RCA Engineer

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18th Anniversary Issue

Technical planning . . . business growth

By now it should be evident to all engineers and managers in RCA that electronics technology remains firmly established as one of RCA's major resources for its future growth. However, such conviction should not lead us to the assumption that we have returned to "business as usual" (meaning to the way it was twenty or thirty years ago.)

Our world has changed. We no longer have the simplistic luxury of being among the few possessors of scarce technologies to be exploited in the vacuum of a large, unaddressed marketplace. Today technology is plentiful and is shared with many competitors with engineering competence equal to our own. New technologies will continue to be developed but on ever higher planes of sophistication. New market opportunities will continue to emerge, but they will be more difficult to address and, more and more frequently, will depend on the application of electronic technology in fields other than those which we have traditionally considered our own.

Excellence in advanced technologies is, and will be, an absolute essential for business success in this changed world but, by itself, it will not be enough. Total and realistic business planning by competent and involved individuals who are above planning by rote will be the other essential ingredient for success and future growth. I firmly believe that engineers, with their objectivity, cost consciousness and common sense, must involve themselves in the business planning process and must appreciate its significance to their work.

J. Hillier
Executive Vice President
Research and Engineering
Princeton, N.J.

Our cover

... is a multiple exposure of the precision-static-torroid deflecting yoke — a key development in RCA's highly successful large-screen, narrow-neck 110° color tv system. The 110° system has allowed RCA to enhance its technical product leadership in the international market. **Photo credit: Tom Cook**, RCA Laboratories.

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RCA Engineer

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

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

Contents

18th Anniversary

editorial input

about this issue

Most issues of the *RCA Engineer* deal with a specific theme and provide rather complete coverage of a particular business area or technology of interest to RCA. One disadvantage of this thematic approach, however, is that it does not usually present a complete picture of the technical breadth and diversity of the corporation.

Therefore, we set aside one issue each year—the anniversary—to publish representative papers from every corner of RCA.

In this, the eighteenth anniversary issue, fifteen different activities are represented among the nineteen papers, and the contents vary as widely as the locations of the authors.

As may be expected in such an issue, survey or introductory-type papers dominate. Brown (p.11) and Mesner (p.30) cover the past, present, and future of television in space. Vilkomerson's introduction to ultrasonic holography (p.6) points toward a technique for displaying images of otherwise inaccessible information contained within opaque structures (e.g., a human body).

Feldstein (p.56) demonstrates the advantages of electroless plating in several applications in the electronics industry, including the fabrication of semiconductor devices, printed circuits, color kinescopes, and decorative parts.

Rounding out the survey-type papers, Isom (p.47) describes RCA's role in 4-channel sound, past and present.

In a tutorial vein, Tyree (p.18) provides guidelines useful in designing binary PSK communications equipment; Granieri (p.65) offers several hints for control system designers; and Schindler (p.81) describes a computer application useful for designers of microwave integrated circuits.

Two management related papers—engineering graphics (Farrell, p.3) and systems engineering management (Lurcott, p.34)—and one division profile—Globcom (Williamson, p.52)—are the semi technical contributions to this issue.

Several other papers in this issue describe equipment, systems, or techniques that represent significant projects within RCA.

This eighteenth anniversary issue is broad and comprehensive—but there was not room enough in one issue to give a complete technical picture of the corporation today. The next issue will be another anniversary-type broad enough in scope to encompass many more activities.

Hopefully, through several issues, both thematic and general, we can capture the technical and business forces at work within RCA.

— J.C.P.

Future issues

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

Corporate management conference
Thyristors
Power tube testing
NBC election returns
Computer-aided design
Advanced receiver development
COS/MOS memories
Automated test facility
Unmanned spacecraft design
Popcorn noise in Op Amps

Discussions of the following themes are planned for future issues:

Global communication
Broadband information systems
SelectaVision systems
Communications, command, control
RCA Ltd. engineering
Consumer electronics

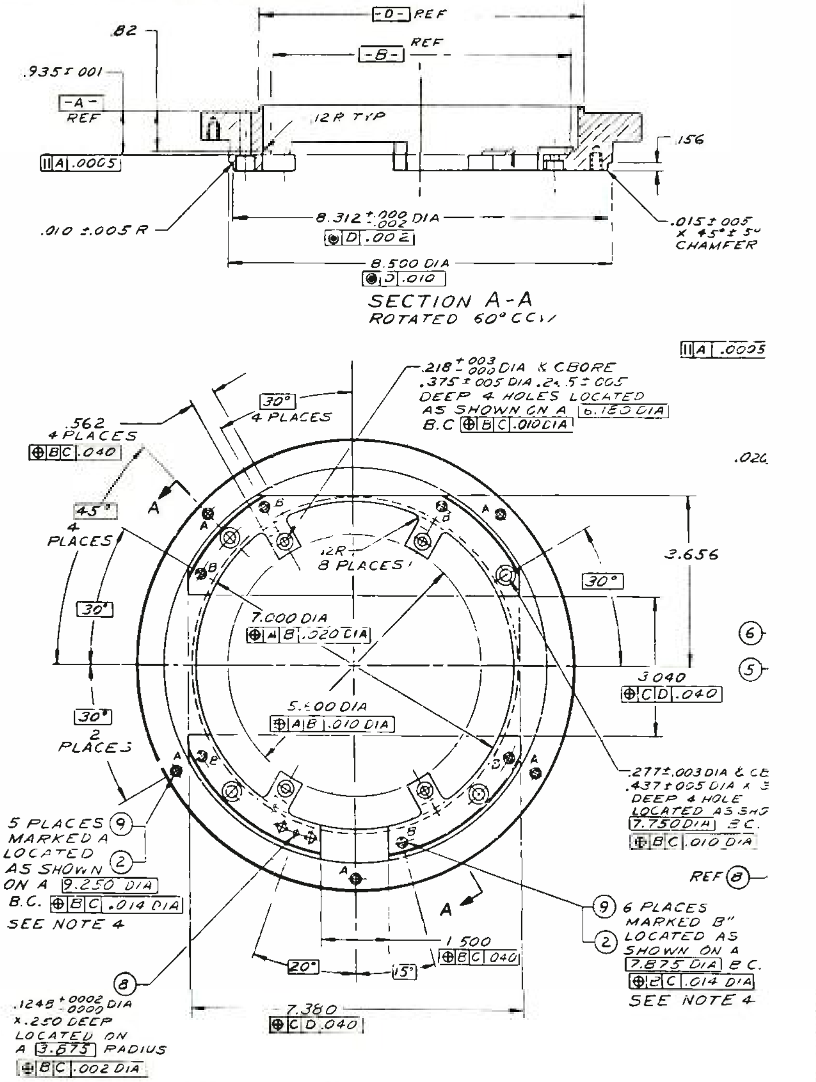
The Engineer and the Corporation

Engineering graphics and college training

Arthur T. Farrell

Both Industry and engineering colleges have a dual responsibility in teaching and training graphics to potential engineers. Industry should assume its responsibility of investing adequate time to train the beginning engineer in the graphics system peculiar to any given company. It may even be cost effective to have the beginning mechanical engineer spend some time on the drawing board, actually preparing drawings for an interim period of time. The colleges should look very deeply into their curricula and be certain that the courses are seasoned with the proper amount of graphics and engineering drawing. This training should take place through the complete four-year program to ensure that the relevant literacy in graphics is continually brought into industry with each engineer.

