AT RCA's EDP ACTIVITIES

by **T. I. BRADSHAW**

Electronic Data Processing
Cherry Hill, N. J.

. . . In Florida, bulldozers attacked a 115-acre plant site. . . . In Massachusetts, workmen put finishing touches on a new industrial building. . . . In Washington, D.C., New York City, and Chicago, big vans unloaded computer equipment. . . . In Cherry Hill, N. J., a new EDP Headquarters was established. . . . In a score of other cities, from Hartford to Los Angeles, other important EDP events took place. All this activity, and more, has marked the **RCA Electronic Data Processing Division's** mushrooming growth in a little over two years to a multi-plant operation involving hundreds of engineers. From its original Camden location, the Division has spread to its current new headquarters at Cherry Hill, N. J., with other major plant locations in Camden, Natick, Mass., and Palm Beach Gardens, Fla. Other major RCA Divisions are involved in important activities in computer research and in development and manufacture of computer components and materials. In addition to these and the many EDP regional offices across the country, RCA Data Processing Centers have been established in Cherry Hill, San Francisco, Washington, D. C., Chicago, and New York City to provide computer services for commercial needs large and small. Additional facilities are planned, nation-wide, to keep pace with RCA's growth and success in Electronic Data Processing.

RCA HAS BEEN involved with the development of computing systems since the early 1940's, producing specialized types of electronic computers for the Armed Forces during and after World War II. The earliest RCA venture in the field of commercial electronic data processing resulted in the giant installation for the Army's Ordnance Tank-Automotive Command (OTAC) at Detroit. That system, utilizing vacuum tubes, for more than five years has been handling literally millions of facts and figures on inventory for OTAC installations around the globe. Ensuing years saw the completion of some special-purpose commercial data-processing equipment.

1958 — THE RCA 501

Then, in December 1958, the RCA 501 was announced — the first completely transistorized, business-oriented data processing system. By using solid-state devices, the RCA 501 requires minimum floor space, and economizes on air conditioning and electric power. Its modular design allows additional peripheral equipment as the need arises. A number of unique design factors quickly brought

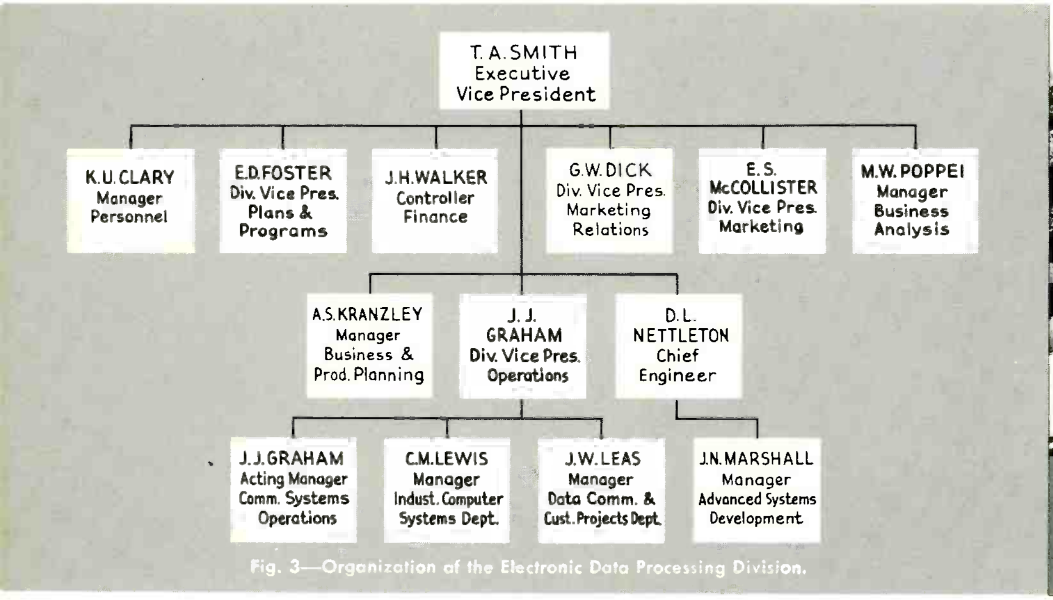

Fig. 3—Organization of the Electronic Data Processing Division.

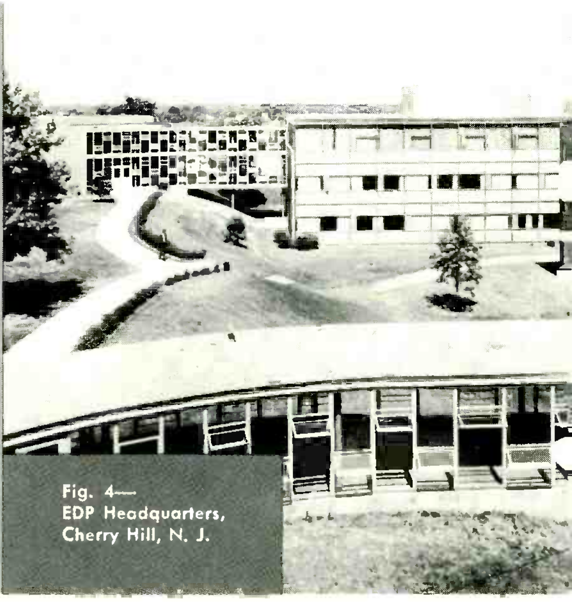

Fig. 4—EDP Headquarters, Cherry Hill, N. J.

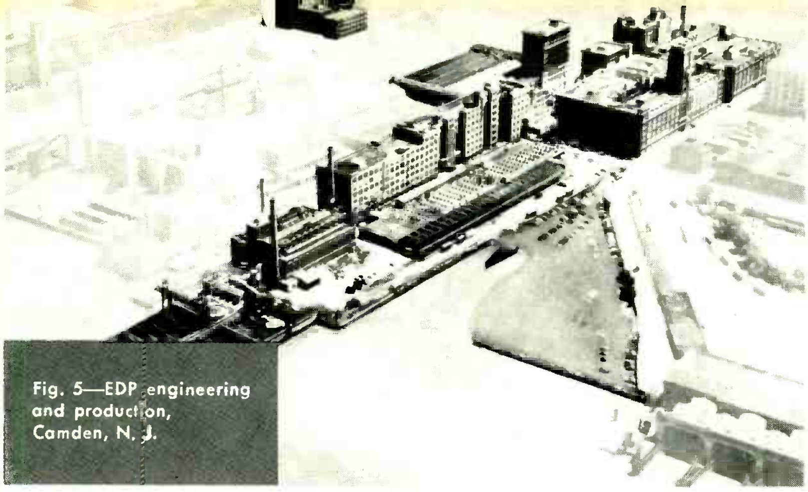

Fig. 5—EDP engineering and production, Camden, N. J.

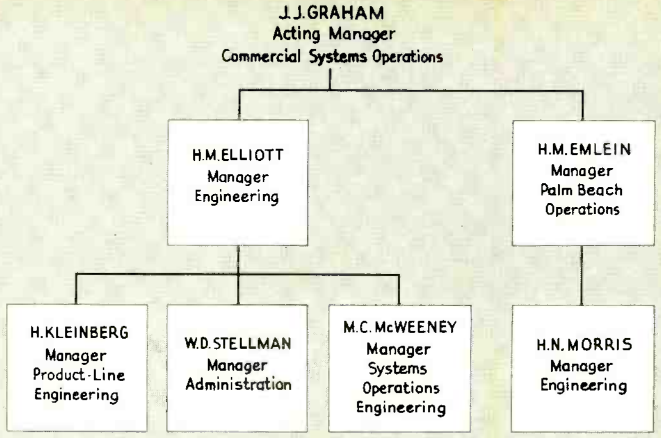

Fig. 6—Commercial Systems Operations Engineering.

the RCA 501 to favor—including a variable-length recording technique for savings in magnetic-tape requirements and machine time, the ability to operate on data whether the tape is being run forward or in reverse, and a time-sharing electronics system permitting several simultaneous operations.

Today, this medium-scale "workhorse" of the RCA data-processing product line is serving such major insurance firms as the New York Life Insurance Company, Travelers in Hartford, Connecticut, and State Farm at Bloomington, Illinois. Other typical RCA 501 system applications include: handling the records of the U.S. Air Force's reserve manpower bank; around-the-clock use at the Scott Air Force Base, Belleville, Illinois; helping the New York Telephone Company speed delivery of millions of directories; doing bookkeeping and billing for public utilities, including the Atlantic City Electric Company and the Niagara-Mohawk Power Company; and handling paperwork for industrial concerns, including Crucible Steel Company, General Tire and Rubber Company and the Owens-Corning Fiberglas Corporation.

1959 — THE RCA 110

In September 1959, the second member of the RCA transistorized computer systems was announced—the RCA 110 Industrial Control Computer, designed for computer coordination of manufacturing activities in automated industrial operations. The RCA 110 combines the advantages of magnetic-core high-speed memory and magnetic-drum memory storage. The computer is supplied its work program in a new, simplified order code; on the basis of these initial instructions. the computer can automatically set up its handling of a given control task.

1960 — THE RCA 301 AND 601

In 1960, two more new RCA data-processing systems were introduced—the compact RCA 301, and the large-scale, powerful RCA 601 Systems, making RCA the first to offer a complete, fully transistorized computer product line, including both basic and peripheral equipment for all types of business, large or small.

The 301 system is designed to provide full-scale data processing for firms with as few as 300 employees. It is the first system to use magnetic disks for its memory storage, along with magnetic tape on reels. The RCA 301 can serve as a complete data-processing system, or as an auxiliary to the larger RCA 501 or 601 systems.

The RCA 601, with its 1.5-microsecond memory and very large capacity, is actually a family of systems, since its concept allows increase or modification of its speed. functions, and capacity in an efficient manner. Its design is an answer to the needs of large-volume applications for one system readily adaptable to present and future requirements.

EDP PLANT EXPANSION

With a full line of data processing equipment and an upsurge of orders, the Electronic Data Processing Division made plans for expansion of its physical plant.

The Industrial Computer Systems Department became an operating reality at the Natick, Massachusetts, Industrial Center, moving into a new building. Within a year, plans were announced for leasing a second building to double the plant's size. a step made necessary by demands not only for RCA 110 industrial computer systems but the RCA 150 data analyzer and the RCA 130 industrial-information transmission link.

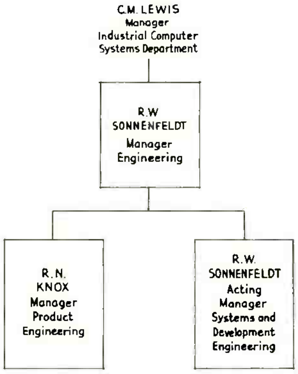

Fig. 7—Industrial Computer Systems Engineering.

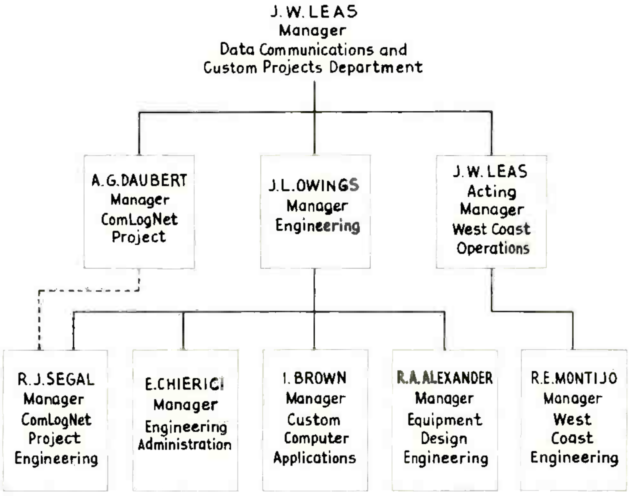

Fig. 8—Data Communications and Custom Projects Engineering.

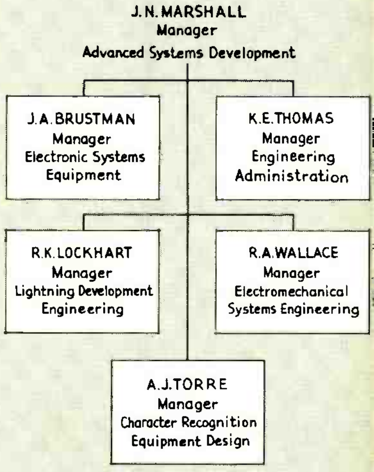

Fig. 9—Advanced Systems Development Engineering.

Housing administration, sales, engineering, and production activities, this plant is located 15 miles west of Boston. Beyond the current expansion plans, there is ample space at the Natick Industrial Center for increasing the RCA Industrial Computer Systems facility to five times its original size.

To turn out the compact RCA 301, ground was broken in August 1960 for a $4,000,000 plant on a 115-acre plot in Palm Beach Gardens, Florida, a new city being created five miles north of Palm Beach itself. Just 48 hours after purchase of the land was completed, a fleet of bulldozers was on hand to start the clearing job. The plant, now in operation, is a complex of one-story buildings, comprising administrative, engineering, manufacturing, and warehousing operations, and covering in all a total of 185,000 square feet (Fig. 2).

DIVISION REORGANIZATION

The rapid growth of RCA's electronic data processing business resulted in the establishment of separate departments and supporting groups; engineering activities were reorganized and the marketing effort was intensified (Fig. 3).

To implement the Division's marketing activity, sales offices are located at Boston, Hartford, New York, Syracuse, Philadelphia, Atlanta, Chicago, Cleveland, Detroit, Pittsburgh, Washington, D.C., Seattle, San Francisco, Los Angeles, Dayton and Dallas—with others being readied at Houston and Denver.

Most of the administrative and home-office personnel of the EDP Division have been consolidated at RCA's Cherry Hill, N.J., location (Fig. 4). The transfer was completed in 1961 when the Product Planning group moved to Cherry Hill. Over a period of six months, nearly 300 EDP personnel were shifted by groups from RCA's Camden complex (Fig. 5), joining more than 100 others already situated at Cherry Hill—including National Accounts and Industry Specialists, the staff of the RCA 501 Computer Center, Marketing Training, and Product Planning employees.

The Cherry Hill move was made possible by the shift of administrative headquarters of the RCA Victor Home Instruments Division and the RCA Sales Corporation to Indianapolis, Indiana, where that Division's production facilities already were located.

The Cherry Hill complex comprises six buildings which the EDP Division now shares with the RCA Service Company. The buildings are situated on 65 acres immediately south of Route 38 and are surrounded by open fields, woodlands, and spacious parking lots. Five of the buildings were erected five years ago, the sixth last fall.

EDP SYSTEMS CENTERS

Two RCA 501 computer centers are housed at Cherry Hill, one operated by the EDP Division and the other by the RCA Service Company. The Division also has a center equipped with a pair of RCA 501's in the Wall Street district of New York City; the RCA Service Company maintains three others in Washington, D.C. and Chicago, and San Francisco.

All the centers serve a three-fold purpose—as a showcase for RCA's computer equipment, as training sites for customer personnel, and to make full-scale electronic data processing available to firms whose business does not warrant computer systems of their own.

ENGINEERING

Playing a key role in the EDP Division are strategically-located complexes of engineering talent. Over-all engineering coordination and planning is exercised by D. L. Nettleton, Chief Engineer of the EDP Division.

The Commercial Systems Engineering (Fig. 6) group is located at Camden with responsibility for development and design of the commercial computer product line, as well as equipment modifications to accept specialized peripheral devices. A smaller engineering group at Palm Beach Gardens, Fla., is responsible for the RCA 301.

THOMAS I. BRADSHAW attended the Hoosac School, Hoosick, N. Y. and Franklin and Marshall Academy, Lancaster, Pa., receiving the B.A. at Franklin and Marshall College in 1937. Excluding three and a half years in the U.S. Navy during World War II, his newspaper career consisted of ten years with the *Philadelphia Bulletin* and eleven years with the *Associated Press*. In 1950 and 1951, he served as an *AP* war correspondent in Korea. He came to RCA in March, 1958, as staff public relations representative for IEP. He now is assigned in a public relations capacity to the Electronic Data Processing Division.

Industrial Computer Systems engineering (Fig. 7) functions at the Natick, Mass., operation. Here the responsibility is the development, design, factory, and field support of the industrial-computer product line. This engineering activity is organized with particular attention to maintaining a capability for short-term custom product design in the control systems field.

Data Communications and Custom Projects Engineering (Fig. 8) is concerned with two principal areas: 1) development of equipment and systems suitable for data communications, including RCA's commercially-announced DaSpan, the MUX/ARQ and magnetic-tape-to-magnetic-tape transmission systems; and 2) design engineering and field support of custom projects with an eye on EDP Division long-term objectives. This group also is responsible for adapting the RCA commercial computer product line for use in military weapons systems, in the event such need arises. The engineering activities are located at West Los Angeles, Calif., Camden, and Pennsauken, N. J.

New techniques and systems approaches for all EDP departments is the goal of Advanced Systems Development Engineering (Fig. 9) operating out of the Pennsauken facility. This group additionally maintains liaison with other RCA activities and with outside corporations, research institutes, and universities with a view toward cooperation in developmental areas.

In addition to these EDP Division engineering groups, other RCA divisions are active in research, development, and production of computer systems, components, and materials.

At the RCA Laboratories' David Sarnoff Research Center, Princeton, N. J., computer research is conducted in such fields as memory-systems, micromagnetics, cryogenics, electronic printing, and integrated electronics. Engineering development applicable to the electronic data processing effort is done within other RCA Divisions, including RCA Semiconductor and Materials Division, RCA Electron Tube Division, and Defense Electronic Products activity.

SUMMARY

The RCA Electronic Data Processing Division has engineered an important product line of computer systems for a broad scope of applications. The successful engineering, production, and marketing of these systems has effected an important corporate growth in the organization and facilities of the EDP Division — a dynamic growth that will continue to keep pace with the computer industry.

AIR IONIZATION AND PHYSIOLOGICAL EFFECTS

The study of air ionization, in relation to health environment, is a relatively new research subject which has just recently become of general interest. The RCA Service Company, working closely with the RCA Laboratories, has designed and is currently manufacturing, merchandising, installing, and servicing two models of air-ionization equipment. There is also a small portable air-ionization measurement instrument under current development. Discussed here is a general background of these research studies and the RCA Service Company's part in providing convenient tools to conduct such research.

by **H. REESE, Jr., Mgr.,**
Nuclear and Scientific Services
Government Services, RCA Service Co.
Cherry Hill, N. J.

YOU MAY NOT THINK of the air you breathe as being electrically charged, but it is. As a matter of fact, it has been shown that each cubic foot of fresh air contains approximately 30,000,000 electrically charged particles called ions. Fresh air normally has approximately equal numbers of positive and negative ions.

NATURE OF AIR IONS

The source of ions and their effect on human behavior is currently the subject of much research. Ionization of the atmosphere can be caused by such phenomena as cosmic radiation, solar radiation (especially through the effect of ultraviolet rays), and nuclear radiation from radioactive materials in and around the earth. Since air consists of a mixture of many different molecules, one would expect "air ions" to be a mixture of the various ionized constituent atoms or molecules. However, it has been found that negative ions are usually oxygen molecules with an excess of one or more electrons and that positive ions are molecules with a deficiency of one or more electrons.

The mass of ions vary. A single ionized atom may have several neutral molecules attached to it or it may have only one. The charge per unit mass is measured in terms of the mobility of the ion in a constant gradient electrostatic field; in other words, ions with a higher charge per unit mass have a higher mobility, or drift velocity, in an electrostatic field. These higher-mobility ions are sometimes referred to as *small ions*, whereas low-mobility ions are referred to as *large ions*. Most technical literature refers to small ions when no distinction as to mobility is made; such is the case in this article.