Drawings . . .
the universal language of the engineer



Is there a communication gap?

KNOWLEDGE OF GRAPHICS and the understanding of the engineering drawings should be a prerequisite for all engineers who use and/or approve engineering drawings. I am unable to comprehend how an engineer can function effectively without a commanding knowledge of "The Language of the Engineer", that is the engineering drawing. After discussions with several recent mechanical and electrical engineering college graduates, I was left with the impression that not only is engineering graphics paid too little attention in curricula, but its inherent value is not recognized or understood. As a result, our educational system has failed to make the potential engineer fully aware of the basic reason for the existence of his profession, i.e. to produce a hardware or software end item which can be sold for a profit.

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Arthur T. Farrell, Mgr., Drafting, Aerospace Systems Division, Burlington, Mass., graduated from Franklin Technical Institute in 1950 and has attended Northeastern University and Lowell Technological Institute. Mr. Farrell joined RCA in 1956 as a Mechanical Draftsman and since that time has worked at all levels of Drafting as a Designer, Leader, Manager and finally to his present position of Manager of the Drafting Group at ASD, Burlington. In addition to his responsibilities in the Drafting management function he has taught an after hours Basic Drafting Course for non-drafting personnel for several years. Mr. Farrell is a member of the RCA G&CS Documentation Management Committee, EIA G31 Drafting Committee, and G&CS Drafting Managers Committee. He serves as an active member of the Industrial Advisory Board for Wentworth Institute & Nashoba Valley Technical High School in the field of design drafting.

This situation has arisen because college curricula, particularly in the area of graphics, has failed to prepare engineers with the wherewithall of satisfying the needs of industry. In the past twenty years of intensive technological growth, the industry has necessarily shifted its demands from an engineer who came into industry with an excellent command of engineering graphics and a high regard for hardware, to a highly theoretical engineer with very little knowledge or concept of end product hardware. The impact of this transition has not completely been felt for several reasons:

- The present mix of the older engineer with hardware experience and the younger non-hardware oriented engineer.
- The increasing role of the engineering associates out of a two-year college program with an in-depth knowledge of graphics.
- The reduction in the demand for Engineers.

I feel the full impact will be felt in the next ten years when the now beginning engineers will have assumed major roles in industry and will have taken this lack of engineering graphics knowledge with them to key management positions. In the interim however, there are several avenues open to industry and academic institutions to stave off this impending crisis, such as:

- Obtaining from Industry a better definition as to what the acceptable level for graphics training should be.
- Looking to our high schools and two-year colleges for additional training of potential engineering students.
- Projecting what role the computer is going to play in this future.
- Merging of ideas through our professional societies in order to acquire better understanding of the problems.
- Teaching of engineering graphics in terms of industrial standards to minimize the relearning cycle for the new engineer.

To understand this problem and to devise a proper solution in time we must look to the past to see how it developed. Professor R.R. Wallicis summarized this very well in his article "Education for Engineering Drawing" published in Graphic Science:

> "As the demise and gradual elimination of drafting courses in engineering degree curricula became rampant in the 1950's and the citadels of this venerable and moss-encrusted discipline began to crumble, new paths were charted to preserve the Empires. Chief among these was the development and enlargement of the topics generally called graphics. These included plotting of graphs and mathematical curve formula, functional scales, graphical calculus, nomography and vector diagrams. With the emphasis on research and scientific methods in our space age technology the "name of the game" in engineering education became to make your course sound scientific often this being the only way to keep it in the curriculum. In some cases, almost half of the basic course in engineering drawing now usually reduced to two or three semester credits, was devoted to the topics mentioned above. As part of this struggle for academic respectability, the name of the Engineering Drawing Division of the American Society for Engineering Education was officially changed to the Graphics Division in 1958. Even these drastic forays into new and what some in our profession consider dead-end excursions into the byways of these minor specialties of industrial activity have failed to halt the decrease and elimination of graphics instruction at the degree college level."

To determine whether this is a real problem to industry or just a figment of an educator's imagination, we must determine the engineer's role as it is defined by the industry that is employing him. What really do we look for as his output in terms of end product? If the answer is the engineering drawing in the case of the mechanical engineer, or the schematic sketch, in the case of the electrical engineer, both have an end result of hardware and reauire a working knowledge of engineering drawings.

The following questions are pertinent to the total problem and require consideration from both industry and education:

- What is the role of the computer in the engineering drawing field?
- What is the real meaning of the engineering signature on the drawing?
- Is there an intermediate layer of the engineering profession coming into being which is keeping the engineer away from the drawing cycle?
- Should the exacting methods of applied dimensions and tolerances be part of the engineering curriculum?

Role of the computer

One of the points that came up several times during my interviews with the younger engineers was the large role that the computer would be playing in all phases of design and drafting of engineering drawings in the very near future. Since they felt the computer would take over more graphics functions, they assumed the knowledge of graphics would not be as important to them as it was to their fellow engineers of 1950 vintage. To some extent this is true. Computers can accomplish all the repetitive tasks presently performed by the draftsmen, such as: lists, wire routing, schematics, logics and certainly some repetitious mechanical drafting tasks. Nonetheless, this leaves the very large field of what I term *mechanical design* unaccounted for. This category requires piece part drawings to be prepared mannually by the designer or draftsman and approved by the engineer. In the aerospace industry, with which I am affiliated, this type of work constitutes approximately 50% of the drawing output. Each drawing is unique within itself and requires an in-depth knowledge not only of graphics but a good knowledge of shop practice in order to intelligently prepare and approve the drawing. There is a family of mechanical drawings which can be eliminated by use of a digitizer or a cathode ray tube coupled to a design assist system, the output of which is a magnetic tape driving a milling machine or a tape controlled drill to produce the end item. The need for the picture drawing certainly would be reduced in the make cycle but would still exist in the inspection, analysis, and competitive reprocurement cycles. However, this does not eliminate the mechanical design layout which defines the shape and function of the part within its assembly.

The role of the computer has increased greatly in the past ten years and will continue to increase. The widespread application of computer graphics techniques will come slowly as the various little steps begin to fit together into a bigger picture. In addition to the slow process, there exists large capital investments that have to be made when an already functioning manual system is replaced by a computer.

In summary, I feel the computer will be playing an even larger role in the field of graphics, it will not supplant the need for teaching graphics at a college level.

Meaning of the engineering approval signature

The meaning of the approval signature on a drawing and the resultant philosophy must be decided by each engineering department. The final acceptance, implementation and application of this philosophy must be made on the level of the individual engineer.

It has been my experience that the individual engineer may, in some instances, delegate part of the technical drawing responsibility to the draftsman or designer. In this case, his signature means that he agrees with what is contained in the drawing but that he has conducted no in-depth review.

The Webster official definition of the word *approve* is "To accept as satisfactory"; to give formal or official sanction to". It would appear that even the dictionary definition of the word "approve" leaves some doubt as to what level should be pursued in order to ensure the drawing is correct.

To arrive at a concrete approval, the drawing itself has to be analyzed as to its total contents; partial responsibility for this analysis is divided between engineering, design, drafting and manufacturing.

A drawing is either directly or indirectly composed of the following elements:

Format	How the total data is formated on the drawing.
Form	The basic shape of the part.
Technical data	The dimension, tolerances, finishes and materials.
Fit and function	How the part fits and functions within its assembly.
Processes	Manufacturing philosophy applied to the part.

Based on this listing, the obvious conclusion is that the engineer, approving the drawing, has to have some knowledge in all areas, but also has to rely very heavily on skill of the other contributors to the document.

The one engineering drawing above the piece part level, that has to be considered at this point, is the design layout. Although this is one of the most important drawings on any project, it usually receives very little recognition as a part of the total product. The design layout is the point at which the majority of engineering decisions should be made relative to fit and function; therefore, engineering approval at that level is more meaningful and important then at the piece part drawing level.

If this is properly accomplished by an engineer competent in graphics, the delegation of responsibility downstream at the piece part level will be less risky.

In summary, the mechanical engineer cannot function effectively, even in a role of reviewer, if he is unable to interpret the document he is reviewing.

Applied dimensions and tolerances

Since the issuance of the American National Standards Institute (ANSI) Y14.5 standard, the application of dimensions and tolerances have taken on a new "dimension". We have passed out of the dark ages of dimensioning, where each individual had his own concept, into an era where all terms and methods are defined in a very precise manner and where formulas and values can be derived from existing data.

This is one of the basic concepts that should be covered for all mechanical engineers who will be in a position of reviewing dimensions as they are applied to a working drawing. An error in judgment, caused by an improperly applied dimension, could cost many thousands of dollars.

The one most important ingredient of a drawing is the dimensions for which there is no margin for human error. I have always stressed that the sloppy drawing can be tolerated, but that an inaccurate dimension cannot.

In addition to using the fractional and decimal system, we are now faced with the metric system, the implementation which will require another training cycle. This segment of mechanical drawing can be applied without a great amount of redundancy in delineation exercises. It should also be noted that as one learns and achieves more knowledge and depth in this subject, one realizes that manufacturing methods and processes must also be considered. As soon as it is determined how the part will be manufactured the cost factors then become an element of the total thought process. Based on these considerations, I feel that, as a minimum, the proper application of dimensions and tolerances as contained in Y14.5 should be taught to those engineers who are headed towards a career in mechanical engineering, since hardware will be one of their prime outputs. Obviously the more immediate responsibility for on-the-job training for specific applications of dimensioning and tolerancing techniques lies with industry.

Emergence of a new profession

The importance of the engineering technician with an Associate Degree in Mechanical or Electrical Technology is definitely increasing throughout the engineering profession. They are relieving the four-year engineering college graduates of many burdensome requirements with which they would normally be involved. Obviously, one such requirement is the preparation of the engineering drawing.

These technicians have been trained to bridge the gap between the highly theoretically oriented four-year engineering graduate in the hardware phase of design from Engineering to Manufacturing. They are divided into several groups depending on the area of specialty: engineering technicians, draftsmen, methods engineers and many others. The curriculum of a two-year associate's degree program usually consists of a balanced arrangement of classroom, laboratory, drafting room and shop work. The student learns by experience as well as studying and listening, to readily apply his knowledge to practical production and construction problems. These graduates are prepared for various technical positions encompassed within the engineering field, but the scope of their education is more limited than that of the professional engineer. These engineering technicians do not plunge as deeply into mathematics and the sciences as do students in four-year engineering colleges, but they go far deeper into the production and construction and understanding of principles underlying such processes. With very little on-the-job training, these individuals are able to perform functions within the engineering structure that, in some instances, fill the void until the engineer acclimates himself to the process of turning theory into hardware. This engineering layer is gradually coming into its own, but only on an individual basis. However, as the relationship is established between these two engineering groups, the engineer can confidently delegate more responsibility for engineering drawing and graphics preparation to the technician.

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Ultrasonic holography

Dr. David Vilkomerson

Holography means recording the amplitude and **phase of a wavefront. Ultrasound is defined as sound (mechanical vibrations) of such high frequency that it cannot be heard; ultrasonic holography, then, is recording the amplitude and phase of wavefronts of ultrasound. We will briefly describe why ultrasonic holography is worth doing, the present state of ultrasonic holography, and the directions we think it will take in the future.**

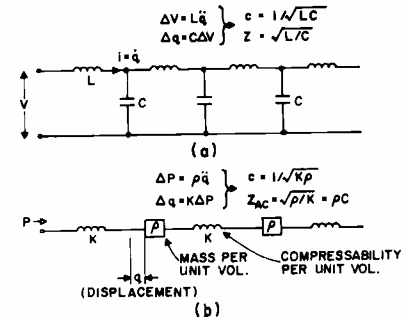

Fig. 1a) A model of an electrical transmission line, and b) an analogous acoustic transmission line.

MECHANICAL PROBLEMS, including the problem of how mechanical displacements propagate, are often viewed by electrical engineers in terms of an analogous electrical system. A useful analog to the propagation of a mechanical displacement is the propagation of a voltage transient down a transmission line. If the voltage is increased at one end of a transmission line, current flows through an equivalent inductance L per unit length that, by charging an equivalent capacitance C per unit length, raises the voltage of the succeeding point on the line. The voltage change propagates down the line at a velocity determined by the way the charge is interchanged by the L's and C's; exactly, the velocity is $c=1/\sqrt{LC}$, where L is the inductance and C the capacitance per unit length. If we model a material with a certain mass per unit volume and a certain "springiness" per unit volume by the sort of transmission line shown in Fig. 1, a change in pressure at one end of the line will cause a displacement of the mass which compresses the connected spring and so propagates the pressure change down the line. As the L's and C's determined the speed of propagation of the electrical line, so the mass and springiness of the material determines the velocity of propagation; it can be shown[1] to be $c=1/\sqrt{K\rho}$, where ρ is the mass per unit volume, and K is the bulk compressability—a quantity inversely proportional to the springiness. This result is intuitively satisfying (as well as correct): a greater mass leads to slower propagation, and greater springiness to faster propagation.