EARLY OBSERVATIONS OF HUMAN REACTIONS TO POSITIVE AND NEGATIVE ION VARIATIONS

Through the centuries scientists, prophets, doctors, and others observed that variations in the winds and weather affected the behavior of people. However, it was not until the twentieth century that such behavior was attributed to air ionization.

As early as the year 1932, Dr. C. W. Hansell of the RCA Laboratories recognized that air-borne ions had an effect on human behavior. While he was at RCA's Rocky Point, Long Island, Laboratory, he noticed a wide swing in the mood of a fellow worker. Later he was able to correlate the mood changes with the polarity of the electrostatic generator used in the lab. He found that the worker was depressed when the polarity of the generator was positive, which would correspond to a high concentration of positive ions in the room, and happy when the polarity was negative. Confirmation of similar observations soon came from other sources. It was found that in places where the negative-ion concentration was artificially or naturally reduced, people would suffer depression.

Since that time there have been many articles that have attempted to correlate the effects of positive and negative ions in the air with human behavior. Dr. I. H. Kornblueh, of the American Institute of Medical Climatology, for example, has done considerable work in this field and has reported that many of the effects of ions are beneficial and warrant further investigation as to possible therapeutic applications.

In a recent paper[1], he compiled data which showed that there are differences in ion concentrations in various parts of the world. While the compilation was considered somewhat inadequate because of a difference in measuring techniques, the frequency and length of time of sample observations, and seasonal differences, there seemed to be a certain uniformity in the average figures with small but significant variations. Measurements made in the Boston and Philadelphia areas showed these locations to be among the lowest in ion density of the areas tabulated; Boston averaging just under 300 positive ions/cc and Philadelphia just under 500 ions/cc. Kislowodsk, Russia, has ion concentrations as high as 2168 positive ions/cc and 1535 negative ions/cc.

HARRY REESE, JR. received his BS in EE from Carnegie Institute of Technology in 1944 and a Master's Degree from the same school in 1948. From 1944 until 1946, he served in the U. S. Navy, with the rank of Lt. (jg), as Radar Officer on the Aircraft Carrier *Croatan*. He was employed as a development engineer for the Brown Instrument Division of Minneapolis-Honeywell from 1946 until 1949. From 1949 to 1952 he was employed as a development engineer at the Oak Ridge National Laboratory where he worked on the Aircraft Reactor experiment and high-voltage accelerators. During this time, he was co-developer of a new-type r-f ion source. From 1952 to 1958, he was Assistant Manager, Nuclear Power Department, Curtiss-Wright Research Division, responsible for supervision of the Physics Section, including reactor physics, instrumentation, hot lab, research reactor, and health physics. In August 1958 he joined the RCA Service Company as Manager of Atomic Energy Services, where he has been responsible for all of the Service Company's atomic energy programs. In May 1960 he was made Manager of Nuclear and Scientific Services.

VARIATIONS IN ION CONCENTRATION VS HUMAN BEHAVIOR

Dr. Kornblueh found that in the less polluted air of the country there are, in comparison with the cities, more small ions and less large ones. Also, in the clean air of high altitudes, the stronger ultraviolet and cosmic radiation produce small ions in greater concentrations than at sea level. He also reported results of tests which support the argument that ion content in a closed room decreases with time to a lower equilibrium level. The test was conducted in a closed classroom which was opened only between classes. There was a marked decrease in small ions and an increase in large ions.

It appears that the data compiled by Dr. Kornblueh and others supports the theory that differences in ion concentrations do affect human behavior. Furthermore, it appears that artificially ionized air can be used to increase ion concentrations to levels that will result in beneficial physiological and clinical effects. There are presently two general methods being used for utilizing artificial air ionization. In the first, additional ions are added to air to bring the concentration up to what could be considered a normal level. The second consists of therapeutic applications such as those for the relief of pain, the acceleration of healing, and mental stimulation.

First, let us consider treatment that involves increasing, by artificial means, the ion concentration in an area to what can be considered a normal level. It has been found, as mentioned above, that the ion concentration in outdoor regions in most parts of the world varies from approximately 200 to 2000 positive ions/cc. The negative-ion content is usually about five-sixths of this level. It has also been found that a positive-ion concentration in the vicinity of 600 to 1000 ions/cc, with the corresponding negative-ion concentration, appears to be present in certain geographical areas that have an invigorating atmosphere, such as in mountainous areas; whereas lower ion concentrations exist in areas that tend to be depressing. It is known that in general negative ions have a higher mobility than positive ions. Apparently there is less inclination for the larger clusters of molecules to attach themselves to an electron or an electron-bearing molecule than for neutral molecules to attach themselves to positive ions. This results in a higher charge per unit mass for the negative ions and a resultant greater mobility.

When a room is closed so that the exchange of air with that outside is poor, it is found that the ratio of positive to negative ions increases because of the negative ions diffusing to the walls and becoming neutral. This same phenomenon can be shown to exist in the ducts and filters of air-conditioning systems. In practically all cases the filters and ducts preferentially remove negative ions from the air, leaving a ratio of positive to negative ions higher than in nature. Since there is an excess of positive ions we would expect that the people exposed to such air would become depressed and possibly exhibit symptoms of claustrophobia (fear of confinement). It is thought that this may explain why some people sometimes desire to open the windows in an air-conditioned building and why, despite uniform temperature, humidity, and a well-filtered system, the air sometimes seems stuffy.

Dr. Hansell has found that air brought out of the earth tends to be more positively charged than normal. This may explain the forewarning of storms that animals receive and the depression brought on in some people by low-pressure areas which tend to draw air and carbon dioxide out of porous earth.

HUMAN REACTIONS VARY WIDELY

It should also be pointed out at this time that not all people are affected in the same way by a change in concentration of air ions. In most experimental work that has been done, it has been found that about one third of the people are unaffected by reasonably large variations in ion concentration. It also appears that the sensitivity to ion concentration increases with age. Thus, if a sufficient ion concentration is added to the air in an air-conditioned area, it would overcome the depression that exists in many people when exposed to this type of environment. It could also be expected that work output would increase in those people so affected because the increase of negative ions has a tendency to increase the metabolic rate.

There is some question as to the ill effects due to exposure to large amounts of negative ions for fairly long periods. As Dr. Hansell sees it, when a person is exposed to negative ions for a long period of time, a portion of his own internal hormonal-enzymatic, negative-feedback control system is relieved of performing some of its normal function and slowly loses its ability to perform its function. The body of the person exposed thus tends to lose its ability to contend with normal environment. In view of this, it appears that the depressions exhibited by the lack of negative ions should not be made up simply by increasing the negative-ion concentration.

If any attempt is made to provide artificial air ionization in buildings, the level should be increased to provide a ratio of positive to negative ion concentration that would more nearly duplicate that found out of doors on a pleasant day. The artificially generated ions should be added in the individual areas that are air conditioned, since adding them before the air travels through ducts would be somewhat inefficient due to the neutralization of the ions on the duct walls.

THERAPEUTIC USES

The second class of treatment utilizing ionized air referred to above is the therapeutic use. It has been found that negative-ion concentrations of the order of 10,000 ions/cc have a very definite effect on the ciliary action (motion of small hairs in nostrils), increasing the activity as the negative-ion concentration increases. The resultant effect is a more rapid clearing of the bronchial tubes and in many cases, relief of congestion such as that which would occur in hay fever and asthma cases. It has been found that a person breathing air containing 10,000 negative ions/cc for 20 minutes to a half hour can obtain relief for as long as 24 hours from asthmatic symptoms.

David, et al.[2], described the use of negative ions in the treatment of burn cases at Northeastern Hospital in Philadelphia. Ion doses ranged from 2000 to 7000 ions/cc. It was found that the negative ions had a very definite analgesic effect (insensitive to pain) on burn patients with either no narcotics being required or much smaller amounts than had been previously required without ionization. In no cases were any ill effects noted in patients exposed to negatively ionized air. Results in connection with burn patients has prompted Northeastern Hospital to investigate the effects of ionization on post-operative cases.

PHYSIOLOGICAL EFFECTS

Kraskevich[3] has reported success in using negatively ionized air for the treatment of mouth sores and ulcers where gargles, and cauterization have had little effect. He exposed a group of 30 patients for 20 to 25 consecutive days to high levels of negative ions for 15 minutes each day. After the treatment, four patients had no recurrences of sores during one and a half years. In 15 patients the relapses were far less frequent, recurring at intervals of three to seven months. In five patients the relapses disappeared for relatively short periods—one to two months; and in four patients, the relapses were just as frequent as before but the number, size and duration of the sores was lessened. Two patients had not responded at all to the ionized air treatment.

The effects of negative ions cannot be simply related to increased metabolic rate, however. A. H. Frey[4] has suggested a hypothesis for interpreting the behavioral effects of air ions. His hypothesis is that negative ions stimulate secretion of the gluco-corticoids (a secretion from the adrenal glands) and positive ions either stimulate the secretion of the mineralo-corticoids or inhibit the gluco-corticoid secretion. Direct experimental evidence is not available at present to test his theory but Frey has pointed out the striking similarity between negative ions and gluco-corticoid effects. For example, Frey has indicated that both negative ions and the gluco-corticoids have a tendency to reduce blood pressure, and to inhibit pain, shock, and malignant growths.

Fig. 1—A desk-table model RU-1 Ion Generator

Krueger[5] performed some rather detailed experiments on excised tracheal strips (removed strips of windpipe) and on rabbits with a special aperture to view the tracheal (windpipe) activity. The animal was permitted to breathe normally by means of a tube inserted in its trachea. His findings indicated that the ciliary rate was increased with negative ions only when oxygen was present and decreased by positive ions only when carbon dioxide was present. This would indicate that the primary carrier for negative and positive ions was oxygen and carbon dioxide, respectively. There is other evidence that the majority of the high mobility negative ions are oxygen molecules attached to electrons. The case for carbon dioxide was not as well established, however.

Krueger also reported that positive ions could exert this physiological effect by causing a local release of 5-hydroxaltryptamine (secretion within the body) and postulates that negative ions increase the rate at which 5-hydroxaltryptamine is oxidized. It was found that when 10 milligrams of 5-hydroxaltryptamine are injected into a rabbit, a condition is produced in the trachea which is indistinguishable from that caused by positive air ions. The ciliary rate decreases, the posterior tracheal wall contracts, the mucosa becomes ischemic (deficiency of blood in the mucous membrane) and its vulnerability to trauma (injury) is greatly increased. The rate at which an animal recovers from these effects was found to be accelerated by negative ions. Resperine drug, which depletes 5-hydroxaltryptamine, causes changes that resemble those produced by negative air ions, such as increased ciliary rate, relaxed posterior tracheal wall, hyperemia of the tracheal mucosa (a superabundance of blood within the mucous membrance), and increased volume and rate of mucous flow.

Fig. 2—A reflector shade which is one of two components of the high-output Ion Generator, model TU-1

In view of the fact that there definitely appears to be behavior and physiological effects due to air-borne ions, many research organizations are currently carrying out work to establish more firmly the direct effects and any side effects that may occur. At the present time, since the statistical evidence is far from conclusive, it is recommended that any therapeutic use of negative ions be carried out by or under the direction of a physician.

RCA ION GENERATOR

The RCA Service Company is presently making available to physicians and research organizations two pieces of equipment capable of putting out large numbers of positive or negative ions. The smaller piece of equipment which is meant to be used on a desk or table top is designated RU-1, shown in Fig. 1.

This unit produces approximately 40,000 negative or positive ions/cc at 4 feet from the unit. The ion density increases close to the unit but becomes difficult to utilize because of the small angle of emission. At 10 feet, the ion concentration drops off to about 1500 ions/cc. This instrument functions to produce ionization when approximately 3,000 volts are applied to a 3-mil-diameter wire, ¾ inch in length. In a metal duct near the air exit port, polarity of the ionized air is changed by reversing the polarity of the power supply. To obtain fairly large doses, 100,000 ions/cc, over large areas such as a hospital bed, a 3-mil diameter wire, about 4 feet long, is installed in a shield much like a fluorescent light fixture. This unit is shown in Fig. 2. When 15,000 volts are applied to the wire in this type of shield, over 1,000,000 ions/cc are produced one foot below the wire. At 3 feet below the wire, the concentration is 150,000 ions/cc. Fig. 3 shows the power supply and switching cabinet.

Fig. 4 shows the ion density measuring equipment, which consists basically of parallel plates across which low voltage is applied. When measurements are made, air is blown between the plates so that ions can be swept out of a known volume of air and measured as a current with an electrometer. Current is recorded so that the integrated dose can be easily measured during a treatment.

One effect that has been noticed in experimental work is the necessity that a patient have a fairly low-resistance path to ground to prevent retention of charge. Also, unless there is repulsion of additional charges of the same polarity from the patient, the dosage may not be represented by the current flowing to ground.

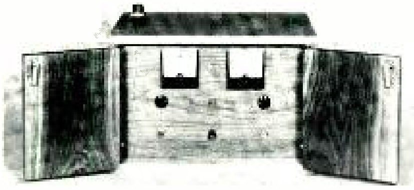

Fig. 3—The power supply and switching unit of the model TU-1 high-output Ion Generator

CONCLUSION

At the present time there is very little good quantitative information concerning the effects of ion-laden air breathed by human beings. There is enough evidence, however, to justify more research. Air ions are not considered to be a cure-all and should not be construed to be so. For these reasons the Service Company recommends that any therapeutic treatment be taken under the supervision of a medical doctor.

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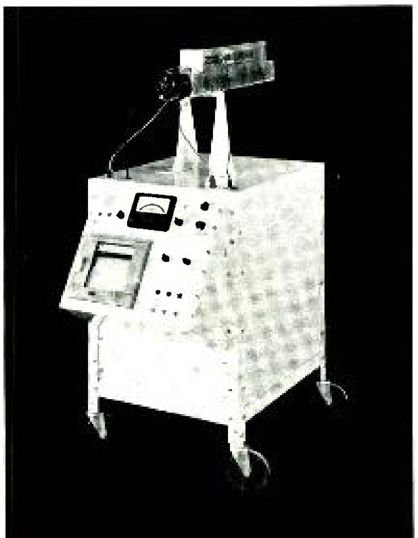
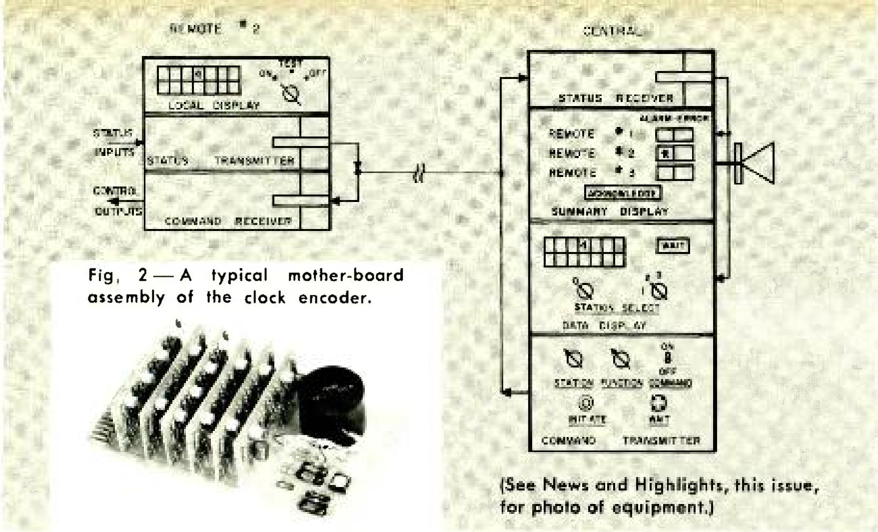
Fig. 4—Ion density measuring equipment.





(See News and Highlights, this issue, for photo of equipment.)

Fig. 1—A typical ALERT installation in which 24 *status* inputs are monitored, and commands are transmitted from the *central station* back to selected *remotes.*

Fig. 2—A typical mother-board assembly of the clock encoder.

THE RCA-130 ALERT MONITOR AND CONTROL SYSTEM

The ALERT supervisory system gathers information at remote points and transmits it to a central station where it may be displayed, logged, inserted in data-processing apparatus, or analyzed for alarm conditions. The system also provides means of transmitting commands from the central station back to selected remotes.

by **A. S. BUCHMAN**
Industrial Computer Systems Dept.
Electronic Data Processing Division
IEP, Natick, Mass.

The RCA-130 Alert system has been specifically developed for industrial applications such as the control and monitoring of microwave systems, oil pipe lines, gas-gathering fields, gas distribution lines, off-shore oil wells, remote broadcast or transmitting equipment, and remote control of inaccessible industrial devices. The new supervisory system is called Alert, meaning *Automatic Logging Electronic Reporting and Telemetering* system.

The computer systems engineering team faced the challenge of designing equipment to be low in cost, high in both equipment and system reliability, and versatile enough for a wide variety of uses without requiring extensive engineering for each new application or installation. The solution to these goals was successfully achieved, resulting in a system possessing valuable and unique features. Present production of RCA-130 Alert systems will be used to monitor and control 236 stations for a Western Union coast-to-coast microwave system being supplied by the IEP Communications and Controls Division.

REMOTE STATION

Fig. 1 illustrates an installation in which the remote station is monitoring 24 *status* inputs; each input is a contact actuated by a limit switch, relay, or other customer-supplied device. The *status transmitter* scans the 24 inputs in sequence and transmits the data at a rate of 15 pulses/sec to the master station. The communication link in this installation utilizes RCA FSK audio tone equipment. The 4- to 8-kc signals are transmitted by a 6-kMc radio system to the master station where the audio tone is received. A *local display* is installed at each remote station for the convenience of maintenance personnel.

MASTER STATION

A single central station monitors many remote stations. The transmitted information is received, decoded, and analyzed for alarm indication by the *status receiver.* The *summary display* summarizes the alarm information for the monitored stations. For each of the monitored remotes, there is an *alarm* annunciator which will turn on a flashing lamp and sound an audible signal if an alarm condition is detected at the remote station. The operator may disable the audible alarm and cause the lamp to stop flashing by pressing the *acknowledge* switch. The lamp will remain on until the fault at the remote stations has cleared itself and a complete *no-fault* report is obtained from the remote station. In the event a second or subsequent alarm occurs before the first one clears, the same sequence of audible alarm and flashing lamp will again take place.

To monitor the communications link, an *error* indication is provided for each of the remote stations. In the event of either loss of transmission or of a transient code error, a special signal is generated which causes the error lamp to go on and the audible alarm to sound. The audible alarm may be immediately inhibited by pressing the *acknowledge* button and, on receiving a valid message indication, the *error* lamp will be automatically extinguished.

The operator at the central may make a detailed inspection of the information from any remote station using the *data display.* Selection of the desired remote station causes all of the lamps to be lighted thereby providing a momentary lamp test. The received message is loaded in the display providing an exact readout, at the central, of the detailed information from the remote. This readout is continuously updated and is automatically retained in the event of loss of transmission.

COMMANDS

The central station is able to control eighteen functions at a remote station. To initiate operation, the desired station is selected on the *command transmitter* and the function number and *on* or *off* command is also selected. Pressing the *command-initiate* button causes the system to send messages which encode the selected information. To assure security of operation, a special checking technique is used in which the first of these messages is stored in a memory at the remote. The second transmission is compared symbol by symbol with the first transmission, and if these two are in exact agreement, the function to be performed is selected. The receipt of the beginning of the third message causes immediate actuation of the controlled function.