We have seen how a pressure change propagates through a material much as a voltage change propagates through a transmission line. In the transmission line, there is a ratio between the voltage at a point and the rate of change of charge (the current, dq/dt) described as the impedance Z: $V/I=Z$. Similarly in any given material, there is a ratio between the pressure and the rate of change of displacement (the particle velocity, $d\varepsilon/dt \equiv u$) given by an *acoustic* impedance, Z_{ac}; i.e.

$$P/u=Z_{ac}$$

The electrical impedance Z of a transmission line is set by the ratio of L to C: $Z=\sqrt{L/C}$; similarly, the acoustical impedance is set by the ratio of the mass to the compressability: $Z_{ac}=\sqrt{\rho/K}$. This result is also intuitively satisfying, since we would imagine that the ratio of pressure to rate of change of displacement should rise as the mass per unit length goes up or the springiness increases (K decreasing). The acoustical impedance Z_{ac} is usually expressed in the equivalent form of ρc $[\rho(\rho K)^{-1/2}=(\rho/K)^{1/2}]$ which is easier to measure.

Continued analysis[2] of the acoustical model reveals that the familiar electrical relations between voltage, current, impedance, and power can be applied to the analogous acoustical qualities; for the electrical transmission line

$$\mathit{Power}\ (W)=VI=I^2Z=V^2/Z$$

and for the acoustical model

$$\mathit{Intensity}\ (W/m^2)=Pu=u^2Z_{ac}=P^2/Z$$

where for both the electrical and acoustical relations the root-mean-square values are used and Z is assumed to be pure real, as it would be for the lossless models assumed.

Dr. David Vilkomerson RCA Laboratories, Princeton, N.J. received the BSEE from the Massachusetts Institute of Technology in 1962, where he had been a National Merit Scholar. In 1962, he joined the RCA Missile and Surface Radar Division, working on radar data processing. He transferred to the RCA Laboratories in 1963 and did research in alloy semiconductor lasers and solid-state cryogenic devices, developing a new superconducting amplifying device, which provided the thesis for the MS in Engineering he was awarded in 1964 by the University of Pennsylvania. Dr. Vilkomerson received an RCA Research Award for Doctoral Study in September of 1964, allowing him to pursue full-time study toward the PhD at Columbia University. After his return to the RCA Laboratories in 1965, he was engaged in research on holograms and optical memories. He received the PhD in 1969. He was a co-recipient of an IR 100 Award for the development of a holographic read-only memory. Dr. Vilkomerson was awarded a Post-Doctoral Fellowship to the Hebrew University of Jerusalem (1969-1970). While there he studied work on ultrasonic holography for medical diagnosis. He is continuing that research presently. He is a member of Sigma Xi, the IEEE and the Optical Society of America.

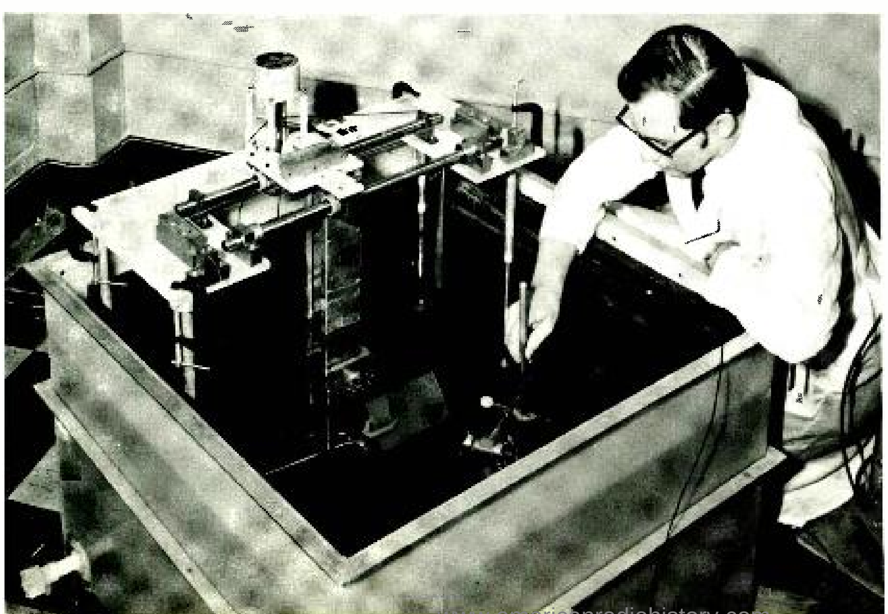

Table I—Acoustical impedance of several materials.

Material	*(Velocity m/s)*	Z_{ac} *(kg/m²-s)*
Air	3.4×10^2	4.0×10^2
Water	1.5×10^3	1.4×10^6
Polystyrene	2.4×10^3	2.5×10^6
Aluminum	6.3×10^3	1.7×10^7
Steel	5.8×10^3	4.5×10^7

The acoustical impedance varies widely: Table I shows the acoustical impedance varying from 400 acoustical ohms (for air) 4×10^7 acoustical ohms (for steel)—in impedance difference of 10^5.

When acoustic waves propagating in one material meet a material of different acoustical impedance at an interface, the situation can be modeled as acoustic waves propagating in one transmission line encountering a transmission line whose impedance is different. As in the electrical analog, a different impedance transmission line makes it impossible to match the boundary conditions unless there is a reflected wave. For example, if sound propagating in steel meets with an interface of air, the velocity of the surface of the steel and the surface of the air mass must be the same. The power carried away in the air wavefront is proportional to u^2Z_{air} which is some 10^5 less than the incident power u^2Z_{steel}. The difference in power must be taken up as a reflected wave. Careful analysis shows the amplitude ratio of reflected wave to incident wave is

$$\frac{U_R}{U_i}=\frac{Z_1-Z_2}{Z_1+Z_2}$$

where Z_1 and Z_2 are the impedances. This is the same formula that is found for the analogous electrical case of two joined transmission lines of differing impedances.