CONSTRUCTION

The smallest unit of construction in the RCA-130 Alert system is the four-input *nor* gate, consisting of a transistor and six resistors. The circuit uses a selected 2N404 (RCA-3875), chosen because of its reliable and reproducible characteristics and very-high-volume production. Silicone-sealed resistors are used exclusively. The basic circuit is a four-input resistance-coupled gate with a four-output load capability. Only two supply voltages are required, and the logic levels are identical to those used in other RCA EDP equipment. The *nor* logic circuit has been very carefully designed to be reliable in spite of the aging of the components in each circuit and in the adjacent circuits. This "worst-case" design assures the ultimate in equipment reliability.

The circuitry is mounted on glass epoxy "baby" boards which hold between one and five of the *nor* circuits, depending upon the particular circuit requirements. The *nor* circuits are used to provide logical gating or are joined back-to-back to make flip-flops, shift registers and ring counters.

The baby boards are mounted on larger "mother" boards which can hold as many as nine baby boards. The printed wiring on the back of the mother board determines the interrelation between the baby boards and the complete mother board constitutes a functional module (Fig. 2). The mother boards are plug-in units. The connector used is a high-pressure self-seating type known for its reliability. Mother boards are mounted in "nests," each of which is 5¼ inches high. These nests will accommodate up to seven of the standard mother boards and are designed for installation in a standard 19-inch rack.

In a complete ALERT system, over 80 percent of the electronics use the *nor* circuit, only six basic types of baby boards are required and approximately 20 different mother boards are used. The practicality of the design is indicated by these figures and by the fact that even the most complex ALERT installations can be assembled by joining seven basic equipments to achieve the variety of functions required by a wide range of applications: 1) status transmitter, 2) status receiver, 3) command transmitter, 4) command receiver, 5) data display, 6) local display, and 7) summary display.

EQUIPMENT RELIABILITY

The combination of a basic circuit designed for worst-case conditions along with the use of circuit components and other materials of highest quality has resulted in equipment with extraordinarily high reliability. The original engineering model of the RCA-130 ALERT system was subjected to a typical MIL-SPEC. temperature-humidity cycle including cold storage at −65°C, hot storage at +85°C, and temperature-humidity cycling from −12°C to +65°C. Equipment is usually tested for three 8-hour cycles of such testing. The ALERT equipment was tested for almost three months of continuous cycling without any component failure. The operation of the equipment was continuously monitored and the results were automatically recorded. In the course of this environmental testing, approximately 2½ million status messages and 1½ million commands were sent; during this time, no message which contained an error was accepted by the system.

COMMUNICATIONS

It is inevitable with a practical communication system that some of the transmitted information will be intermingled with noise when received. The communications systems determine the *bit error rate;* that is, the number of bits which may be transmitted on the average before a bit is detected erroneously. This rate is determined by the signal-to-noise ratio ($S{:}N$) of the communications system, the nature of the noise which is encountered, the type of transmission used and the nature of the filters and characteristics of the receiver.

In the RCA-130 ALERT system, the preferred means of communication utilize audio tones which are transmitted using frequency shift key (FSK) techniques. This is an FM transmission in which one frequency is identified with a *1* and a slightly different frequency is identified with a *0*. This means of transmission is preferable to AM because (as in any FM transmission) means of improving the $S{:}N$ may be provided. Such improvement is gained at the expense of bandwidth and requires appropriate input and post-detection filters in the receiver. Fig. 3 is a plot of $S{:}N_{in}$ versus $S{:}N_{out}$ for an ideal FM system where the modulation index β may be regarded as being roughly proportional to the bandwidth for a given transmission rate.

Fig. 4 is a plot of bit error rate versus $S{:}N$ at the receiver output for a binary transmission channel and white noise. An AM system at 16-db $S{:}N$ results in a bit error rate of 10^{-3}. With FSK transmission and a modulation index of 1.5, $S{:}N$ is improved (from Fig. 3) to 25 db, which results in a bit error rate of better than 10^{-10}.

This example illustrates both the power of FM techniques and also indicates that with $S{:}N$ ratios greater than about 18 db, errors are rare occurrences.

CODING

In any real system some of the received information will be in error due to noise. Therefore, it is advisable to test the validity of the received information before accepting it. This is accomplished by the bit-by-bit parity check of the RCA-130 ALERT systems. In this technique, for each symbol to be sent, two bits are transmitted. A *1* is transmitted as a *10* and a *0* is transmitted as a *01*. A powerful test is provided at the receiver by checking each symbol which is transmitted to make sure that it consists of a single *1* and a single *0*. If any received symbol contains either two *1*'s or two *0*'s, it is known to be in error and will be rejected.

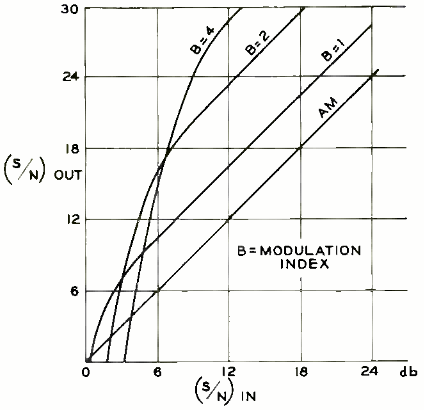


Fig. 3—The S:N ratio improvement by use of FM.

In an installation where one bit in 100,000 would be in error due to the nature of the communication system, 10-billion bits would be transmitted before an error would occur which the checking system could not recognize. With a bit transmission rate of 15 bits/sec, the mean time between messages with errors would be 100 minutes, and utilizing the ALERT system bit-by-bit checking, the mean time between accepting improper messages would be twenty years.

An additional and most important feature of this coding is that it provides the time synchronization between the remote and master stations. Since each reported item must be made up of a *10* or a *01*, a transition (from *1* to *0* or from *0* to *1*) must occur in the middle of each item. This transition is detected and is utilized to indicate that a new item has arrived. Thus, the incoming information carries its own timing in its format regardless of the

A. S. BUCHMAN graduated from Cornell University in 1948 with a B.S. in Mechanical and Industrial Engineering. Prior to joining RCA, he was with the Shallcross Manufacturing Company, in the design of industrial automation systems, and then by the Ford Instrument Company, on control systems and analog computers. At RCA, he has been instrumental in the development of air-borne reconnaissance systems and has been project engineer on optical, electronic, and ultrasonic techniques for process control and inspection. He participated in the data system study of Matterhorn and wrote the final report on the study. Today, Mr. Buchman is Leader, Design and Development Engineers, in the EDP Industrial Computer Systems Department.

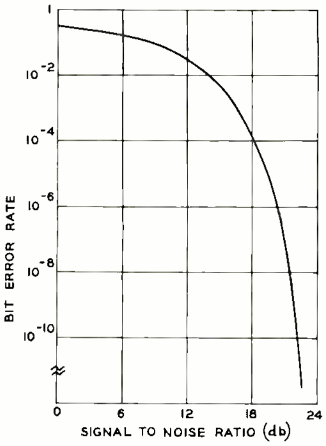


Fig. 4—Bit error rate vs. S:N ratio.

information content. In the RCA-130 system, there is no requirement for rigid synchronization between master and remote and therefore there is no practical limit to message length.

It is necessary to transmit an indication of the beginning of a new message. This *start-of-message* pattern must be different from any *information* message. It is logically dictated that such a pattern must either be longer than the random information message or must contain a normally forbidden code such as *11* or *00*. Fig. 5 shows the format for an ALERT message. The start-of-message pattern consists of six symbols: the first four provide a forbidden code; the next two symbols provide a test and synchronization pattern to assure that the basic start pattern is accurate and to properly phase the receiving logic. The error-detecting logic is designed to accept a correct start-of-message pattern while rejecting all other errors.

SYSTEM FLEXIBILITY

The RCA-130 system has been designed to be extraordinarily flexible so that the same equipment may be used, without basic modification, in a great variety of applications. The inputs to the specific system described were limited to contact positions. Other types of inputs which can be accommodated are analog signals, impulse duration, direct code inputs such as from teletype systems and multiplex contact inputs. Analog variables may be sampled and digitized in a converter, the output of which is treated as a group of binary inputs. Multiplexed inputs may be used where there are a great number of contacts which can be logically grouped in such a way that only a summary of each group is read out under normal message transmission, but any individual group can be read out on demand.

In the illustrated system, two types of output displays were indicated, the Summary Display and the Data Display. The logical operation of the Summary Display may be readily modified to meet particular customer demands and additional annunciator lamps can be supplied as required. The outputs from an RCA-130 system are digital in nature and may readily be logged on a typewriter or directly introduced into control devices or a computer. Additionally, the outputs may be utilized in digital-to-analog converters to provide signals suitable for strip-chart recording or for set-point controllers.

The modular construction of the system permits changing the number of inputs or outputs or adding stations without redesigning circuits or equipments. These changes are readily effected by adding additional plug-in modules or equipments identical to those in the basic system.

SYSTEM STRUCTURE

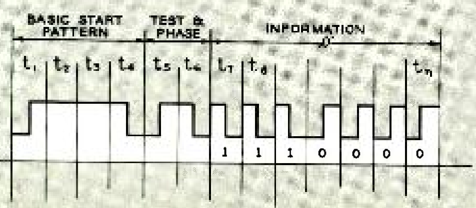
The system organization may be varied to provide the most economic and useful configuration. The system may operate in any one, or even a combination of three modes:

1) *Free-running:* each remote transmits information continuously.
2) *Interrogated:* the remote will send replies only when it receives a command to do so.
3) *Self-initiate:* the remote will automatically send a message if a change of status such as an alarm (or, if desired, the clearing of an old alarm) occurs.

In the free-running mode (Fig. 6a) there must be a *status transmitter* at every remote, and there must be a *status receiver* at the master station for each remote monitored. All remotes are "talking" at the same time, and frequency-sharing (multiplex) of the communication band is used by assigning each station a narrow portion of the available band. In the interrogating arrangement (Fig. 6b) there is a status transmitter at each remote, but only one status receiver at the central. Stations are identified by a digital address. The central station automatically interrogates each of the remote stations in sequence and the central status-receiving equipment is time-shared between the remote stations. Since only one remote "talks" at a time, the available communication band is time-multiplexed.

Combined with an interrogation system, a self-initiate feature may be included. In this configuration, the advent of a new alarm or emergency at a remote station permits this station to jump out of the reporting sequence in order to send an emergency message to the central station indicating that trouble has occurred. When self-initiate is used, a separate tone is required to control this function.

Fig. 5 — Waveform showing format for an ALERT message.



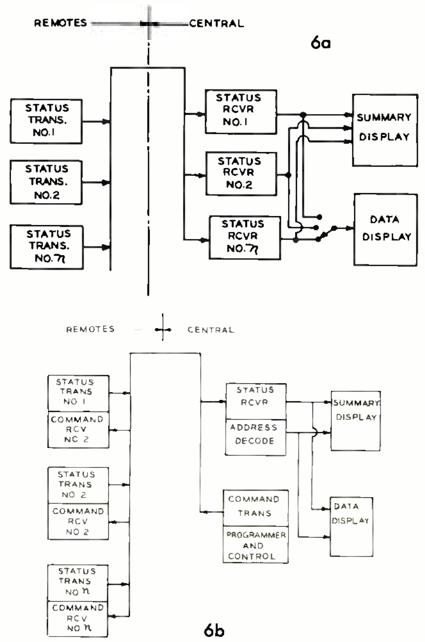


Fig. 6—System arrangements showing: a) *free-running* system, and b) *interrogated* system.

CONCLUSION

The design requirement of low cost has been achieved by means of circuit standardization and logic simplification, not at the expense of quality. Equipment reliability is assured by use of "worst case" circuit design and quality components. System reliability is optimized by FM transmission, the unique self-synchronizing code and bit-by-bit parity checking. The ability to use the equipment in a variety of applications without redesign has been achieved by planned modularization on several levels.

ACKNOWLEDGEMENTS

The suggestions, advice and guidance given by R. W. Sonnenfeldt have been crucial in determining the design of this equipment. Success of the design is due in large part to the efforts and abilities of a large design team whose core members were George Barrett, Joe Cashen, Abe Harel and Dave Priestley.

MILITARY DIGITAL COMMUNICATIONS

By
DR. L. E. MERTENS, Mgr.
Digital Communications Engineering
Surface Communications Division
DEP, Camden, N. J.

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

Modern global military operations demand rapid, accurate data communications and processing capabilities for the heavier traffic loads and ever-decreasing reaction times. The prolific development of digital data communications systems and techniques in the past decade results from the challenging pace established by increasingly stringent military operating requirements.

Application of digital techniques to data processing and communication has led to a new era in military electronic systems. Meeting the stiff performance goals inherent in these sophisticated systems creates many unique problems involving special engineering and production capabilities. Military systems are usually optimized for specific applications and hence include data-processing and data-communication equipment that tends to be highly integrated with the other system functions. Other considerations peculiar to the military equipment comprise severe operating environments, extreme size and weight restrictions, and ultimates in reliability and security.

ADVANTAGES OF DIGITAL COMMUNICATIONS TECHNIQUES

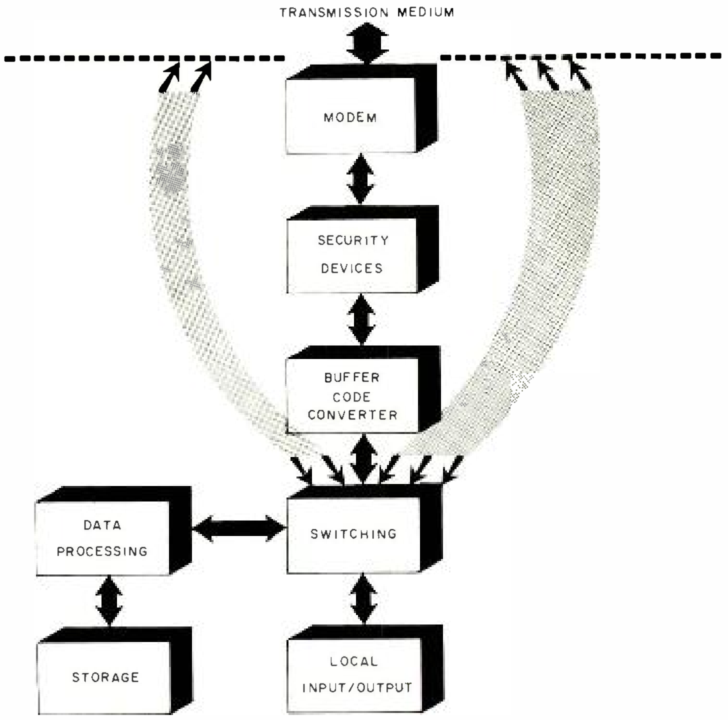
Digital techniques have been applied in military systems to establish links between a growing number of digital processors and computers. The natural digital language is the most convenient way of providing this function; further, digital communication systems handle large amounts of data in a short time and can be designed to provide any desired degree of accuracy and error protection.

The digital approach readily lends itself to security protection. Security aspects are so important in certain applications that considerable effort is being made to develop digital transmission methods for analog signals such as speech and video. Although digital speech transmission presently imposes a penalty in bandwidth or equipment requirements, it is expected to become more and more widely utilized in critical military areas.

There are also implementation advantages associated with digital techniques; a relatively small number of basic module building blocks can be assembled to perform virtually any complex function. This design approach permits concentration of circuit-design effort upon a small number of basic circuits and minimizes maintenance and logistics problems. Such concentrated effort results in a thorough design with emphasis on attainment of maximum reliability.

SurfCom's Digital Communications section has designed, tested and proved several sets of circuit modules operating in several common speed ranges and having wide environmental capabilities. These circuits are available in several

Fig. 1—Typical digital communication system.



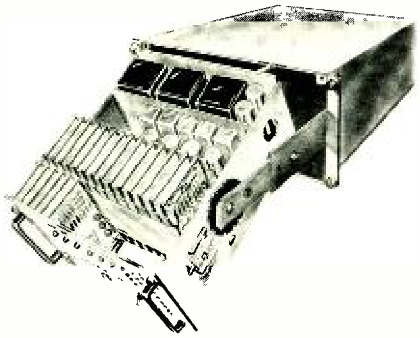


Fig. 2—Photo of a diphase "modem" drawer.

basic packaging types to suit specific military applications.

DIGITAL COMMUNICATIONS IN MILITARY SYSTEMS

Fig. 1 shows functions provided by digital communications subsystems in a tpyical military communication system. The *modem* (a *mo*dulator-*demo*dulator) represents the interface between the digital-processing and communication subsystems and the transmission system. A modem accepts digital signals and converts them into suitable waveforms for driving transmission lines or transmitters. Special waveforms and multiplexing techniques are employed to make maximum use of channel capacity and to achieve the highest system performance (lowest error rates) in noise or interference. A wide variety of modems has been developed to handle transmission media and data sources. Some modem techniques include frequency-division multiplexing, time-division multiplexing, and asynchronous, synchronous, and differentially synchronous detection. Modems have been developed to handle data rates over a broad range from approximately 75 bits/second (teletype rates) to 10-million bits/second (TV rates). Surf Com has been very active in developing diphase modems to be used with telephone lines. The diphase system offers high performance and relatively high data rates with extreme simplicity. A typical full duplex-diphase modem is shown in Fig. 2.

The modem shown in Fig. 1 is working in conjunction with a security device. Since techniques used in security devices are classified, it is sufficient to state that standard digital formats are converted into secure digital code and vice versa.

Code translation and buffering subsystems convert between various digital codes such as "Fieldata", and "Baudot" systems, message formats, and transmission rates. These subsystems may perform framing and timing operations as well as inserting parity bits for error detection and correction. A large portion of SurfCom work is in code translation and buffering. Some typical applications include conversion of information from codes and rates suitable for telephone lines to codes and rates suitable for ground-to-air transmission. Code translation is also used to change the message format to a high-redundancy code for ultra-reliable communications in missile launching. Special forms of coding have also been developed for anti-jamming.

As indicated in Fig. 1, many communication channels may converge on a central office. These channels in general have different characteristics because of the method of transmission or the source of information. In the central office, the information is usually converted into a common code and format. This may be done in the buffers, code translators, or in a central multiplex processor. The incoming and outgoing information channels must be interconnected into various complex networks required by the system subscribers.

This switching function is indicated in Fig. 1 and may be performed on a "circuit" or "message" switching basis. The circuit switching subsystem provides in telephone exchange fashion a direct conductive connection between the channels. While relays and crossbars are currently the predominant circuit switching devices, RCA has conducted considerable research and development on employing special high-speed relays (dry-reed relays) and solid-state cross-points. Complete digital transistor logic and parametron logic have recently been developed for controlling the switch crosspoint matrices.

The message switching technique is a "store-and-forward" process, using computer processors to accumulate suitable traffic for given destinations and then transmit messages. Many sophisticated operations are used to keep a tally of the messages, determine alternate routing, check security clearance, priority, and destination. In advanced communication systems, such as ComLogNet and UniCom, both circuit switching and message switching will be employed.

A data-processing subsystem is also indicated in Fig. 1. Data processing can involve either *on-line* or *off-line* operations. A typical on-line data processing operation is the control data-processor function employed in message switching. In communication control centers, computers may also assist in filtering, abstracting, and displaying traffic and equipment status. Computers may be employed off-line for network simulation to plan further development of the system or to analyze past traffic load patterns for assistance in optimizing control of the existing system.

Data-processing functions require extensive storage devices which can take the following forms:

1) random-access, high-speed memories with storage capabilities of several-thousand words and access times of a few microseconds
2) magnetic drums with larger storage capabilities but longer access times than (1)
3) magnetic tape stations with multimillion word storage and very long access times, or
4) punched paper tape.

Surface Communications is developing advanced techniques in all these areas with specific emphasis on high-speed operation and major reductions in size and weight. For example, recent work in thin magnetic films at the RCA Laboratories is being applied to a tactical random-access memory to produce a 20-to-1 volume reduction over conventional magnetic-core memories.

Local input and output devices are extremely vital to any system. They range from conventional control knobs and indicators to electroluminescent panels (see article this issue by L. E. Haining), and high-speed, multiple hard-copy printers. One of the most advanced input-output devices being developed in SurfCom will be used for the automatic conversion of speech information (phonemes) to digital format. The output of this speech-recognition device could directly feed computers, hard-copy printers and translation devices. Other speech-processing equipment is aimed at reduced bandwidth transmission of digital speech information.

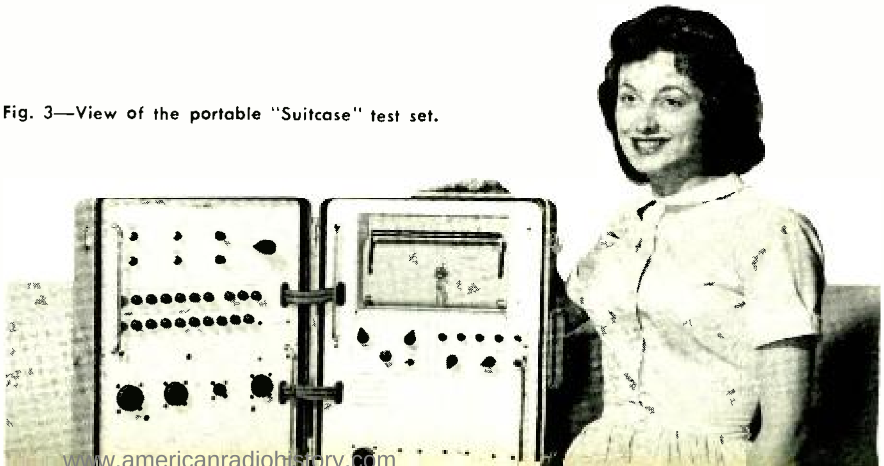


Fig. 3—View of the portable "Suitcase" test set.

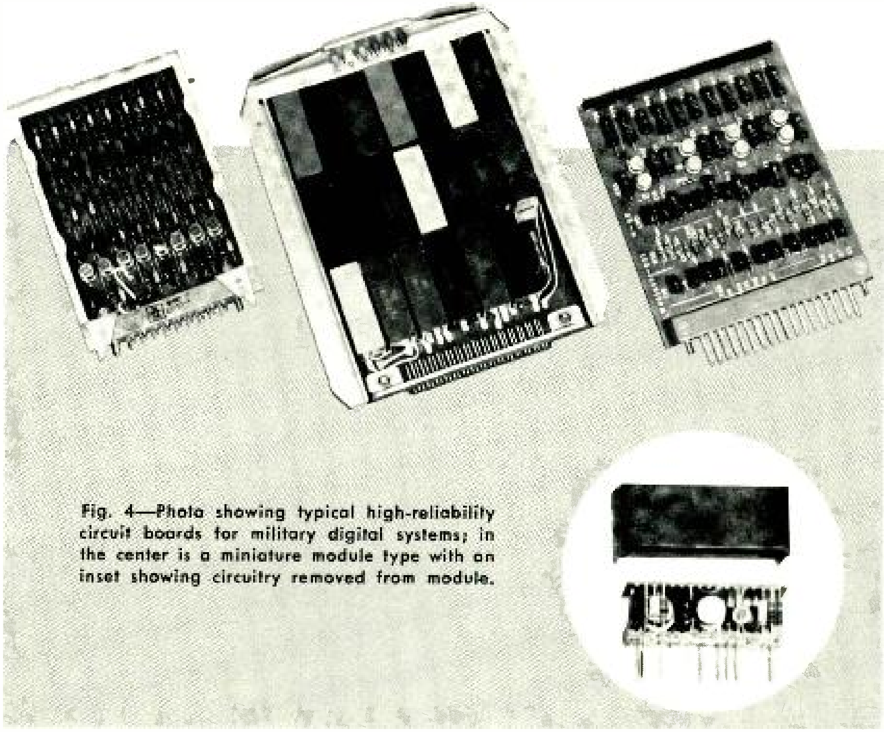


Fig. 4—Photo showing typical high-reliability circuit boards for military digital systems; in the center is a miniature module type with an inset showing circuitry removed from module.

A WEAPON CONTROL SYSTEM

To illustrate the application of digital techniques to military systems, a typical weapon-control system application can be considered. Such a command network must provide message encoding; digital data modulation for wire-line transmission; demodulation; checking; and decoding of the command messages. Stringent requirements for availability, survivability, and anti-jam capability would dictate that each facility serve as a node in a complex network. Digital techniques can implement the line selection, data checking, and retransmission rules adopted to provide message propagation through the network. Special digital processing might be required to insure against inadvertent or unauthorized weapon launch. For such high reliability, self-verification would be required and could be achieved by:

1) monitoring selected critical points continuously;
2) monitoring all possible functions while processing a special test message; and
3) suitably checking concurrent with command message processing.

A status communication system continuously reports the decisions of the self-verification function in addition to weapon-system status data. A separate digital communication system can be established to carry status information from the weapon site to the control facilities. In suitably encoded format, all pertinent data concerning the availability, security, and current status of the weapon can be reported and displayed at the control stations. A single-thread status link can provide for data collection and multiplexing; message construction; modulation; demodulation; demultiplexing; and the lighting of display lamps. Ground-support equipment is required to provide field maintenance of communication and processing equipments. The RCA micromodule "Suitcase" Test Set (Fig. 3) could provide semiautomatic checking and fault isolation. The test set shown is programmed by punched cards and can isolate a fault to a single equipment drawer. Depot maintenance and repair can also be implemented by tape-programmed automatic checkout equipment. RCA is designing several such equipments.

COMLOGNET CIRCUIT SWITCHING UNIT

Circuit-switching applications can be illustrated by ComLogNet, which employs an automatic electronically controlled data-communication switchboard using reed-relays as the switching element. The switchboard provides four-wire metallic nonblocking switching for 50 circuits and was designed for orderly expansion in groups of 50 circuits, up to a total of 200 circuits.

The ComLogNet switchboard developed by the SurfCom Systems Laboratories is capable of tandem and local operation, with automatic alternate routing between switchboards. Along with primary routes, one or two alternate routes are available; any terminal may be used as a line or trunk without restriction. Data tributaries operate at a bit rate of (75×2^n) from 75 to 4800 bauds, each terminal operating at a particular assigned rate. This rate assignment is changeable by altering the semi-permanent (wired) memory in the switchboard. Connections are provided only between compatible stations.

The ComLogNet switchboard handles three levels of priority. It will interrupt a low-priority call to process a high-priority message when there are no idle lines or trunks available. Switching is performed with 8-bit Fieldata code. Upon establishing a connection (which can be done in 20 milliseconds) the transmission path in the switchboard passes analog signals up to 4-kc bandwidth as well as binary signals up to 4800 bauds.

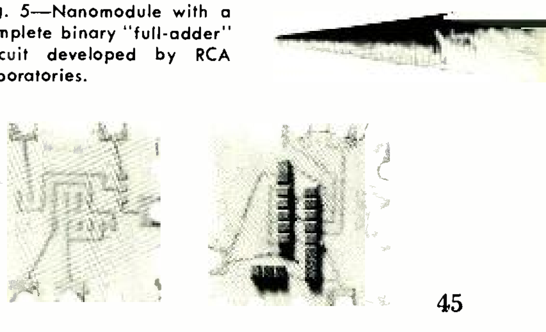
The prime component in the ComLogNet Switchboard is the glass-sealed dry-reed relay; it consists of hermetically sealed metal contacts in an inert atmosphere with high-contact pressures. Such features result in long life and high reliability. A switchboard indicator-panel records the condition of certain points in the system and provides automatic switching of redundant circuits in the system during maintenance and trouble shooting.

STORED-PROGRAM MAGNETIC TAPE SEARCH UNIT

The ComLogNet tape search unit illustrates an example of an off-line data processor used in a communications system. The tape search unit reads a reference tape, compares the data with the criteria—and then writes the information on magnetic tape, prints a hard copy, or prepares a punched paper tape. Messages containing information concerning the communications system are recorded on magnetic tape in blocks of characters and extraction of these blocks depends upon a satisfactory comparison between the operator-specified criteria and data characters in the information block being searched.

The four major groups of equipment comprising the tape search unit are 1) the input-output buffer units, 2) the magnetic-core storage unit, 3) the instruction-control unit, and 4) the data-processing unit. The input-output devices consist of printer, three magnetic tape stations, and a console.

Fig. 5—Nanomodule with a complete binary "full-adder" circuit developed by RCA Laboratories.



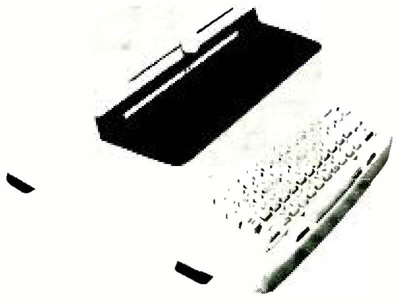


Fig. 6—Engineering model of the electroluminescent verifying keyboard.

The random-access magnetic core memory stores 4096 words (each containing 18 bits) and has a memory read-write cycle time of 5 microseconds. The two cycles available are *read-regenerate* and *write*.

The instruction control unit addresses the memory, receives the instruction word, and then generates control signals which execute the instruction accordingly. The complement of 25 instructions include *add*, *subtract*, *compare*, *load*, *store*, *read-from*, *write-in*, and *transfer*. The data-processing unit executes instructions such as, *add*, *subtract*, and *compare;* the main unit is a high-speed adder.

NEW DEVELOPMENTS IN DIGITAL COMMUNICATIONS

During the past two decades an extensive mathematical theory for the analysis of information, communication, and processing has been developed. This allows the engineer to determine certain physically achievable limits for information capacity of a transmission channel and also allows accurate prediction of error rates under specified channel conditions. It is also possible for the designer to determine optimum systems analytically representing the best theoretical performance possible under various constraint conditions.

The principal applications of information theory in digital communications have been for error protection. Many methods are being investigated for modifying the message redundancy in order to achieve higher transmission rates and lower error rates. Codes from simple parity checks to complex block coding have been developed; equipment engineers are now attempting to develop economical methods of employing these coding techniques.

System concepts including the use of feedback and adaptive systems have been developed to improve performance under certain interference conditions. The feedback system uses received information to request repetition of the incorrect portion of a transmitted message. In the adaptive systems, the characteristics of message transmitting or receiving equipments are varied to suit the existing chanel conditions.

Prolific developments in new devices, particularly solid-state, applicable to digital communications appeared during the past decade, and industry was quick to adopt a virtually complete solid-state circuit implementation. Several families of circuit modules have been developed to achieve specialized results for various military customers. Printed circuit boards such as those shown in Fig. 4 are an example of RCA's current production on militarized and transistorized digital communications equipment. The GKA-5 module (left in Fig. 4) has been standard for several years; the board shown on the right in Fig. 4 represents an *ultra-reliable* module. By ultra-reliable is meant an improved mean-time-between-failure of one to two orders of magnitude compared with that of standard military parts; connections to this module are made by permanent wire-wrap connections rather than by less reliable connectors.

Equipment miniaturization has received strong emphasis. Families of modules (small encapsulated circuits) known as *minimodules*, *micromodules*, and *advanced micromodules (nanomodules)* have been developed.

A typical printed circuit board employing minimodules is shown in the center of Fig. 4; it is about the densest packaging achieveable with conventional techniques and components. The micromodule provides an order of magnitude improvement in packaging density over that of the minimodule; families of both high-speed and medium-speed micromodule circuits have been developed for Digital Communications (printed-circuit cards employing micromodules can be seen in Fig. 9).

Fig. 7—Major MICROPAC characteristics.

GENERAL CHARACTERISTICS	
1. General Purpose	
2. 1.6 mc Clock Frequency	
3. Binary, Synchronous, Serial by Bit	
4. Alpha-numeric, Six-Bit Characters	
OPERATION TIMES (Including Memory Access)	
1. Addition	78 μ sec
2. Multiplication	944 μ sec
3. Short Multiplication (18 bits)	308 μ sec
4. Transfer of Control	78 μ sec
5. Memory Cycle (Including shifting)	39 μ sec
INTERNAL CHARACTERISTICS	
1. Word Length	38 bits, including sign and parity
2. Arithmetic	Binary, sign magnitude
3. Instruction Code	FIELDATA subset
4. Index Registers	Two (implemented in memory)
5. Memory Capacity	2048 words, expandable to 8192 words
INPUT-OUTPUT CAPABILITY	
1. Control Panel	
2. Paper Tape Reader/Memory Loader	30/300 char./sec.
3. Paper Tape Printed/Punch	15/30 char./sec.
4. One Read-Time I/O Channel	2400 bits/sec.
PHYSICAL CHARACTERISTICS	
1. Weight/Volume	100 lbs/2.5 cu. ft.
2. Power Required (DC)	350 watts
3. Environmental Conditions	-40°F to 125°F 0 to 97% RH

The advanced micromodule, or nanomodule, represents another order-of-magnitude size reduction over the conventional micromodule. In this case complete circuit functions are laid out on single micromodule wafers. A unipolar transistor, *full adder* advanced micromodule is shown in Fig. 5.

A major objective for miniaturized and tactical equipments has been the development of lower-power circuits. Recent developments of microenergy switches allowed the design of high-speed gates with less than 5-milliwatt power dissipation compared to dissipations in standard gates of close to 100 milliwatts. This low-power consumption capability is essential in highly miniaturized equipment, since it is desirable to eliminate special provisions for cooling such as fans and blowers.

New devices such as parametrons, binistors, and tunnel diodes are currently available to the circuit designer and each is being investigated for potential application in Digital Communications products.

To keep pace with the rapid developments in higher speed and smaller size of the processing electronics, advances in the state-of-the-art are required in the input-output area. In many cases input-output equipments represent a large fraction of system cost and volume. As applications of miniaturized circuits increase, the volumetric portion of input-output equipment will increase to unrealistic levels. SurfCom has been attacking the problem from the standpoint of using new techniques for the implementation of input-output equipment. Two of the most interesting and promising techniques are the use of electroluminescent panels (see article this issue by L. E. Haining) and low-mass transducers for the production of hard copy. Fig. 6 shows the engineering model of an electroluminescent verifying keyboard being developed under an advanced research and development program.

MICROPAC

The dramatic trend toward reduction of volume in digital equipment has been pioneered by several programs within RCA. The Digital Communications activity was fortunate to participate in one of the first investigations of microcircuit application to large-scale digital systems. The MicroPac is a general-purpose automatic data processor designed to demonstrate the capabilities of micromodule equipment; major characteristics are indicated in Fig. 7. The Micro-

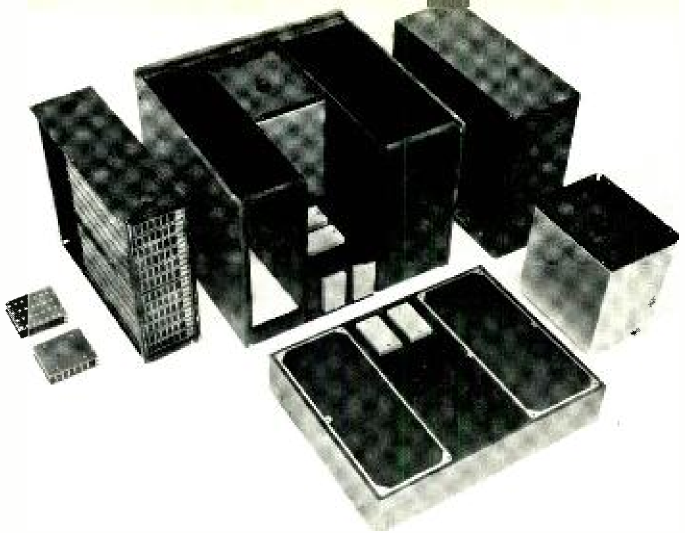


Fig. 8—MICROPAC mockup disassembled to show subsystems.

Pac is a binary synchronous digital computer operating in a serial mode at a clock frequency of 1.5 mc. It has a basic random-access memory of 2048 words, expandable in multiples of 2048 words to a maximum of 8192 words. It contains 20 mechanized instructions. Operating speeds are approximately 80 microseconds for arithmetic and transfer operations and 1000 microseconds for multiplication and division. Three types of input-output are provided: the control panel, a paper-tape reader and printer-punch, and a real-time communication channel.

A full-scale mock-up of MicroPac is shown in Fig. 8. Complete with transit case, MicroPac will weigh approximately 100 pounds and occupy approximately 2.5 cubic feet. The four major sections are: control panel, circuitry, memory, and power supply. The circuitry includes the arithmetic and control logic and the memory circuits. Approximately 1300 logic modules and 300 memory modules are required for a MicroPac with a memory word capacity of 2048. Space is available in the unit shown in Fig. 8 for two memory sections, each containing a 2048-word core memory unit. Each unit is maintained at a relatively constant temperature by a thermoelectric-control system. The power supply provides about 250-watt d-c power and 400-cps power for the circuitry cooling fans.

New packaging concepts had to be developed to employ micromodules in large-scale systems. These techniques were carefully analyzed to take into account the needs for cooling the modules, making interconnections between modules, and attaining the highest packaging density. A circuitry booklet concept (see Fig. 9) was developed to 1) achieve adequate printed wiring space between modules, 2) increase the number of connector pins per module, 3) channel the flow of cooling air to provide efficient heat transfer, and 4) increase rigidity and strength of module mounting. The circuitry booklet concept employed in the MicroPac makes many of the interconnections between micromodules by printed wiring. Therefore, a considerable amount of the machine logic is on the card and all micromodule input and output pins need not be brought out through the connector. This approach is termed *logic-on-card* and is the best approach for high-packaging density and high reliabilities. A concept for *universal logic* (i.e., where all circuit inputs and outputs are brought out through connector pins) was also developed. The micromodule universal logic approach is easier for the designer to apply but involves a loss in packaging density of about 40 to 50 percent, as shown in Fig. 9.

The results of design effort indicate that dramatic reduction of equipment volume can be readily achieved with the micromodular packaging technique of the MicroPac program. Thus, approximately 62,500 modules, or 100,000 transistors and associated components in diode transistor digital logic, may be mounted, cooled and interconnected in a single 6-foot rack.

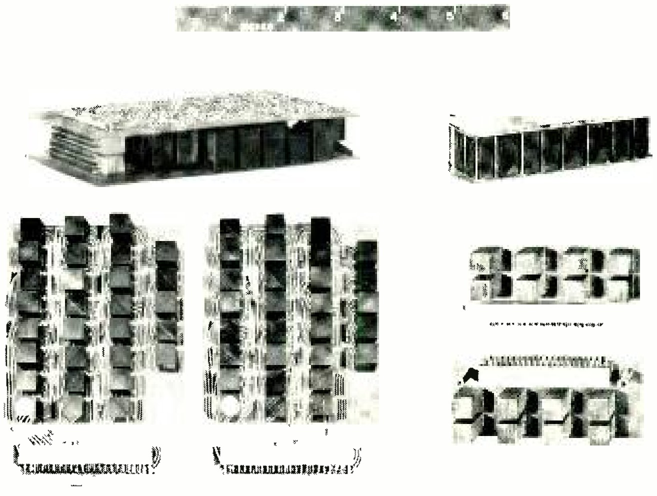
The miniaturization of logic circuitry has progressed so far that many of the other system elements represent high proportions of the over-all equipment volume. For example, in MicroPac the entire circuitry for the memory and logic occupies less than 30 percent of the machine. The memory stacks involve 25 percent of the machine, the power supply 30 percent and the control panel 15 percent. Hence, before further miniaturization becomes economically warranted, significant improvements in memory and power-supply packing density must be achieved.