The transmission-line analogy is a very useful one, and the use of quarter-wave sections of material as a transformer and "invisible" half-wave sections, as well as quasi-Smith chart calculations and tuning "stubs" appear frequently in acoustic design.[3] While the transmission line is one-dimensional, the material carrying sound waves is three dimensional, and acoustic waves travel through the medium the way electromagnetic waves travel through the "three-dimensional transmission line" of space. The acoustic medium is linear, *i.e.* superposition for the wave quantities holds, in the same way that it holds for the field quantities of an electromagnetic wave such as light. As a result, one can make Huygen's constructions and Fresnel-Kirchoffer integrals for the "field quantities" of pressure or particle velocity just like the ones for the **E**-vector of light. The acoustic wavefronts show the same behavior as light waves, traveling in straight lines, diffracting when passing through apertures, etc.

The described propagation of acoustic wavefronts has been simplified by 1) assuming that all the displacements are small so nonlinear behavior of the medium is avoided and 2) neglecting to consider that other propagating modes, such as shear waves (as opposed to the described longitudinal waves), surface waves, etc., are possible, and that the "ideal" longitudinal wave can convert to one of these other propagating modes. In liquids and under certain conditions in solids, no shear can be maintained, and longitudinal waves remain longitudinal and, if the amplitude of the acoustic wavefront is kept within the linear range of the carrying medium, the described propagating characteristics will be realistic.

What makes the propagation of acoustic wavefronts so useful is 1) that acoustic wavefronts propagate through liquids and solids in which light does not and 2) that different materials have different acoustic impedances, which leads to reflected wavefronts. These two characteristics mean that if we propagate acoustic wavefronts through dense composite structures, the reflected acoustic wavefronts reveal the interfaces within the structure. Practically, this means we should be able to find faults in a weld or tumor in an organ. How to analyze the reflected wavefronts to give this information is discussed in the next section.

Making acoustic images visible

An early use of acoustic wavefronts to obtain information that could not be obtained optically was sonar. The mismatch in impedance between the water and the steel hull of a submarine gave a strong reflection; timing the roundtrip gave the distance, and directional receivers provided the direction to the target.

After the war, sonar-like systems were employed to detect the locations of flaws in weld or cracks in metal surfaces; in media like metals, acoustic wavefronts propagate with little attenuation, and the sudden mismatch at an air-filled gap produced strong reflections.

The same methods were applied to medical diagnostic use. In one particularly successful example, the distance from the midline fissure in the brain, which separates the two lobes, is measured from the sides of the skull to detect a shift in brain position caused by swelling, a tumor, etc. Successsful location of the placental position in obstetrics also proved possible.

This sonar-like technique, called echosonography, suffered from lack of sensitivity and low resolution. The sensitivity is limited because the signal energy is a result of a short pulse; the pulse must be short to have resolution in the longitudinal direction. The resolution is low because when a small transducer is used to try to get a narrow beam, the diffraction of the acoustic wavefront from the small transducer spreads the beam. A large transducer gives a collimated beam that is too wide to resolve small features.

Another problem with sonar-like systems for medical diagnosis is the difficulty in interpreting the "blips on the scope" with physical structures. With training this became possible, but the need for this training made for slow acceptance by the community of physicians.

Over the years, a number of techniques to convert acoustic wavefronts to images have been proposed. [A good review of these is found in Berger.[4]] Unfortunately, the images obtained by these techniques have been poor. This is, in part, a materials problem. Water is commonly used as the medium for acoustic experiments because its impedance is close enough to transducers and common materials so that acoustic energy can be coupled in and out of it. (Air, with its ex-

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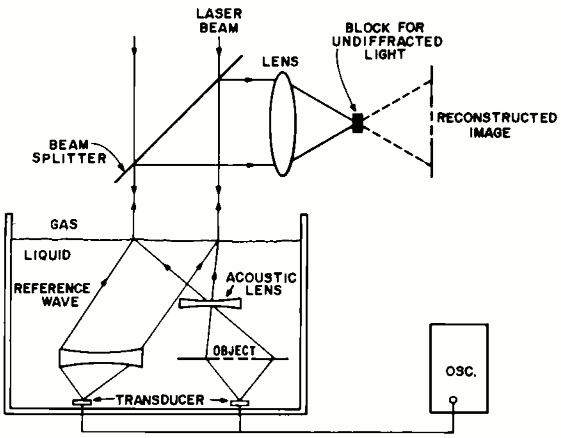


Fig. 2—A focused-image acoustical holography system.

tremely low impedance, is not suitable.) However, no material has both an impedance very close to water and a sonic velocity different from water. Making lenses for acoustic wavefronts is like trying to do optics without glass.

In addition to the lens problem, many techniques are of limited sensitivity. The maximum intensity that can be used in water before nonlinear effects occur is about 5 W/cm^2. The maximum intensity considered safe for the human body is about one-tenth of that value. For medical diagnostic purposes in particular, there are large losses in the object to be investigated, leading to weak signals.

Holography does not need lenses; the curvature of the wavefront is recorded by the change in phase across the hologram. [One early article on holography was entitled "Lensless Photography."[5]] Therefore, no acoustic lenses would be required for acoustic holography.

In optical holography, the object beam and reference beam, coherent from a common source, interfere on a surface sensitive to intensity. For optical holography, this can be photographic emulsion. The interference fringe pattern so formed records the amplitude and phase of the object beam. [Ref. 6 provides a review of optical holography].

There is an analogous intensity-sensitive surface available for acoustical holography which is quite convenient: the liquid-air interface.[7] Just as the oscillating electromagnetic fields of light produce a unidirectional force that is proportional to light intensity reflecting from an object, the oscillating pressure of an acoustic wave produces a unidirectional force that is proportional to acoustic intensity reflecting from an impedance mismatch. Such an acoustic mismatch at the liquid-air interface moves under the acoustic radiation pressure until surface tension forces equal the radiation pressure force. If coherent acoustic object and reference beams interfere at the liquid-air interface, there will be regions of high acoustic intensity, where the beams are in phase, and low acoustic intensity, where the beams are out of phase. (This corresponds to the dark and light fringes of a photographic plate made into a hologram.) The greater radiation pressure at the intense regions will deform the surface; the elevation above the unexcited surface will be proportional to the acoustic intensity. The water will appear to have static ripples.

The hologram normally consists of a uniform intensity background plus the signal term—the rapidly spatially-varying term due to the product of the amplitudes of the object and reference beam. Because the signal term is proportional to the product of the reference and object beams, there is a heterodyne gain, *i.e.*, the observed signal term has been increased by use of a strong "local oscillator." Even with a 1 W/cm^2 reference beam, the surface deviation is not very much. The surface deviation, b, at a water-air interface is

$$b \sim 10^{-2} \Lambda^2 (I_s)^{1/2} \text{ (cm)}$$

where Λ is the acoustic wavelength and I_s is the intensity of the object beam, in W/cm^2. For a one μW/cm^2 object beam of wavelength 1 mm (1.5 MHz in water), b is about 1000Å.