THE DIGITAL COMMUNICATIONS ORGANIZATION

An organization is established in Surface Communications Engineering to handle programs in digital communications and data processing. Capabilities exist for systems study and analysis as well as circuit design, mechanical design, prototype fabrication, programming, test, and delivery.

The Digital Communications activity has been organized in four major product areas: *Data Communications*, *Tactical Data Processing*, *Subscriber & Input-Output Engineering*, and *Site Communications*. Data Communications handles modems, buffers, and code conversion equipments and complete systems using these functions. Tactical Data Processing specializes in the stored program processing systems. Subscriber & Input-Output Engineering and Magnetic Recording provide basic capabilities in digital input-output devices. Site Communications provides speech processing, human factors engineering, and audio systems capability.

Fig. 9—MICROPAC logic-on-card booklet open and meshed (left) and micromodule universal logic booklet open and meshed (right).



THE "WHITE ROOM" AT CAMBRIDGE

Employees of the DEP Surface Communications Division at Cambridge, Ohio, are justifiably proud of the new **White Room,** which started operations just four months after initial planning began. A White Room, for the benefit of the uninitiated, is a "clean" production facility in which critical and high-reliability electronic hardware is manufactured for defense purposes.

by **C. N. VALLETTE**
Surface Communications Engineering
DEP, Camden, N. J.

PRESENT MISSILE and space programs invoke reliability requirements on electronic equipment several orders of magnitude greater than that conceived possible just a few years ago. This challenge, successfully met in the research and development laboratories, is now being reflected in electronic hardware designs. To assure that high reliability in such equipment design is met, factory assembly and testing capabilities must be improved concurrently.

PLANT-WITHIN-A-PLANT

Recognizing that such improvement in manufacturing capability had to be revolutionary rather than evolutionary, RCA decided to build a unique new facility from scratch. Industry was surveyed; present and planned missile electronic programs were analyzed; specialists were consulted. From this effort criteria and specifications were produced.

The Cambridge factory already in the process of conversion from a home-instruments to a defense plant, was selected and construction crews went to work. From the bare concrete floor, the new 38,000-square-foot "plant-within-a-plant" rapidly took shape (see Fig. 1). Construction was completed in May 1961. Although a pilot project, it is simultaneously a production plant. Stringent production, quality control, and workmanship standards are applied to all hardware built in the White Room, ranging from printed-circuit minimods to complete racks of equipment.

This new White Room combines new production processes, techniques and rigid worker disciplines with tightly controlled environment.

DUST CONTROL

A major facet of the controlled environment in the White Room facility is that of dust control. Air-borne particles which settle on conductors and printed circuit boards prior to soldering or wire-wrapping contribute to field circuit failures. To minimize this possibility, the White Room specifications include rigid control over dust. An over-pressure of approximately 0.1 inch-H_2O is maintained throughout the White Room. Pressure is high in critical areas and diminishes toward the *personnel entry* and *material receiving* areas. This assures an outward flow of air to prevent the influx of air-borne contaminants into the dust-critical areas.

The air conditioning system has a 90-percent dust-filtering efficiency (National Bureau of Standards discoloration test method) and will remove 80 percent of dust particles 0.3 micron and larger. To give an idea of the size of a micron, particles smaller than 10 microns cannot be seen by the naked eye; cigarette smoke particles average 1.0 micron diameter or less. But, and it's a large "but," the actual dust count in the White Room depends on the number of people in the room and on their activity, despite the ten complete air changes per hour provided by the air filtering system.

People, it seems, directly or indirectly generate most of the air-borne contaminants which make the needle on the Royco particle counter move upscale. Skin and hair particles, cosmetics, coughs, and sneezes are direct sources of contamination; shuffling of papers, handling of tools and fixtures, even fast movement around the room are indirect contributions to the creation and stirring up of dust. Strict discipline of personnel in prohibiting smoking, eating, application of cosmetics and combing of hair in the White Room helps minimize air-borne particles; continued motivational training keeps production workers constantly alert to the dust and dirt problem.

ENTERING THE WHITE ROOM

All personnel must enter through doors marked *Personnel Entry* to take an "air shower" in a vestibule-like conditioning area; here, a rush of surrounding air removes all loose lint from clothing. At the same time, a tacky floor mat helps clean the soles of shoes. After proceeding to a locker room and exhibiting a special badge—the worker dons a hat, smock, and booties over his regular clothes; apparel is a white dacron blend, since cotton is lint-pro-

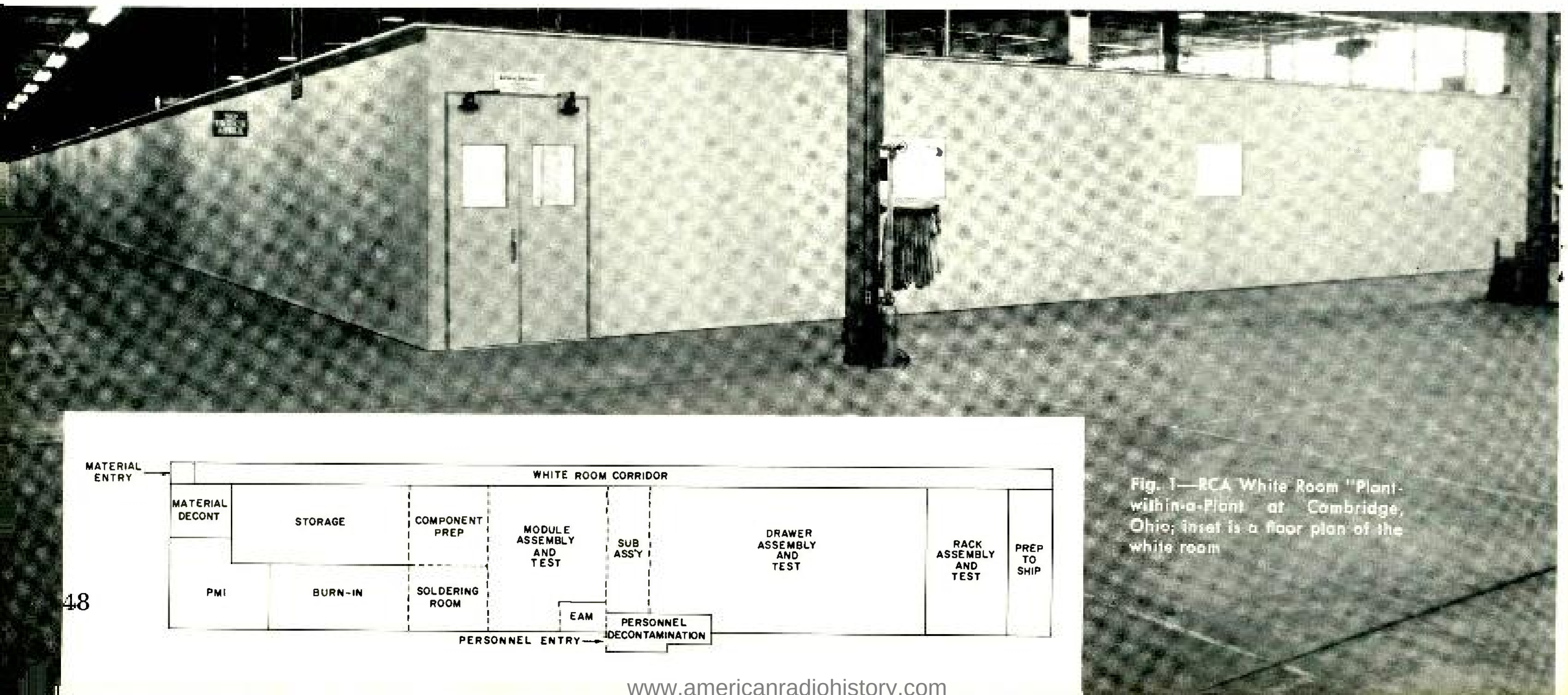


Fig. 1—RCA White Room "Plant-within-a-Plant at Cambridge, Ohio; inset is a floor plan of the white room

Fig. 2—White Room worker inserting component matrix boards in pre-conditioning racks

ducing and nylon develops static. The worker or visitor is then ready to enter the White Room proper.

FLOW OF INCOMING COMPONENTS

Crated material and components are brought into an unpacking area through a separate entry. After the heavy outer crates are removed, inner cartons and containers are moved into the *White Room Receiving* area: here, inner cartons and packing material are removed and promptly disposed of. Electrical components are individually packaged in small plastic containers, skin-paks or envelopes; no "bulk-pack" containers are used.

Material is then moved to the next area, a *Material Decontamination* room where vacuum hoses thoroughly remove remaining bits of packing material and dust. Vacuum nozzles for cleaning floors, walls, electronic hardware, and components are part of a central vacuum cleaning system with convenient hose outlets provided at strategic points throughout the White Room.

INSPECTION

Next is the *Purchased Material Inspection* (PMI) area where an assortment of gauges and instruments perform a 100% inspection of every incoming electrical component; here, an aura of cleanliness becomes noticeable; air is cool and smells clean; it is held at 72 ± 2°F throughout the White Room the year around, and relative humidity is controlled to 45 ± 5 percent. The walls and hung ceiling are a pleasant white or off-white, and the floor is a light linoleum tile. Observation of personnel in the PMI area reveals that in addition to dacron attire each inspector wears fine-mesh gloves, with rubber outer "fingerlets" on thumb and forefinger; this prevents deposits of perspiration and skin oils on component leads. Components are handled gently, with the use of tweezers in most cases.

PRECONDITIONING AND TESTING

The high-population components (resistors, capacitors, transistors, and diodes) are then delivered to the *Preconditioning area.* Here they are mounted on special matrix boards, each holding up to 200 components. Boards are fed through an automatic tester to measure parametric values, and measurements are automatically recorded on data cards by electronic accounting machines (EAM). Each component has its own "life-history" data card, and each has an individual serial number; some are so small that they can be read only with a magnifying glass.

After the component values are measured, the matrix boards are inserted in the preconditioning racks where they are subjected to a low-stress aging cycle of 500 hours. The 81 racks can handle approximately 250,000 components at a time. At the end of the cycle, the parameters are again measured and more EAM cards are punched out. Comparing initial and final measurements to determine whether the change in value in 500 hours exceeded the stringent drift criteria is a monumental task; it is accomplished by an RCA 501 computer. The computer readout indicates, by serial number, the components which must be rejected.

LEAD CUTTING

In the *Component Preparation and Storage Area,* matrix boards are removed, rejects culled out, and components sorted in accordance with their predestined position on a printed-circuit board. Leads are automatically cut and preformed by lead-forming machines; these were developed especially for high-reliability components to prevent nicking, chipping, or flaking of the gold-plated leads. No mechanical stress is placed on the components. After forming, the components are "kitted" and stored in celled styrofoam trays; each tray contains the exact assortment of components needed to assemble a printed-circuit module. Throughout the entire operation, gentle, individual treatment is afforded each component.

MODULE ASSEMBLY

In the module assembly area, about one hundred girls in spotless white dacron work at rows of formica-topped assembly benches. The relative quiet in the room and the high level of light produced by the plastic enclosed fluorescent ceiling fixtures are impressive; 100 foot-candles of minimum illumination is provided in all areas of the White Room. Contrast this with average office lighting which measures only 50 foot-candles. Many module assembly operations and all inspection operations are performed under large magnifying lenses.

Each employee is trained and indoctrinated under a comprehensive pro-

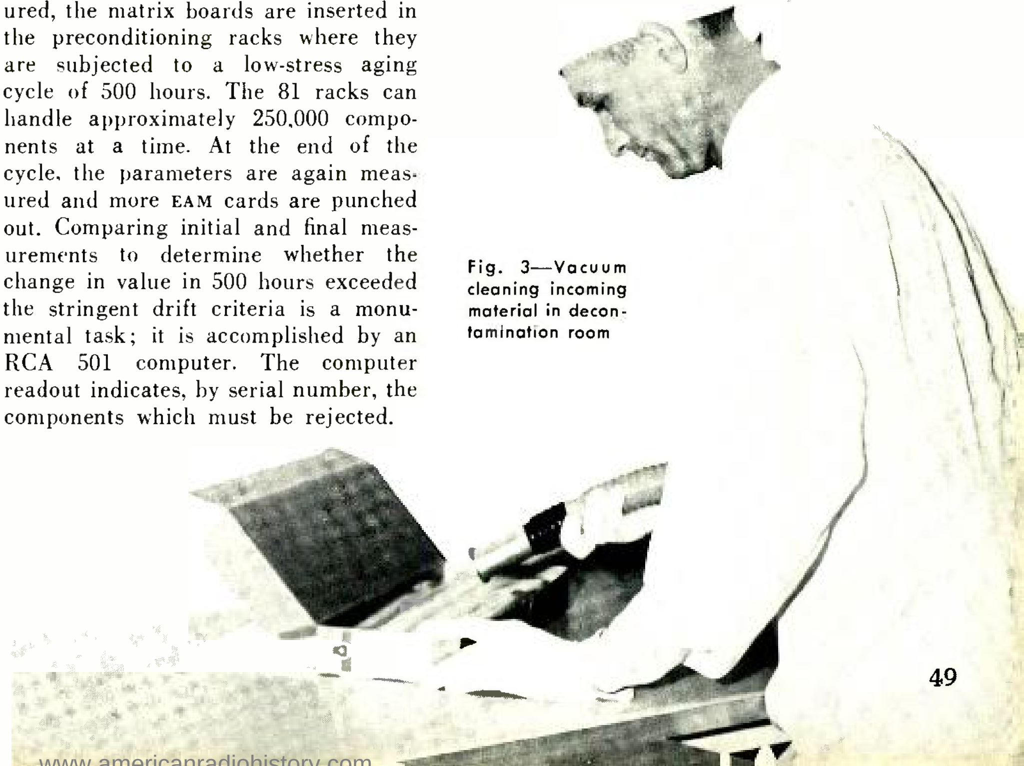
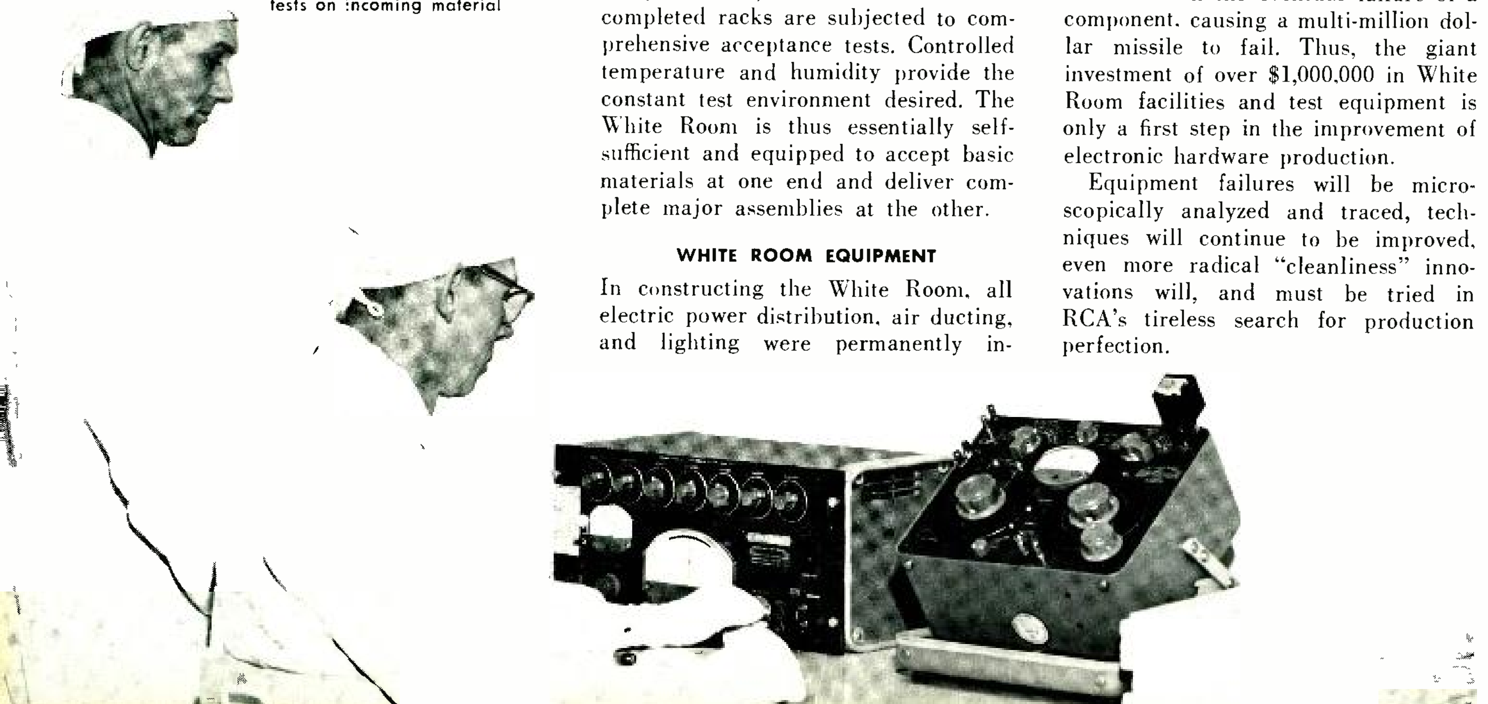


Fig. 3—Vacuum cleaning incoming material in decontamination room

C. N. VALLETTE studied engineering at Drexel Institute and at Union College where he received a BSEE degree; he is now working toward an MSEE degree at Villanova University. Mr. Vallette has been Senior Project Member in the Program Management Office for a large weapon system for the past year and a half. Prior to this, he was Communications Project Engineer on the BMEWS program at Missile and Surface Radar Division of RCA. Before joining RCA, Mr. Vallette was self-employed as an Electronics Consultant, being a Licensed Professional Engineer in Pennsylvania. Earlier he was employed at General Electric Co. for eight years in television studio equipment design. He is a Member of the IRE, AIEE, and Sigma Xi.

gram in which trainees are selected on the basis of aptitude, manual dexterity, and visual acuity. Initial orientation, motivation and training is followed by continual refresher courses to maintain high motivation. To "tweezer-fit" small components into very small holes on a printed circuit board is a painstaking process at best; to do it with gloves on would seem almost impossible. As might be anticipated, occasionally a component is dropped to the bench top, a fall of about 10 inches. The operator immediately signals another girl who shuffles through a stack of EAM cards, takes the card and dropped component and replaces them with a new card and component. There is a good reason for this meticulous procedure: a component dropped only a few inches may fracture internally and this defect might not show under test. Rather than risk failure of an entire rack of equipment, it is safer to discard the component before it can become part of a weapon system. Since each component is serialized, data cards are changed so the computer can record the fact that "resistor 6KJ505 on board 43MN20 in drawer 123R62"; has now been replaced with "resistor 6KJ917" — all part of information control. Cards are fed through a wall slot to EAM equipment kept in a separate room; this prevents dissemination of chaff generated by the card punching machines.

Fig. 4—Performing electrical tests on incoming material



After assembly, modules are taken to the *Solder Room* where boards are soldered and sprayed. The solder room has special exhaust treatment to minimize dissemination of fumes, vapors, and other airborne particles. After leaving the solder room, soldered boards are inspected under a high-power lens for wetting and quality of every soldered joint and module path. Any question of doubt as to soldering perfection subjects the module to a reject tag; it must then be reworked or discarded.

RACK ASSEMBLY

In another area of the White Room, drawers and racks are assembled and wired. All harnessing and connectors are automatically wire-checked on a tape-programmed tester. Modules no longer plug into multipin connectors in the drawers; a "wire-wrap" technique is used in which bare wire is wrapped in a tight spiral around the protruding connector pins, giving a more reliable connection than solder could provide. Subassemblies and completed drawers are individually, dynamically checked; in the final test area, completed racks are subjected to comprehensive acceptance tests. Controlled temperature and humidity provide the constant test environment desired. The White Room is thus essentially self-sufficient and equipped to accept basic materials at one end and deliver complete major assemblies at the other.