This doesn't seem like very much until we remember we are in a holographic mode, and that if a beam of light strikes this surface and is reflected, it will be phase-modulated (a phase hologram) of about $\lambda/5$ in phase excursion. This means about 25% of the reflected light will be diffracted at an angle to the directly reflected light; the angle of diffraction will depend upon the spatial frequency of the interface modulation.

The liquid-air interface allows holographic recording, since the pattern of ripples corresponds to a phase hologram recording. Because the ripple-height is dependent on the angle of the impinging beam, however, there is nonuniform response to different image components. In addition, when these static-ripple holograms are played out, because of the difference in wave-lengths between the light (5×10^{-4} mm) and the acoustic wavelength (about 1 mm), the image is demagnified. Consider an acoustic beam of wavelength Λ, propagating at an angle of θ to the surface where it interferes with a reference beam perpendicular to the surface; a static pattern of wavelength

$$d = \Lambda/\sin\theta$$

will be found, as some simple geometry will show. When the surface is illuminated by a perpendicular beam of light of wavelength λ, the optical ray due to the signal will be diffracted at an angle of

$$\theta_r = \sin^{-1}(\lambda/d)$$
$$= \sin^{-1}[(\lambda/\Lambda)\sin\theta]$$
$$\approx (\lambda/\Lambda)\theta$$

Fig. 3—An image, obtained by acoustical holography, of a poor bond (the mottled black area) in a steel-aluminum bonded engine bearing stock. (Photo courtesy of Holosonics, Inc.)

Fig. 4—The interior of the human elbow region, obtained by 3-MHz ultrasonic holography. Note the attachment of the tendons to the bone, an important site not visible in x-rays. (Photo courtesy of Holosonics, Inc.)

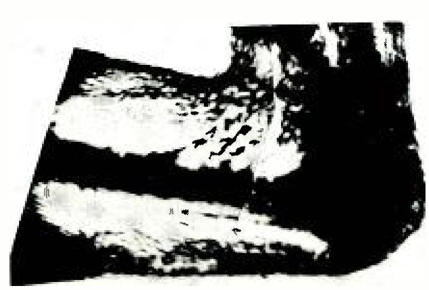
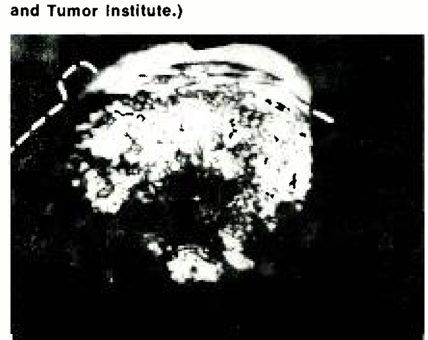


Fig. 5—Interior of human breast by 3-MHz ultrasonic holography. The black mass in the outer and lower left edge is a tumor. (Photo courtesy of Holosonics, Inc. and M. D. Anderson Hospital and Tumor Institute.)



We see the optical ray due to the acoustic ray has been reduced in angle by the ratio of the wavelengths. Some consideration of the way images are formed shows that this is a demagnification by the wavelength ratio. In addition, the longitudinal demagnification is the square of the lateral demagnification. If we read the ripple pattern out with light, we must give up the idea of seeing a true three-dimensional image as we see with conventional holograms.

Focused-image holography, where the image is focused onto the recording surface, cannot give three-dimensional images, but eliminates many of the other problems. Fig. 2 shows a focused-image acoustic holography system. The object acoustic wavefront is focused on the liquid-air interface where it interferes with a strong reference acoustic beam; the height of the ripples formed at any point will be proportional to the strength of the object acoustic wavefront at that point. With the optical system shown in Fig. 2, the amount of light reaching the screen will be proportional to only the diffracted light because the directly reflected light is blocked by the stop. Therefore, the image on the screen will accurately represent the intensity of the acoustic image focused on the interface. Note that there is no demagnification in this system.

This system developed by B. Brenden and his coworkers[8] at Batelle-Northwest and then at Holosonics, is commercially available. Fig. 3, 4, and 5 [courtesy of Dr. Brenden and Holosonics, Inc.] indicate how well the system works. Fig. 3 shows a typical industrial application; Fig. 4 and 5 show medical diagnostic use. The attachment of the tendons to the humerus shown in Fig. 4 are impossible to see in x-ray photographs. The detection of tumors, are shown in Fig. 5, appears feasible. As one example, in a study of rat tumors using a similar holographic system, six of ten small tumors were detected; using standard x-ray techniques, none could be detected.[9]

There are several other systems where light is used to retrieve the acoustic wavefront information; Mueller's recent review article describes the systems well.[10] The system used by Holosonics is representative of these light-coupled systems in its resolution and sensitivity. These systems seem quite suitable for seeing within metal parts, honeycomb structures, etc., and will probably become one of the most important tools of nondestructive testing.

For external structures of the human body, such as the limbs or breast, their sensitivity is adequate, as the pictures show. Unlike metal, however, human tissue absorbs ultrasound strongly. The attenuation coefficient is directly proportional to the ultrasonic frequency: at 3 MHz (0.5-mm wavelength in human tissue) the attenuation coefficient is about 2.7 dB/cm; at 6 MHz, 5.4 dB/cm. For the 20-cm roundtrip from the surface of the body to the organs and back, this corresponds to 54 dB of attenuation for a 3-MHz probing wavefront. The power reflection coefficient from an interface of an organ with the surrounding tissue can be calculated from the impedance mismatch; it is estimated to be −50 dB. [See Ref. 11 for a fuller analysis of the expected signal strength.] The total attenuation due to both absorption in the tissue and reflection from the interface is over 100 dB. Since the maximum intensity on the human that is considered safe is 100 mW/cm^2, the signal acoustic intensity is about 10^{-11} W/cm^2. This low level of acoustic intensity produces a ripple in a liquid-air interface of a few angstroms, well below that detectable.[11]

To use ultrasonic holography to see deep within the human body, more sensitive methods are required. Electronic techniques can produce the needed sensitivity.

Electronic-acoustical holography

Among the first methods of acoustical holography was one that used a piezoelectric detector to generate a voltage proportional to the acoustic field where the references and object beam interfered.[12] The voltage on the detector modulated the output of a lamp. The detector and lamp was scanned over a plane; as the detector responded to the holographic information, the optical output of the lamp was focused onto a photographic film. The result was an optical hologram.