WHITE ROOM EQUIPMENT

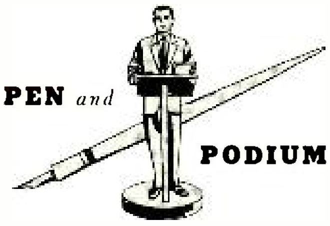
In constructing the White Room, all electric power distribution, air ducting, and lighting were permanently installed in and above the ceiling. After installation of the white ceiling panels, hard-surfaced asbestos composition wall panels were erected and the seams sealed. Thus, areas may be rearranged to accommodate different mixes of production with minimum reconstruction time and cost. All machinery and main distribution panels are located outside the White Room to allow their maintenance and modification without entry to the clean area. The junctures of walls, ceiling and floor are concaved and building support columns enclosed to eliminate corners and crevices where dust can hide; there is no unnecessary trim to catch dust. Many of the walls have picture windows which serve a dual purpose: they allow the production worker to feel less isolated, and visitors can observe White Room activity without physical entry.

Fig. 5—Assembly of components on printed circuit board

CONCLUSION

Despite rigidly controlled environment, strict personnel and material-handling disciplines, and other extreme precautions taken, it is still considered possible that a speck of contamination could be concealed in a soldered joint and result in the eventual failure of a component, causing a multi-million dollar missile to fail. Thus, the giant investment of over $1,000,000 in White Room facilities and test equipment is only a first step in the improvement of electronic hardware production.

Equipment failures will be microscopically analyzed and traced, techniques will continue to be improved, even more radical "cleanliness" innovations will, and must be tried in RCA's tireless search for production perfection.



PEN and PODIUM

Based On Reports Received Over a Period of About Two Months

ELECTRON TUBE DIVISION

Nuvistor Two-Meter Converter
R. M. Mendelson: *RCA Ham Tips*, May 1961

Stoichiometry of Ceramic Dimensional Control
W. C. Allen: *American Ceramic Society Bulletin*, June 1961

Porous Nickel Oxide
I. S. Solet: *Nature*, July 1, 1961

An Internal Disappearing Filament for Maintaining Constant Temperature in a Vacuum
I. S. Solet: *Review of Scientific Instruments*, July 1961

A Shear-Compensated Hysteresigraph for Thin Magnetic Films
M. J. Schindler: *Review of Scientific Instruments*, July 1961

A New Method of Magnetron Tuning and Frequency Stabilization
R. M. Salzer and R. Steinhoff: *IRE International Convention Record*, July 1961

Some Special Sample Mounting Devices for the X-Ray Fluorescence Spectrometer
E. P. Bertin and R. J. Longobucco: Conference of Applications of X-Ray Analysis, Denver, Colorado, August 7-9, 1961

Nuvistor Preamplifier for Amateur Receivers
M. R. Adams and P. B. Boivin: *RCA Ham Tips*, August 1961

The Nuvistor Triode as a Video IF Amplifier
K. W. Angel and J. Gote: *IRE Transactions on Broadcast and TV Receivers*, August 1961

A Stable Low-Noise Tunnel-Diode Downconverter
A. Presser and F. Sterzer: IRE WesCon Meeting, San Francisco, Calif., August 22-25, 1961

Stable Low-Noise Tunnel-Diode Frequency Converters
F. Sterzer and A. Presser: *Proceeding of the IRE*, August 1961

A Low-Cost L-Band Oscillator Package for Air-Traffic Control Transponders
P. W. Gipslis: National Aerospace Electronics Convention, Dayton, Ohio, May 8-10, 1961

A High-Gain C-X-Band Traveling-Wave Tube for Drone Applications
W. J. Caton and H. J. Wolkstein: National Aerospace Electronics Convention, Dayton, Ohio, May 8-10, 1961

Traveling-Wave Tubes for Satellite Microwave Repeater Applications
M. Nowogrodzki: National Aerospace Electronics Convention, Dayton, Ohio, May 8-10, 1961

Low-Temperature Solder Glasses in the Electron-Tube Industry
J. L. Gallup: Symposium of American Scientific Glassblowers Society, New York City, May 26, 1961

Design Considerations for Modulators and Converters Using a New Miniature Beam-Deflection Tube
M. B. Knight and J. T. Maguire: *Electronic Equipment Engineering*, May 1961

A Rapid Method for Estimation of Grid-Cathode Contact Potential
A. G. F. Dingwall: *Advances in Electron Tube Techniques 1960*, May 1961

The Nuvistor Triode as a Video IF Amplifier
K. W. Angel and J. T. Gote: IRE Conference on Broadcast and Television Receivers, Chicago, Ill., June 19-20, 1961

Picture Characteristics of Image Orthicon and Vidicon Camera Tubes
R. G. Neuhauser: SMPTE Convention, Toronto, Canada, May 7-12, 1961

The Plasma Triode—A Low-Temperature Thermionic Converter
W. B. Hall and K. G. Hernqvist: 15th Annual Power Sources Conference, Atlantic City, N. J., May 9-11, 1961

Comparative Evaluation of Image Orthicon and Vidicon Camera Tubes
F. S. Veith and R. G. Neuhauser: TV Symposium, Montreux, Switzerland, May 18, 1961

Ceramics for Electron Devices
M. Berg: Symposium of American Scientific Glassblowers Society, New York City, May 26, 1961

How Vacuum-Tube Problems Are Solved by the Use of Radio-Isotopes
H. A. Stern: *Advances in Electron Tube Techniques 1960*, May 1961

Degassing and Permeation of Gases in Tube Materials
R. H. Collins and J. C. Turnbull: *Advances in Electron Tube Techniques 1960*, May 1961

The Effects of Oxygen on Emission of Oxide Cathodes
W. G. Rudy: *Advances in Electron Tube Techniques 1960*, May 1961

SEMICONDUCTOR AND MATERIALS DIVISION

An Electric-Fence Control Circuit
C. R. Turner and J. Eimbinder: *Electronics Illustrated*, July 1961

Materials and Form Factors for Micromodule Inductors
G. G. Hauser: *IRE International Convention Record*, July 1961

Determining Permissible Dissipation for Silicon Power Transistors
J. Eimbinder and C. R. Turner: *Electronic Design*, August 16, 1961

An Ultra-Low-Distortion Transistorized Power Amplifier
C. F. Wheatley and H. M. Kleinman: *IRE Transactions on Broadcast and TV Receivers*, August 1961

DATES and DEADLINES

Professional Meetings and Calls for Papers

MEETINGS

Oct. 23-25, 1961: East Coast Conf. on Aerospace & Navigational Electronics, IRE-PGANE; Lord Baltimore Hotel, Baltimore, Md. *Prog. Info.:* W. C. Vergara, Dir., Adv. Res. Dept., Bendix Radio, Towson 4, Md.

Oct. 23-25, 1961: URSI-IRE Fall Mtg.; URSI; IRE-PGAP, CT, I, IT, & MTT; U. of Texas, Austin, Tex. *Prog. Info.:* A. W. Straiton, P. O. Box 8026, University Station, Austin 12, Tex.

Oct. 24-26, 1961: 8th Ann. Mtg. of PGNS Symp. on Aerospace Nuclear Propulsion, IRE-PGNS, AEC, NASA; Hotel Riviera, Las Vegas, Nev. *Prog. Info.:* P. M. Uthe, Lawrence Radiation Lab., U. of Calif., Box 808, Livermore, Calif.

Oct. 25-26, 1961: Reliability Assurance Techniques for Semiconductor Specifications Conf., AIA, ASQC, EIA, IRE-PGRQC, JEDEC, (with participation by DOD, USAF, USA, USN); Dept. of Interior Auditorium, 18th and C Sts., N.W., Washington, D. C. *Prog. Info.:* W. H. von Alven, ARINC Research Corp., 1700 K St., N.W., Wash. 6, D. C.

Oct. 26-28, 1961: 1961 Electron Devices Mtg., IRE-PGED, Sheraton-Park Hotel, Wash., D. C. *Prog. Info.:* Dr. I. M. Ross, Bell Telephone Labs, Rm. 2A-329, Murray Hill, N. J.

Oct. 30-31, 1961: IRE/EIA Radio Fall Mtg., Hotel Syracuse, Syracuse, N. Y. *Prog. Info.:* Virgil Graham, EIA Eng. Dept., 11 W. 42 St., N. Y. 36.

Nov. 6-8, 1961: Spec. Tech. Conf. on Non-Linear Magnetics, IRE-PGEC, PGIE; AIEE; Statler-Hilton Hotel, Los Angeles, Calif. *Prog. Info.:* Dr. Ted Bernstein, Space Technology Labs., POB 95001, L. A. 45, Calif.

Nov. 7-9, 1961: 7th Conf. on Radio Interference Reduction & Elec. Compatibility, IRE-PGRFI, 3 Military Services, ARF, Ill. Inst. of Tech., Chicago, Ill. *Prog. Info.:* H. M. Sachs, Armour Res. Foundation, 10 W. 35 St., Chicago, Ill.

Nov. 13-16, 1961: 7th Ann. Conf. on Magnetism & Magnetic Materials, IRE, AIEE, AI Phys., ONR, & AIME; Hotel Westward Ho, Phoenix, Ariz. *Prog. Info.:* F. E. Luborsky, G. E. Res. Lab., P. O. Box 1088, Schenectady, N. Y.

Nov. 14, 1961: Electronic Systems Reliability Symp., IRE; Linda Hall Library Aud., 5109 Cherry St., Kansas City, Mo. *Prog. Info.:* A. Goldsmith, Wilcox Electric, Kansas City 27, Mo.

Nov. 14-16, 1961: Northeast Electronics Research & Engineering Mtg. (Nerem), IRE; Somerset Hotel & Commonwealth Armory, Boston. *Prog. Info.:* F. K. Willenbrock, Harvard Univ., Cambridge 38, Mass.

Nov. 24-25, 1961: American Physical Soc., Univ. of Chicago & Windermere Hotel, Chicago, Ill. *Prog. Info.:* K. K. Darrow, 538 W. 120 St., New York 27, N. Y.

Nov. 27-30, 1961: ASME Winter Annual Mtg., Statler Hilton Hotel, N.Y.C. *Prog. Info.:* ASME Mtgs. Dept., 345 E. 47th St., New York 17, N. Y.

Nov. 30-Dec. 1, 1961: IRE Conf. on Vehicular Communications, IRE-PGVC; Hotel Radisson, Minneapolis, Minn. *Prog. Info.:* H. V. T'Kach, 620 N. 6th St., Minneapolis 11, Minn.

Dec. 12-14, 1961: Eastern Joint Computer Conf. (Ejcc), IRE-PGEC, AIEE, ACM; Sheraton Park Hotel, Wash., D. C. *Prog. Info.:* George Heller, IBM, Bethesda, Md.

CALLS FOR PAPERS

Dec. 27-29, 1961: American Physical Soc., U. of Calif., Los Angeles, Calif. *DEADLINE:* Abstracts, **10/20/61** to H. A. Shugart, U. of Calif., Berkeley 4, Calif.

Jan. 22-26, 1962: 68th Ann. Mtg. American Mathematical Soc. (with Mathematical Assn. of America), Cincinnati, Ohio. *DEADLINE:* Abstract, **11/17/61** to American Mathematical Society, Providence, R. I.

Jan. 24-27, 1961: American Physical Society; New York City. *DEADLINE:* Abstracts, **11/10/61** to K. K. Darrow, 538 W. 20th St., New York 27, N. Y.

Feb. 7-9, 1962: Natl. Winter Conv. on Military Electronics, IRE-PGMIL, Air Force; Ambassador Hotel, Los Angeles, Calif. *DEADLINE:* Unclassified and Confidential classified papers: 100-wd. abstract, 500-wd. summary, short author's biography *prior* to **11/15/61** (authors responsible for obtaining all necessary clearances for Confidential papers); unclassified abstracts to M. E. Brady, Chrmn., Technical Program Comm., Space Technology Labs., P. O. Box 95001, Los Angeles 45, Calif.; Confidential abstracts to Maj. J. L. Blilie, USAF, USAF Systems Command, Regional Off., 6331 Hollywood Blvd., L. A. 28, Calif.

Feb. 14-16, 1962: 1962 Intl. Solid-State Circuits Conf., IRE, AIEE, U. of Penna.; Sheraton Hotel and U. of Penna., Philadelphia, Pa. *DEADLINE:* 300-500 wd. abstracts, **11/1/61** to R. B. Adler, Rm. C-237 MIT Lincoln Lab., Lexington, Mass.

Mar. 26-29, 1962: 1962 IRE Intl. Conv.; Waldorf Astoria and N. Y. Coliseum, New York City. *DEADLINE:* (3 cys. each, 100-wd. abstract and 500-wd. summary) **10/20/61** to Dr. D. B. Sinclair, IRE Inc., 1 East 79th St., New York 21, N. Y.

April 11-13, 1962: Sthwst. IRE Conf. & Elec. Show (Swireco), Rice Hotel, Houston, Tex. *DEADLINE:* Abstract, **12/1/61** to Prof. M. Graham, Rice Univ., Computer Project, Houston 1, Tex.

May 1-3, 1962: Spring Joint Computer Conf., IRE-PGEC, AIEE, ACM; Fairmont Hotel, San Francisco, Cal. *DEADLINE:* Papers, **11/10/61** to R. I. Tanaka, Lockheed Missiles & Space Co., 3251 Hanover St., Palo Alto, Cal. *NOTIFY INTENT TO SUBMIT ASAP.*

May 6-10, 1962: Electrochemical Soc. 1962 Spring Mtg., Statler-Hilton Hotel, Los Angeles, Cal. *DEADLINE:* 75-wd. abstract **12/15/61** to Electrochemical Soc. Hqrs., 1860 Broadway, New York 23, N. Y. *Underline name of author who will present paper.*

May 14-16, 1962: Natl. Aerospace Electronics Conf. (Naecon); IRE-PGANE; Dayton, O. *DEADLINE:* Abstracts, **1/5/62** to R. Nordlund, NAECON, 1414 E. Third St., Dayton, O.

May 22-24, 1962: Natl. Microwave Theory & Techniques Symp., IRE-PGMTT, Boulder, Colo. *DEADLINE:* 50-100 wd. abstracts and 500-1000 wd. summaries, with up to 6 figures suitable for reproduction, **12/18/61** to R. W. Beatty, NBS Boulder Labs, Boulder, Colo.

May 23-25, 1962: Natl. Telemetering Conf., IRE-PGSET, AIEE, IAS, ARS, ISA; Sheraton Park Hotel, Wash., D. C. *DEADLINE:* Abstracts, **12/15/61** to D. G. Mazur, Code 620, Goddard Space Flight Center, Greenbelt, Md.

May 23-26, 1962: Acoustical Soc. of America, New York City. *DEADLINE:* Abstracts, **2/21/62** to W. P. Mason, Bell Telephone Labs., Murray Hill, N. J.

June 18-21, 1962: 4th US Natl. Congress of Applied Mechanics, US Natl. Comm. on Theoretical & Applied Mechanics, AIChE, AMS, APS, ASCE, ASME, IAS, SESA; U. of Calif., Berkeley, Calif. *DEADLINE:* Papers & Abstracts, **1/1/62** to W. Goldsmith, Dept. of Applied Mechanics, U. of Calif., Berkeley 4, Calif.

June 25-30, 1962: Symp. on Electromagnetic Theory & Antennas; The Technical University of Denmark, Oster Voldgarde 10G, Copenhagen K., Denmark. *DEADLINE:* 1200-wd. summaries, **12/1/61** to H. Lottrup Knudsen, above address. *(USSR expected to undertake two sessions.)*

Aug. 21-24, 1962: Western Electronics Show and Conf. (Wescon), IRE, WEMA: Los Angeles, Calif. *DEADLINE:* Approx. **May, 1962.** *For info.:* Wescon, 1435 La Cienega Blvd., L. A., Calif.

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

INDUSTRIAL ELECTRONIC PRODUCTS

Frequency Division Multiplexing on Transoceanic Cables
W. Lyons: IRE Convention, New York City, March 22, 1961

Automatic Electronic System for Handling International Telegrams
E. D. Becken and R. K. Andres: 5th National Symposium on Global Communications, Chicago, Illinois, May 24, 1961

Multiprogramming the RCA 601
R. D. Smith: Annual Meeting Association for Computing Machinery, Los Angeles, Calif., Sept. 1961.

A Measurement of Alertness Based on Electroencephalographic Time Series Analysis
D. S. Himmelman: 4th International Conference of Medical Electronics, New York City, July 1961

Effects of Impulse Noise on Digital Data Transmission
A. B. Bodonyi, *Thesis*, Polytechnic Institute of Brooklyn, June 1961

Research Methods in Origin and Destination Analysis
N. G. Vivona: Operation Research Society, Chicago, Illinois, June 1961

True Motion Radar Indicator
C. E. Moore: Norwegian Engineering Conference, Lillhammer, Norway, and Navigational Conference, Oslo, Norway, June 1961.