It was soon recognized that the signal term in the hologram is the one generated by the crossproduct of the reference and object beam. This crossproduct is generated by the squaring operation inherent in taking the intensity, which was all photographic film could do. The piezoelectric detectors generated a voltage proportional to the amplitude of the acoustic wavefront; therefore, the crossproduct signal term could be more easily obtained using an electronic multiplier, multiplying the object wavefront signal by the oscillator that drove the insonifying transducer. Such a system eliminated a number of spurious terms and led to good holograms.[13]

The electronic approach became less popular as the light-coupled systems improved. The light-coupled systems needed no mechanical scanning devices and operated in real time. A major problem in the electronic acoustical holographic systems was converting the electronic signals back to light so that an optical hologram could be formed. While the electronic detection was quite sensitive, the conversion to an optical record had so many non-linearities and noise-generating processes that little advantage in output imagery over the light-coupled systems could be gained.

The solution to the conversion problem is to avoid it. The information about the reconstructed image is in the electronic signal before it is converted to light. The amplitude and phase on the area of the hologram is due to the diffraction of the acoustic field from the object. By solving the diffraction equations in the backward direction, we can calculate what the object must be. With electronic computers, this becomes feasible. A group at IBM first reconstructed acoustic holograms in this way.[14]

At RCA Laboratories, as part of the research into holographic processes, a computer-reconstruction acoustical holography system was constructed. In addition to the computer reconstruction, other steps were taken to insure high sensitivity. Various filtering techniques of communication theory were employed using digital signal processing to achieve long integration times. The device, known as Holographic Ultrasonic Device II

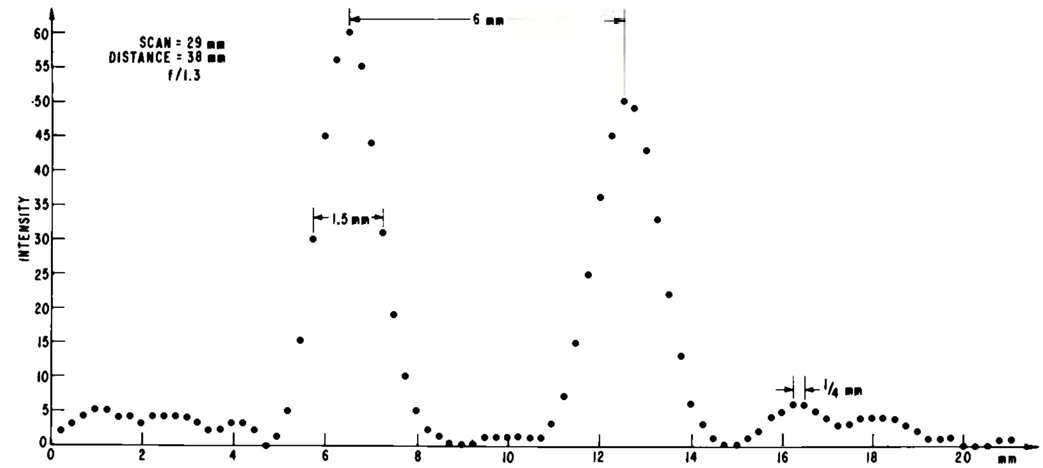


Fig. 6—The computer reconstruction of the ultrasonic intensity at the surface of a sheet of wood containing two 1-mm holes (not quite the same size) separated by 6 mm. The hologram was made by HUD II at detected power level of 10^{-10} W/cm², at f/1.3.

(HUD II), used a single linear scan to obtain one line of the image of the object.

A typical output of HUD II is shown in Fig. 6. It is a plot of the reconstructed sound intensity at the surface of a sheet of wood with two 1-mm holes, 6 mm apart. It is the result of a 27-mm scan, 38-mm from the wood sheet. The resolution is at the theoretical limit, the *f*-number of the system multiplied by the wavelength. More significantly, the signal power level was about 10^{-11} W/cm², or about the power level expected from acoustic signals deep within the body. HUD II is the most sensitive acoustical holography system known.

A straight-forward extension of the HUD II system would be one where a full raster scan would be made, resulting in a two-dimensional plot of the acoustic field at any plane in the object space. While such a system is feasible, it is not practical. It would require on the order of 10,000 measurements over the hologram plane; this would require too much time for a scanning system or too much fabrication to make a parallel array of detectors.

Instead, we plan to use the computer synthetic-aperture synthesis; in this process, the signal from the perimeter of the aperture is made to yield the equivalent resolution of the full aperture. This process has been used in radio astronomy,[15] but never before for a low f-number system. The benefit of such a system is the reduced number of detection positions. While a full aperture of 100×100 positions requires 10,000 positions, the equivalent resolution imaging can be achieved with the $\pi \times 100$ positions of the perimeter. Besides requiring greater computing, the synthetic aperture reduces the sensitivity by the relative areas of the annular aperture to the full aperture, or in our example, $\pi/100$. However, it can be shown[11] that electronic detection is greater than 10^5 times as sensitive as light-coupled acoustical holography systems, so a factor of about 30 still leaves the electronic system much more sensitive. According to the analysis cited,[11] even with the sacrifice of sensitivity involved in using a synthetic aperture, electronic acoustical holography using high-speed electronic computing should have more than enough sensitivity to image tissue structures deep within the human body.

Successful computer simulations using an annular synthetic aperture have been run; and preliminary tests of HUD III, which mechanically scans a detector in a circle to implement an annular aperture, show encouraging results. It is hoped that the system will successfully produce two-dimensional images from any plane in space at power levels well below any existing systems. Hopefully, internal organs of the body will be able to be imaged with HUD III.

Conclusions

Acoustical holography can be used to obtain information otherwise unobtainable from the inside of opaque structures. The light-coupled acoustical holography systems are relatively simple and operate in real time; their sensitivity is suitable for imaging the inside of nonabsorbing complex structures, *e.g.* metal structures, and small thickness of absorbing material like the human body, *e.g.* a hand or breast. Electronic systems, such as those now being developed at RCA, require high speed digital computing, but are orders of magnitude more sensitive. Theoretical and experimental results indicate that such electronic systems should be capable of imaging internal body structures. The ability to see the configuration of the soft tissues could radically improve medical diagnosis.

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Video in vacuo: television's role in space

Dr. G. H. Brown

Editor's note: Commercial RCA television and Dr. George H. Brown have been very closely coupled by his distinguished work on the RCA family of high-gain turnstile and superturnstile tv antennas. Since the early days of television, first RCA black-and-white and now color television cameras have ventured into outer space. This paper, presented December 7, 1972 by Dr. Brown on the occasion of the Shoenberg Memorial Lecture at the Royal Institution, traces television's invaluable role in the exploration of space. We believe Dr. Brown's paper is a fitting tribute to the television art and to Sir Isaac Shoenberg, who led the research team that developed the British 405-line, all-electronic tv system. (Shoenberg's life and work are reviewed in the Vol. 13, No. 9, May-June 1971 issue of the *Royal Television Society Journal*).