Allocation of Frequencies for the Mobile Radio Service—Should Changes Be Made?
G. A. Olive: Wes Con, San Francisco, Calif., August 1961

ASI—An Anti-Saturation Inverting Building Block for High Speed Computer Logic
H. Ditkofsky and A. I. Pressman: WesCon, San Francisco, Calif., August 1961

High Density Digital Magnetic Tape Recording
C. N. Batsel and W. L. Ross: WesCon, San Francisco, Calif., August 1961

A Tunnel Diode Tunnel Rectifier 15 Nanosecond Memory
M. M. Kaufman: WesCon, San Francisco, Calif., August 1961

Control of Intermodulation Interference
N. C. Colby: Meeting of Association of Police Communications Officers, Long Beach, Calif., August 1961

DEFENSE ELECTRONIC PRODUCTS

A Modern Acoustic Missile Launch Locator
R. M. Carrell and R. Richter: *Journal of Audio Engineering Society*, July 1961

Some Aspects of Airborne Radar in the Defense Against Submersibles
Dr. G. V. Nolde: *Proceedings of 7th Annual Radar Symposium*, University of Michigan, May 31-June 2, 1961

Analysis of a Tri-Dimensional Feed Horn Support Structure
Z. M. Slusarek: National Conference and Exhibition of the IRE Professional Group on Product Engineering and Production, Philadelphia, Pa., June 15, 1961

Navigation for Rendezvous in Space
A. Schneider, E. Wallner, E. Capen, C. King: Institute of Navigation, Williamsburg, Va., June 30, 1961

An Optical Selection Device
E. Kornstein: Conference on Optical Instruments and Techniques, London, July 13, 1961

Design Considerations for Micromodule Equipment
B. I. Andrews: WesCon, IRE, San Francisco, Calif., August 22, 1961

Instrumentation Television
M. D. Ross: Society of Photographic Instrumentation Engineers, Los Angeles. Aug. 7, 1961

TV Surveillance for Missile Launchings
J. Castleberry: Society of Photographic Instrumentation Engineers, Los Angeles, Aug. 7, 1961

Dependancy of Crosstalk on Upper and Lower Cutoff Frequencies in Pam Time Multiplexed Transmission Paths
A. M. Straube: WesCon, IRE, San Francisco, Calif., Aug. 22, 1961

Communication System Noise Level Nomograph
W. J. Connor: *Electronic Design*, Aug. 61 issue

Noncritical Negative Resistance Amplifiers
T. G. Marshall: WesCon, IRE, San Francisco. Calif., Aug. 22, 1961

Envelope Delay of M-Derived Filters
J. Frank: *Electronic Design*, Sept. 61 issue

Implementation of Large Information-Retrieval Problems
J. Minker: Gordon Research Conference. New Hampton. N. H., July 5, 1961

A Computer for Geographers
L. T. Reinwald: Association of American Geographers, East Lansing, Michigan, August 29, 1961

RCA LABORATORIES

Characteristics of a Uranium-Doped Calcium Fluoride Maser
Z. J. Kiss, J. P. Wittke: 19th Annual Conference on Electron Device Research, Troy, N. Y., June 22, 1961

Modulation and Detection-Lecture I. The Digital Communications System
K. H. Powers: University of Penna., School of Enginering, Phila., Pa., June 26, 1961

Modulation and Detection-Lecture II. Optimum Waveforms
K. H. Powers University of Penna., School of Engineering, Phila., Pa., June 26, 1961

Mechanisms of Electroluminescence
E. E. Loebner: Gordon Research Conf. on the Chemistry & Metallurgy of Semiconductors, Tilton, N. Hampshire, July 14, 1961

Determination of Zirconium and Hafnium With Xylenol Orange & Mothylthymol Blue
K. L. Cheng: 18th International Congress of Pure and Applied Chemistry, Montreal, August 14, 1961

Spectrophotometric Determination of Traces of Gold With 4,4′—BIS (Dimethylamino) Thiobenzophenone
K. L. Cheng: International Symp. on Microchemical Techniques, Penn State University, University Park, Pa. August 15, 1961

The Crystal Structure of Tetramethyl Ammonium Mercury Tribomide
J. G. White: American Crystallographic Assoc., Boulder, Colorado, August 1961

The Direct Conversion of Solar Energy Utilizing Photovoltaic Cells
P. Rappaport: U. N. Conference on New Energy Sources, Rome, Italy, Aug. 21-31, 1961

Photoelectronic Analysis of High-Resistivity Gallium Arsenide
R. H. Bube, J. Blanc, H. E. MacDonald: International Conference on Photoconductivity, Cornell University, Ithaca, Aug. 21-24, 1961

Photo-Hall Effect in Photoconducting Insulators
R. H. Bube, H. E. MacDonald, J. Blanc: International Conf. on Photoconductivity, Cornell University, Ithaca, N. Y., Aug. 21-24, 1961

High Electric Fields in Cadmium Sulfide
R. Williams: International Conf. on Photoconductivity, Cornell University, Ithaca, N. Y., Aug. 21-24, 1961

Large Photovoltage in Crystals With Stacking Faults—A Proposed Model
D. O. North: International Conf. on Photoconductivity, Cornell University, Ithaca, N. Y., August 21-24, 1961

Electrooptical and Electromechanical Effect in Ternary V-VI-VII Compounds
R. Kern: International Conf. on Photoconductivity, Cornell University, Ithaca, N. Y., Aug. 21-24, 1961

Low-Cost Photovoltaic Conversion of Solar Energy
P. Rappaport, H. I. Moss: United Nations Conference on New Energy Sources, Rome, Italy, Aug. 27, 1961

The Sputtering of Silicon Carbide by Positive Ion Bombardment
R. E. Honig: Conference on Mass Spectrometry, Munich, Germany, Aug. 28-Sept. 1, 1961

Mass Spectrometric Studies of Solid Surfaces
R. E. Honig: Joint Conf. on Mass Spectrometry, Oxford, England, Sept. 12-15, 1961

Ordering of Cations in Spinelis
A. Miller: International Conf. on Magnetism and Crystallography, Kyoto, Japan, Sept. 1961

Contribution to Magnetic Anisotropy From Cations Which Locally Distort the Crystal Lattice
P. K. Baltzer: International Conf. on Magnetism and Crystallography, Kyoto, Japan, Sept. 1961

Anistropy of the Spin-Spin Correlation Function
P. J. Wojtowicz: International Conf. on Magnetism and Neutron Diffraction, Kyoto, Japan, Sept. 25, 1961

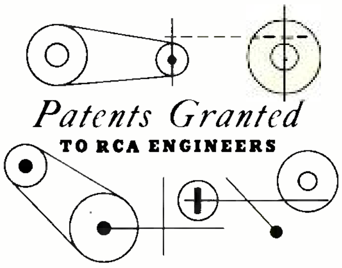
Image Processing in Synthetic Visual Organs
E. E. Loebner, T. Henneberger: International Biophysics Congress, Stockholm, Sweden, Aug. 3, 1961

High Electric Field in CdS
R. Williams: Photoconductivity Conf., Cornell Univ., Ithaca, N. Y., Aug. 21, 1961

Recognition of the Spoken Word by Machine
H. F. Olson, H. Belar: 2nd Annual Bionics Symp., Cornell Univ., Ithaca, N. Y., Aug. 30-Sept. 1, 1961

Threshold Logic—A Theoretical Basis for Neuron Models of Perception
R. O. Winder: 2nd Annual Bionics Symp., Cornell Univ., Ithaca, N. Y., Aug. 30-Sept. 1, 1961

Basic Photoconductive Mechanisms in Electrophotography
W. Ruppel: Coll. Fundamental Processes in Photography, Zurich, Sept. 11-14, 1961



Patents Granted
TO RCA ENGINEERS

Based on Summaries Received over a period of about two months

SEMICONDUCTOR AND MATERIALS DIVISION

Frequency Converter
2,997,578—August 22, 1961; J. W. Englund

HOME INSTRUMENTS DIVISION

Kinescope Coupling Circuit
2,995,622—August 8, 1961; C. W. Hoyt & L. P. Thomas, Jr.

Tunable Oscillator Circuit
2,997,579—August 22, 1961; T. Murakami and J. C. Achenbach

RCA VICTOR COMPANY, LTD. MONTREAL

Tube Failure Detection Circuit
2,994,817—August 1, 1961; J. Fuglesang

ELECTRON TUBE DIVISION

Electron Tube Mount
2,992,348—July 11, 1961; P. Okstein

Shielded Magnet-Assembly for Color-Kinescopes Etc.
2,991,381—July 4, 1961; R. H. Hughes

Tri-Color Phosphor Screens of the Mosaic Variety
2,991,383—July 4, 1961; A. E. Hardy

Shockproof Mount
2,991,390—July 4, 1961; T. M. Shrader

Self-Shielded Electron Tube
2,995,673—August 8, 1961; O. H. Schade, Sr.

Electron Tube Construction
2,996,637—August 15, 1961; L. P. Garner and W. N. Parker

INDUSTRIAL ELECTRONIC PRODUCTS

Relay Circuit
2,992,367—July 11, 1961; R. S. Sinn

Perforation Sensing Circuit
2,994,476—August 1, 1961; R. S. Sinn

Relaxation Oscillators
2,994,838—August 1, 1961; E. Eberhard

Pulse Generator
2,994,855—August 1, 1961; F. C. Hassett and A. J. Kline, Jr.

Radar
2,991,466—July 4, 1961; I. F. Byrnes and C. E. Moore

DEFENSE ELECTRONIC PRODUCTS

Transistor Tone Control Feedback Circuit
2,994,040—July 25, 1961; F. D. Waldhauer

Developing Apparatus
2,991,754—July 11, 1961; S. W. Johnson

Detection of Signal in Noise
2,991,358—July 4, 1961; C. F. Wilcox

Ear Pads
2,990,553—July 4, 1961; R. E. Ulrich and G. A. Taylor

Sensitivity-Control-Circuits for Radar Systems and the Like
2,991,468—July 4, 1961; F. L. Post

Radar Test Set
2,991,469—July 4, 1961; R. J. McCurdy

Automatic Correction Circuit for Stored Electrical Data
2,995,744—August 8, 1961; F. D. Covely and A. C. Stocker

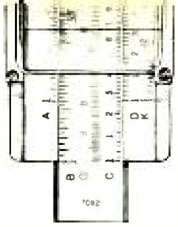
Pulse Width Modulator
2,998,578—August 29, 1961; H. G. Shore

Signal Generator Having an Output Linearly Related to An Input Function
2,998,573—August 29, 1961; R. Beagles

Moving Target Indication
2,998,599—August 29, 1961; L. E. Matson, Jr. and W. W. Weinstock

Radar Target Position Plotting Apparatus
2,998,481—August 29, 1961; P. Forman

Engineering NEWS *and* HIGHLIGHTS



ASTRO AUTHOR TEAM, HUTTER, INSLEE, MOORE, GET TOP SMPTE JOURNAL AWARD; KROLAK, DEP APP. RES. AND NEUHAUSER, ETD, RECEIVE HONORABLE MENTION

RCA engineers and physicists dominated the recent *Journal Awards* announced by the Society of Motion Picture and Television Engineers. **Dr. E. C. Hutter, J. A. Inslee,** and **T. H. Moore,** of the DEP Astro-Electronics Division, Princeton, received the top *Journal Award* for the most outstanding paper published during 1960 in the *Journal of the SMPTE*. Their paper, "Electrostatic Image and Signal Recording," described what the Award Committee termed ". . . an ingenious method of image recording which could have endless possibilities in this space age . . .". [EDITOR'S NOTE: *See the* RCA ENGINEER, *Vol. 6, No. 6, April-May 1961, for their article on this technique.*]

Concurrently, the SMPTE named author team **L. J. Krolak,** DEP Applied Research, Camden, (and author this issue), **R. G. Neuhauser,** Electron Tube Div., Lancaster, (author last issue) and **W. P. Seigmund,** American Optical Co., to receive one of four *Honorable Mention Awards,* for papers published in the same period. Their paper was "Fiber Optics—A New Tool in Electronics".

The awards were made on Oct. 3 at the 90th SMPTE Convention, Lake Placid Club, N.Y.

DEP-BURLINGTON GETS CONTRACT FOR HYDROFOIL AUTOPILOT

At Burlington, Mass., the DEP Aerospace Communications and Controls Div. will undertake a new Navy contract to research and develop an autopilot system for hydrofoil craft. (See Blanchard and Wellinger, *Automatic Control for Hydrofoil Craft,* RCA ENGINEER Vol. 7, No. 1, June-July 1961, p.28.

The program covers the lateral and longitudinal control system for fully submerged foil craft in the 110-ton and 300-ton classes. Work will be performed by the same group of engineers that developed the automatic control system for the 5-ton hydrofoil craft *Sea Legs* (see article).

The autopilot system design will utilize unique advances that led to the development of an RCA Ultrasonic Height Sensor earlier this year, according to **W. B. Kirkpatrick,** Manager, Marketing, Aerospace Communications and Controls Division.

This transistorized device provides instantaneous and constant measurement of the changing height of waves from crest to trough, enabling the hydrofoil craft to proceed smoothly, without loss of speed, through automatic adjustment as dictated by the sensor. Other applications for the instrument include seaplanes (for use in landings) and oceanographic ships (for use in sea state measurements).

WEST COAST M&SR RENAMED DATA SYSTEMS DIVISION BY DEP

The efforts of DEP in the data-handling field have become increasingly important to the Department of Defense and RCA. Accordingly, this work will be concentrated at the Van Nuys, California facility and the name of the division is changed from West Coast Missile and Surface Radar Division to *Data Systems Division*, DEP.

H. R. Wege is assigned the responsibility for directing all data-handling programs being carried on by DEP. Mr. Wege will make his headquarters at the Van Nuys location and will report to **A. L. Malcarney,** Executive Vice President, DEP.

During the period of this assignment, the Moorestown Missile and Surface Radar Division and the Major Defense Systems Division will be directed from Mr. Malcarney's office.

BURLINGTON DEP PLANT GETTING SECOND ADDITION IN THREE YEARS

Construction has begun on the addition of 175,000 square feet to the Burlington plant, the second addition within three years of its initial opening. The plant is occupied by DEP Aerospace Communications and Controls Div. Completion of the addition is scheduled for early 1962.

The Burlington facility, located on a 157-acre tract, was formally opened in October, 1958. The one-story building, at the junction of Routes 3 and 62, just off Route 128, originally consisted of 132,000 square feet of laboratory space. In 1959, a 75,000-square-foot addition was erected.

The new addition, which will house office, service and manufacturing facilities, will feature a high-bay area 30 feet in height, to give capability for assembly of large military gear such as missiles.

DORDICK NAMED RESEARCH ASSOCIATE IN MEDICAL ELECTRONICS

H. S. Dordick, of the DEP Aerospace Communications and Controls Division, Camden, has been named a Research Associate in Medical Electronics in the Division of Obstetrics and Gynecology, Pennsylvania Hospital, Philadelphia, Pa. The renewable one year appointment allows official affiliation with the hospital in furthering research in applying electronics techniques to medicine. —*D. Dobson.*

RCA 130 ALERT EQUIPMENT (SEE BUCHMAN ARTICLE, THIS ISSUE)

Included here are pictures of the new RCA 130 ALERT equipment described by Buchman elsewhere in this issue, received too late for inclusion with the article. Below: remote equipment; right, central equipment.

FIRST-HALF 1961 PROFITS IN HOME INSTRUMENTS SET 10-YR. RECORD

The first half of 1961 was the most profitable in RCA home-instrument operations in the past ten years. Profit after taxes in the first half of 1961 for this phase of RCA business, which includes color and black-and-white TV receivers, phonographs, and radios, was 4 percent ahead of 1955, the previous high for the past decade.

In addition, total home-instrument sales for the first six months were the best for the period since 1957. Color-TV receiver profits during the period were 45 percent ahead of the initial six months of 1960—especially significant, since color-TV-set manufacturing and marketing first turned into a profitable venture in 1959 and then in 1960 reached the seven-figure profit level. At the same time, black-and-white TV operations has also showed profit improvement.

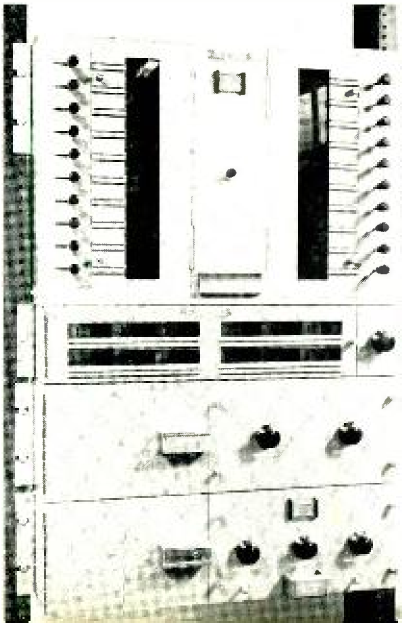
Improved operating performances in all categories, plus economics resulting from a tighter, more efficient organization have contributed to RCA's best showing since the early boom years of black-and-white TV. Initial distributor and dealer orders of the 1961-62 line of RCA Victor television, phonograph and radio merchandise were especially heavy in the summer 1961, and inventory levels throughout distribution are exceptionally low, circumstances that justify optimism for the rest of 1961.

RCA RECEIVES TWO CONTRACTS FOR ATLAS CHECKOUT

The DEP Data Systems Division, Van Nuys, Calif., has received two contracts totalling $1,917,000 from General Dynamics/Astronautics for Atlas Missile launch control and checkout equipment.

The equipment will be used at the Pacific Missile Range, and for accelerated activation of the *F* series Atlas Missile sites. The work will include engineering study and procurement of launch control and checkout equipment, and manufacture of additional Mobile Automatic Programmed Checkout Equipment (MAPCHE) to be used at the *F* series Atlas sites.

The West Coast Division has designed, manufactured and installed stationary and mobile automatic checkout equipment for the Atlas *D, E,* and *F* series sites.



DR. RAJCHMAN NAMED DIRECTOR OF NEW COMPUTER RESEARCH LAB

Dr. J. A. Rajchman has been named Director of the Computer Research Laboratory at the RCA Laboratories, Princeton, by **Dr. J. E. Hillier,** Vice President, RCA Laboratories. Dr. Rajchman, who is nationally known for his work in computer research, numbers among his many contributions the magnetic core memory system, and has for the past few years headed an RCA Laboratories group in work on high-speed computer techniques.

Dr. Rajchman has been with RCA since 1935. He received his PhD from the Swiss Federal Institute of Technology. Prior to WW II, he made pioneering contributions to development of the electron multiplier tube and, during WW II, was among the first to apply electronic techniques to digital computers for fire-control. Subsequently, his work produced a succession of new information-storage techniques and devices—the Selectron electrostatic storage tube, magnetic core memory, magnetic switching circuits, the transfluxer, and the magnetic plate memory.

Dr. Rajchman has received a number of *RCA Achievement Awards* and in 1960 was recipient of the *Morris Liebmann Memorial Prize* of the IRE for his work on magnetic devices for information processing. He is a *Fellow* of the IRE, and Member of the APS, ACM, and Sigma Xi.

RCA PUBLISHES CURRICULUM GUIDE FOR ELECTRONICS IN HIGH SCHOOLS

The Communications Products Dept., Meadowlands, Pa., has published a curriculum guide to assist secondary schools in establishing electronics programs.

The volume contains outlines of sample courses, progressing from classroom instruction in fundamentals to laboratory work with new components.

The book is priced at $2.00 and may be obtained from authorized RCA electronic training products distributors in major cities or by writing to *RCA Audio Products, Meadow Lands, Pa.*

UNIVERSAL TRANSISTOR CLOSER TO REALITY

A new silicon transistor that can perform the jobs of up to 40 percent of the more than 2,000 transistor types now on the market has been developed by the Semiconductor and Materials Div. The development is a significant step towards a "universal" transistor.

The new unit is the first in the industry adaptable to such a wide variety of uses. The first public showing of the 2N2102 was made at the 1961 Western Electronics Show and Convention in San Francisco.

The new 2N2102 transistor results from newly perfected manufacturing technology. Triple diffusion and planar manufacturing techniques have been wedded, both relatively new and highly exacting processes, in a single transistor.

Scheduled for commercial introduction into the military and industrial markets early in September, the 2N2102 is expected initially to sell in the $12.00 range.

DEP APP. RES. WORK IN NEURAL NETWORKS

DEP Applied Research, Camden, engineers (l. to r.) F. L. Putzrath, T. B. Martin, and E. P. McGrogan discuss a neuron model Each presented papers on neural networks and models recently at the National Electronics Conference in Chicago, Oct. 9-11, 1961. In the background is the DEP Applied Research lab setup containing 100 neuron models. (EDITOR'S NOTE: Watch for an RCA ENGINEER article on neural networks in a coming issue.)

RCA SCIENTISTS DEVELOP IMPORTANT TECHNIQUE TO MASS-PRODUCE MATERIAL FOR SUPERCONDUCTIVE MAGNETS

A new mass-production process for rapid and continuous growth of crystalline niobium-tin has been developed at the RCA Laboratories that opens possibilities for the first time for widespread practical use of simple superconductive magnets, using no power.

The new mass-production process was developed by a research team including the co-inventors, **Dr. J. J. Hanak** and **J. L. Cooper,** working under the direction of **Dr. F. D. Rose,** Associate Laboratory Director, Materials Research Laboratory. During recent phases of the project, the group has been aided by **K. Strater** and **L. Gnau,** of the Electron Tube Division, Harrison.

The promising characteristics of niobium-tin as a superconductor have been known for some time, but application has been delayed by absence of a process for making it in wire form in quantity. A superconductive magnet, wound with niobium-tin wire, or made with a thin film of the material, could produce very strong magnetic fields with no input of power except for a small initial pulse to start the current flowing. Its special properties keep it superconductive even when the magnetic field rises to a very-high level.

The technique was developed in a continuing two-year program for the Air Force Systems Command. Among many possible applications, the niobium-tin wire could be used in a magnet weighing only about 20 pounds, exclusive of accompanying refrigeration equipment, and started with a 6-volt battery pulse, to produce a magnetic field over a volume now requiring a 100-ton electromagnet operated continuously by 100 kw. Another possibility is replacement of the relatively cumbersome electromagnet used in masers. It is a development which could rival in importance the development of mass-production techniques for transistors.

SURFCOM OFFERS RCA SPECIAL NETWORK-ENGINEERING CAPABILITIES

The Advanced Systems Group of the DEP Surface Communications Systems Laboratory, New York, now has available for use of the Corporation-at-large a specialized capability in the field of network design and theory.

The group has combined the traditional filter design techniques with EDP computer techniques, and can now reduce the effort required to determine filter characteristics and manufacturing tolerances. Use is being made of a library of digital-computer programs dealing with various phases of network analysis and synthesis compiled especially for the purpose.

These programs have proven highly effective in facilitating design of complicated filters, and in making possible realization of stringent or unusual specifications. Among the routines presently utilized is one that accomplishes a complete analysis of the general ladder-type network, both with ideal and dissipative elements, involving functions to at least the 30th order. Included in this category of networks are the frequently used Butterworth, Tchebychev, and Cauer filters.—*C. W. Fields.*

PERT METHOD OFFERED TO RCA 501 USERS

The PERT method (Program Evaluation Review Technique) for planning, controlling, and checking business and scientific projects is now being offered as a free "Package" to users of RCA 501 DEP systems. This PERT method is an adaptation of that used by the Navy and Air Force for administering their large-scale development programs. This program has been implemented by the Management Science Section, EDP Division, Cherry Hill, N. J. The computer program being offered is supported by instruction manuals and consultation.

[EDITOR'S NOTE: *Watch for an article on PERT in a coming issue of the* RCA ENGINEER].

C. D. MITCHELL LEAVES ETD COMMERCIAL ENGINEERING

The Commercial Engineering activity of the Electron Tube Division lost one of its most distinguished members when **Clair D. Mitchell** retired on July 31st after a fruitful career of 39 years with RCA.

In addition to his extraordinary contributions to the technical and editorial excellence of Electron Tube Division and Semiconductor and Materials Division publications, Mr. Mitchell pioneered in the difficult fields of electronics definitions and graphical symbols, serving on technical committees of the IRE, the American Standards Association, and the Joint Electron Device Engineering Council. He also assisted the Electronic Industries Association in the development and use of a workable type-registration system for electron tubes and semiconductor devices.

He was employed as a tube engineer by the Westinghouse Lamp Company from 1922 to 1928, when he transferred to RCA. He was a member of the staff of Commercial Engineering since the activity was started in 1930, and served as Mgr. of Cathode-Ray Tube and Power Tube Commercial Engineering from 1954 to 1959. From 1959 until his retirement, he was Administrator, Commercial Engineering Coordination.

Mr. Mitchell is a Sr. Member of IRE, and was awarded a *Life Membership* this year. He received the *RCA Victor Award of Merit* in 1953 for his *"continuous, persistent, and skillful attention to those important details which make the difference between mediocrity and excellence."*

C. D. Mitchell

ENGINEERS IN NEW POSTS

In the Semiconductor and Materials Division, **K. M. McLaughlin**, Mgr., Computer Products and Materials Dept., has named **R. D. Lohman** as Mgr., Computer Device Engineering. Also in that Department, **F. E. Vinal**, Mgr., Memory Products Operation, announces his organization to include: **R. V. James**, Mgr., Quality Control; **H. J. Schwartz**, Plant Mgr., Needham Plant; and **L. A. Wood**, Mgr., Materials Engineering. **E. O. Johnson**, Chief Engineer, SCM Div., has appointed **Dr. R. B. Janes** as Mgr., Advanced Applications.

In Industrial Tube Products Dept., ETD, **E. E. Spitzer**, Mgr., Power Tube Operations, has named **P. T. Smith** as Mgr., Power Tube Applied Research Laboratory. Mr. Smith has been a Technical, Director, C-Stellarator Associates.

In DEP, the organization of the newly renamed Data Systems Division (Van Nuys; formerly West Coast M&SR) has been announced by **H. R. Wege**, Vice President and General Mgr., to include: **G. Q. Decker**, Mgr., Marketing Dept.; **A. C. Bos**, Mgr., Business and Product Planning; **G. F. Breitweiser**, Chief Engineer and Projects Mgr., Engineering Dept.; **W. A. Bennett**, Administrator, Program Coordination; **M. A. Maurer**, Plant Mgr.; **M. E. Collins**, Mgr., Product Assurance; and **R. C. Willman**, East Coast Representation. Mr. Wege is serving as Acting Mgr., Data Systems Center, Bethesda, Md.

In the DEP Moorestown Missile and Surface Radar Div., **S. N. Lev**, Division Vice President and General Mgr., announces his staff to include: **W. O. Carlson**, Administrator, ARPA Scientific Liaison; **F. J. Drakeman**, Plant Mgr., Moorestown Plant; **J. L. Frederick**, Mgr., Marketing Dept.; **A. L. Hammerschmidt**, Chief Engineer, Engineering Dept.; **R. A. Newall**, Mgr., Tradex-Press Program; **P. A. Piro**, Mgr., Range Instrumentation Program; and **M. W. Rogers**, Mgr., Product Assurance.

In DEP, **W. G. Bain**, Vice President and General Manager, Communications and Aerospace, has announced the organization of the Minuteman Program as follows: **R. C. Bitting**, Mgr., Minuteman Program; reporting to him are: **C. G. Arnold**, Mgr., Systems Engineering; **R. V. Luongo**, Mgr., Contract Administration; **I. K. Munson**, Mgr., Production; **J. R. Neubauer**, Mgr., Research and Development; **T. C. Reeves**, Mgr., Reliability.

In the Broadcast and TV Equipment Division, (now under Group Executive Vice President, **C. M. Odorizzi**, see story) **C. H. Colledge**, Division Vice President and General Manager, names his staff to include: **T. L. Dmochowski**, Administrator, International Liaison; **D. F. Hahn**, Mgr., *Radiomarine* Marketing Dept.; **R. L. Holtzheimer**, Mgr., Broadcast and TV Equipment Manufacturing Operations; **A. F. Inglis**, Mgr., CCTV, Film Recording, and Scientific Instruments Dept.; **J. P. Taylor**, Mgr., Marketing Administration; **E. C. Tracey**, Mgr., Broadcast Equipment Dept.; **M. A. Trainer**, Mgr., Electronic Recording Products Dept.; and **V. E. Trouant**, Chief Engineer, Engineering. Mr. Inglis' staff includes: **A. M. Miller**, Mgr., Film Recording and TV Systems Operations, whose group, in turn, includes: **J. L. Pettus**, Mgr., Engineering; and **L. H. Harmon**, Mgr., Manufacturing. Mr. Taylor's staff includes **S. W. Pike**, Mgr., Functional Design; and **J. W. Wentworth**, Mgr., Educational Electronics, in addition to the various advertising managers for Broadcast, Communications, and Industrial Controls, and others. Mr. Tracey's Staff includes: **T. M. Gluyas**, Mgr., Broadcast Studio Engineering; and **J. E. Young**, Mgr., Transmitting Equipment and *Radiomarine* Engineering.

In the Communications and Controls Division (now under Group Executive Vice President **C. M. Odorizzi**, see story) **S. E. Arnett**, Mgr., Graphic Arts Dept., has appointed **H. C. Gillespie** as Mgr., Engineering.

T. A. SMITH NOW DIRECTS EDP EXCLUSIVELY; C. M. ODORIZZI ASSUMES RESPONSIBILITY FOR RCAC, BROADCAST, AND COMMUNICATIONS-CONTROLS

On August 30, 1961, **J. L. Burns**, President, RCA, announced that because of the increasing importance of electronic data processing, **T. A. Smith**, Executive Vice President, would devote his entire attention to the management and direction of these activities. Mr. Smith will continue to report to Mr. Burns, as in his previous responsibilities as Executive Vice President, IEP. [Editor's Note: *Mr. Smith is an author this issue; see p. 2.*]

In addition to the activities presently reported to him, **C. M. Odorizzi**, Group Executive Vice President, will now be responsible for RCA Communications, Inc.; the Broadcast and TV Equipment Division, and the Communications and Controls Division. Mr. Odorizzi continues to report to Mr. Burns.

J. J. GRAHAM APPOINTED DIVISION VICE PRESIDENT, OPERATIONS, EDP

J. J. Graham has been appointed to the newly created position of Division Vice President, Operations, of the Electronic Data Processing activity. Mr. Graham had served as Division Vice President and General Manager, IEP Communications and Controls Division, since May 1960. He will be responsible for the direction of all engineering in commercial systems operations, data communications and custom projects, and industrial computer systems. Mr. Graham also will be responsible for the manufacture of all EDP equipment as well as the marketing of custom projects and industrial computer systems.

DUNLEAVY NAMED GENERAL MANAGER, COMMUNICATIONS AND CONTROLS DIV.

Appointment of **Francis J. Dunleavy** as General Manager, Communications and Controls Div. was announced recently.

Mr. Dunleavy, formerly General Manager, IEP Industrial Controls, joined RCA in 1959 as General Manager of the Industrial and Automation Division. In his new position, he will direct the activities of the Detroit Industrial and Machine Tool Dept., Microwave Dept., and Aviation Equipment Dept. Mr. Dunleavy succeeds **J. J. Graham**.

DEGREES GRANTED

H. J. Ghandour, Broadcast Transmitter Equipment Engineering, Camden, received his MSEE from the University of Pennsylvania in June 1961.—*S. F. Dierk.*

H. Gillis, DEP Applied Research, Camden, received his MS in Physics from the University of Pennsylvania in June 1961.
—*F. W. Whittier*

PROFESSIONAL ACTIVITIES

DEP-ACC, Camden: **D. B. Dobson**, Systems Support Engineering, (and RCA Engineer Ed Rep) has been named Eastern District Publicity Chairman of the Aerospace Technical Conference to be held in Washington, D.C., in late-summer, 1963. **O. T. Carver** attended the SETE Design Course in New York.

RCA Laboratories, Princeton: **L. E. Flory** was Chairman of the Conference Committee for the 4th International Conference on Medical Electronics, combined with the 14th Annual Conference on Electrical Techniques in Medicine and Biology, in New York City.

DEP-M&SR, Moorestown: **A. J. Mannino** was Transactions Chairman for the 6th Symposium on Quality Controls Methods and Management of the American Soc. for QC, at Penn State University. **H. D. Greiner** is Philadelphia Section Conference Representative for the 11th Mid-Atlantic Conference of the ASQC; he is also Membership Committee Chairman for the Philadelphia Section.

EDP: **T. T. Patterson** (Pennsauken), served on the Conference committee and moderated a Session at the 1961 IRE Conference on Technical-Scientific Communications. **M. Bauman**, Sr. Scientific Applications Representative (Cherry Hill), is conducting a Technical Session on "Automatic Programming" at the Oct. 19 Philadelphia Section Dinner Meeting of the ASQC.

RCA Svc. Co.: At a joint meeting of the ASQC and the IRE-PGRQC, **H. D. Voegtlen** will moderate a panel on "Professionalism in Reliability and Quality Control" on Nov. 28, 1961.

DEP-SurfCom, Camden: **C. W. Fields** served as Arrangements Chairman for the 1961 IRE Conference on Technical-Scientific Communications.

DEP App. Res., Camden: **F. W. Whittier** and **M. G. Pietz** served on the Committee for the 1961 IRE Conference on Technical-Scientific Communications.

DEP-MDS, Moorestown: **W. Dennen** and **M. W. Nachmann** served on the Conference Committee for the 1961 IRE Conference on Technical-Scientific Communications. Mr. Dennen also moderated the opening Keynote Session. **R. R. Welsh** spoke on "Survival Insurance in the Missile Age" at the Associate Group Meeting of the Philadelphia Section, ASME.

WOODWARD NAMED TECHNICAL CONSULTANT FOR DEP-ACC

J. D. Woodward, formerly Chief Engineer, Camden Engineering Dept., DEP Aerospace Communications and Controls Div., has been named Technical Consultant for the Division.

In this new capacity, Mr. Woodward is responsible for providing guidance to the Division Vice President and General Manager of ACC, **I. K. Kessler**, in technical matters, for coordination of technical plants and policies for the Division, and for the integration of the technical capabilities at the Camden and Burlington locations to optimize Division effectiveness. In his new position, he continues to report to Mr. Kessler.

REGISTERED PROFESSIONAL ENGINEERS

Dr. G. H. Brown, Vice President, Engineering .... PE 11889, New Jersey

H. C. Huber

P. J. Riley

HUBER REPLACES ANSCHEUTZ AS ACC ED REP; RILEY ASS'T SURFCOM ED REP FOR CAMBRIDGE

In the DEP Aerospace Communications and Controls Division, Camden, **H. C. Huber** has taken over the Editorial Representative duties formerly held by **E. Anscheutz.** In the DEP Surface Communications Division, Editorial Representatives **C. W. Fields** and **R. E. Patterson** will be assisted by **P. J. Riley,** who they have named as an Assistant Editorial Representative to handle the Cambridge, Ohio, SurfCom activities. Both will serve on **F. W. Whitmore's** DEP Editorial Board.

H. C. Huber (Cdr., USN, ret.) joined RCA in August of this year as Staff Engineer, Communications Engineering, ACC, immediately after his retirement from the U.S. Navy. He graduated from the U.S. Naval Academy in 1942 (BS) and was assigned various duties in shipboard fire-control, ASW, and AEW operations. He later graduated from the Aviation Electronics Officer's School and acted as Electronics Officer in Navy ASW and AEW squadrons. He has over 3500 hours of flight time as a pilot of multi engine aircraft. He has done R&D work in sonar, radar, and communications. Immediately prior to his retirement from the Navy, he was responsible for R&D programs in air-borne communications, IFF, AEW radar, and air-borne data-processing.

P. J. Riley, Mgr., Product Assurance and Value Improvement Engineering, SurfCom, Cambridge, received his BA in Physics from Temple U. in 1951. After engineering and engineering-management positions with Burroughs, Remington-Rand Univac and Boonton Radio Corp., he joined RCA in 1958 as Sr. Project Engineer in Central Engineering, DEP Staff. There he worked on digital-module design for BMEWS, Atlas, micromodules, and DAMP, and on formulation and implementation of DEP engineering-standards projects. He moved to SurfCom in 1959 as a Leader on Project AMIE, responsible for product assurance and value engineering. In April of this year, he was named to his present position, and is responsible for all reliability, value improvement, and human-factors engineering at Cambridge. He is a Sr. Member of the IRE, and a Member of the AIEE and the Franklin Institute.

S. H. WATSON NAMED FELLOW OF THE STANDARDS ENGINEERS SOCIETY

The Standards Engineers Society has conferred the award of *Fellow* upon **S. H. Watson,** Mgr., Standards, RCA Staff, Camden, N.J. The award was formally announced and presented at the Society's tenth Annual Meeting in Chicago, Sept. 20, 1961.

G. RUSSELL SELECTED FOR GRADUATE STUDY PROGRAM

In the DEP Missile and Surface Radar Div., Moorestown, **G. Russell,** of DAMP Project Engineering, has been selected for the RCA Graduate Study Program. He will pursue graduate studies at the University of Pennsylvania, while continuing his RCA engineering work on a part-time basis.—*T. Greene*

Pictured above are the men who generate article ideas and work with RCA ENGINEER authors in the big DEP Moorestown Missile and Surface Radar Division. They also keep news of engineering and professional activities coming to the Editors. L. to r.: F. Anderson, Ass't Ed Rep; R. Howery, RCA ENGINEER Ed Rep; T. Greene, Ass't Ed Rep; and H. Brelsford, Ass't Ed. Rep.

M&SR NAMES HOWERY ED REP; ANDERSON, BRELSFORD, GREENE ASS'T ED REPS

At the DEP Moorestown Missile and Surface Radar Division, **R. W. Howery** is serving as RCA Engineer Editorial Representative. He is being aided by H. A. Brelsford, F. W. Anderson, and T. G. Greene as Ass't Ed Reps., (see photo, above). All serve on F. W. Whitmore's DEP Editorial Board. [Editor's Note: *Readers are reminded that* **I. N. Brown** *now serves as Ed Rep for the Major Defense Systems Division at Moorestown.*]

H. A. Brelsford, Mgr., Mechanical Dethe University of Kansas in 1948. Upon graduation he joined the RCA Radar Microwave and Receiver Design Activity. In 1952, he became Leader of the Receiver Sub-unit. In July 1958, he became Mgr. of the Receiver Unit, responsible for receiver and frequency-control systems. In December, 1959, Mr. Howery was appointed Mgr., Advanced Technique Development, for the applied research and development of techniques for future radar systems, including MHD AC-power generation, hydromagnetic stability and turbulence, high-energy fast-pulse power systems, movable plate capacitor systems, light-weight radars, light modulators, signal filtering, optical signal processing, auto- and cross-correlation, and 3-D Displays. Mr. Howery has a Professional Engineers License from the State of New Jersey and is a member of the IRE..

H. A. Brelsford, Mgr, Mechanical Development and Design Microwave Activity, Moorestown Missile and Surface Radar Division, received his BSME from Newark College of Engineering in 1938, and credits in EE from Drexel Institute. Joining RCA in 1938, Mr. Brelsford has been with the Electron Tube Division, and the former Defense Engineering Products Div. prior to moving to Moorestown. Promoted to Group Leader in 1947, he was responsible for supervision of the SHORAN Group which produced both manual and automatic high precision bling-bombing equipment. At M&SR, he has managed activities which have produced transmitting, computing, microwave, and other equipment. Mr. Brelsford holds a Professional Engineering License in the State of New Jersey. He has three patents and is author of several engineering articles. He is a member of PGPEP, IRE, and other professional organizations.

F. W. Anderson graduated from Brooklyn Polytechnic Institute with a BEE Degree in 1940 and obtained an MSEE degree from Harvard University in 1941. He served for 4½ years as a USN radar officer during WWII, and is now a Commander, USNR. For ten years he was with Bell Telephone Laboratories, in electronic circuit design of telephone and military equipment. For two years he was manager of an ballistic-missile instrumentation operation at GE. Mr. Anderson is now Radar Equipment Engineering Manager of three Electrical and one Mechanical D&D Engineering Units in the Radar Data Conversion Engineering Section, DEP-Moorestown M&SR. He is a member of Tau Beta Pi and Eta Kappa Nu.

T. G. Greene obtained his BSEE including an additional year studying Management Engineering, at Rensselaer Polytechnic Institute. He joined RCA in 1942 as a Radar Testman, and then served as a USAAF Radar Officer in WWII. Returning in 1948, Mr. Greene served for five years on the staff of EPD Engineering doing engineering personnel work. In 1953, he joined M&SR Engineering as Leader of the General Electrical Engineering Unit. Mr. Greene was responsible for the development of a program to use the BIZMAC Computer to design a complete interconnection of a major electronic system, applied in the cabinet wiring for BMEWS. In February, 1959 Mr. Greene joined Radar Projects Engineering and assumed responsibility for the DAMP Research Center Operation. He was also responsible for an extensive training program for RCA Service Company Personnel manning the U.S.A.S. American Mariner. Since January 1961, he has been responsible for Technical Coordination within the Radar and Instrumentation Systems activity.

ED REPS COOPERATE ON THIS ISSUE

The "displays" material featured in this issue touches upon work done in a number of activities in RCA. To assemble such a feature series of articles took cooperative, special effort on the part of the RCA men below: l. to r.: F. W. Whittier, ED Rep, DEP Applied Research, Camden; G. DeLong, Electron Tube Div., Lancaster; C. A. Meyer, RCA ENGINEER Engineering Editor, Electron Tube Division, Harrison; and W. G. Fahnestock, Ed Rep, Electron Tube Division, Lancaster.

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