APPROXIMATELY eighteen months ago, upon reading the published version[1] of the first Shoenberg Memorial Lecture by Professor McGee, I reflected upon the many facets of Sir Isaac's life which had been unknown to me. I had met him several times, but far too few. I recollected the last time that I had been with him when, twice in the same month of November in 1959, he had me to lunch with Dr. Broadway and Dr. Lamont. On both occasions he plied me with wine and bombarded me with questions which ranged over the entire gamut of modern technology. His questions did not trouble me in the slightest for he quickly answered his own queries before he fired the next volley.

My further reflections included speculations as to the identity of those men who in the future would be invited to deliver other Shoenberg Memorial Lectures in honor of a most remarkable man. I thought of Professor McGee whose privileges included, in addition to those of knowing intimately and working with Sir Isaac, delivering the first Shoenberg Memorial Lecture at perhaps the same podium or at least in the same hall which had been graced by Sir Humphry Davy, Lord Rayleigh, Sir J. J. Thomson, Guglielmo Marconi and Michael Faraday. I was not included in these speculations.

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The participation of RCA Corporation in the TIROS meteorological satellite program started in 1958...

In responding to the invitation conveyed to me, I have chosen to address myself to the role of television in the exploration of space. Space - outer space - is so full of man-made objects that it is almost impossible to keep an account of the total. Those to which my company has contributed part or all of the design and development are documented with reasonable accuracy but they are hidden by a cloud of acronyms such as:

TIROS —Television & Infra-Red Observation Satellite

TOS —TIROS Operational System

ITOS —Improved TIROS Operational System and, incredibly,

ICICLES—Integrated Cryogenic Isotope Cooling Engine System.

The participation of RCA Corporation in the TIROS meteorological satellite program started in 1958, with the first TIROS satellite being launched on April 1, 1960, from Cape Kennedy in Florida. TIROS I was placed in a nearly circular orbit of about 450 miles altitude, crossing the equator at an angle of forty-two degrees. The satellite was roughly cylindrical, approximately forty-two inches in diameter and nineteen inches high. The equipment on board TIROS I was

Dr. George H. Brown, formerly Executive Vice President, Patents and Licensing of RCA received the BSEE in 1930, the MSEE in 1931, the PhD in 1933 and the Professional EE degree in 1942, all from the University of Wisconsin. In May, 1962, Dr. Brown was honored by the University of Wisconsin with a Distinguished Service Citation for leadership in industry and engineering. In 1933, Dr. Brown joined RCA Manufacturing Company in Camden. In 1942, he transferred to the newly formed RCA Laboratories at Princeton. It was during his career at Camden that he developed the Turnstile antenna, which has become the standard broadcast antenna for television. During World War II, Dr. Brown was responsible for important advances in antenna development for military systems, and for the development of RF heating techniques. He and his associates also developed a method for speeding the production of penicillin. From 1948 to 1957, Dr. Brown played a leading part in the direction of RCA's research and development of color and UHF TV systems. In 1952, he was appointed Director of the Systems Research Laboratory. In 1957, he was appointed Chief Engineer of the Commercial Electronic Products Division at Camden, and six months later was named Chief Engineer, Industrial Electronic Products. In 1959, he was appointed Vice President, Engineering, of RCA. He became Vice President, Research and Engineering, in November 1961, and was named Executive Vice President, Research and Engineering in June, 1965. Dr. Brown has received numerous awards and citations for his pioneering work in research, design, and development and for his work in the community. Dr. Brown is a Fellow of the IEEE, the Royal Television Society, and the AAAS; a member of Sigma Xi, The Franklin Institute, and the National Academy of Engineering. A prolific inventor, Dr. Brown holds 80 U.S. patents. He is a Registered Professional Engineer of the State of New Jersey and the author of numerous articles appearing in scientific journals since 1932.

Fig. 1 — Great Britain outlined by clouds. Ireland and northern France are also visible. Picture from TIROS IV.

powered by an array of 9000 solar cells which charged a bank of storage batteries.

Two primary ground stations were used in this mission. One was located in Hawaii and the other at Fort Monmouth, New Jersey. Contact was possible by at least one of these ground stations during a part of thirteen orbits each day, with another additional three orbits each day during which no contact was possible. In addition, at RCA's Astro Electronics Division near Princeton, New Jersey, signals were received and pictures viewed.

Two identical television cameras were on board, one with a 104° wide-angle lens and the other a narrow-angle camera with 12° coverage. Each camera used a one-half inch vidicon camera tube with electromagnetic deflection and focus. A 500-line picture with a 2-second frame rate was obtained. When the satellite was not in direct communication, the pictures were recorded on magnetic tape and played back for transmittal to earth on command received from a TIROS control station when the satellite was within range of the ground station.

In spite of the name of this satellite, the infra-red equipment did not arrive in time for the flight, so the bird flew without it.

TIROS I was deactivated after 90 days. A number of functions had ceased. The transmitters were turned off in order not to clutter the radio channels and to make them available for future use. In the meantime, thousands of pictures had swamped the various agencies who had expressed an interest in the results.

All ten spacecraft were successfully orbited and all ten exceeded the mission objectives

TIROS II was launched on November 23, 1960, this time with infra-red sensors consisting of two radiometers, a tape recorder and a transmitter. TIROS II functioned for 376 days.

Eight more TIROS satellites followed. All ten spacecraft were successfully orbited and all ten exceeded the mission objectives. As the program progressed, it moved from experimental to operational. The ten TIROS satellites were followed by two ITOS and nine ESSA (Environmental Science and Services Administration) satellites in a variety of orbits and orbital heights, with vast improvements in cameras and control techniques. The latter group of satellites used television cameras equipped with one-inch vidicons operating with 800 scanning lines at 6.5 second frame rates. Over two million pictures of cloud cover and earth formations have been produced.

The beneficial results of these weather-satellite missions have been:

1) Hurricane observations and warnings.
2) In-depth research on hurricanes.
3) Study of cloud formations.
4) Night temperatures and clouds, by means of infra-red studies.
5) Tracking of ice floes.
6) Help for cartographers, including mapping of Antartica.
7) Fast service for airmen, with the jet stream quickly identified by cloud patterns.

Europe tuned in during 1964, when France established a receiving station at Lannion during August, followed by Great Britain, Italy and South Africa. A cold line was established with Russia in November, 1964. Cloud photographs, together with analyses, from Russian and American weather satellites, flow between Washington and Moscow.

The entire series has now culminated in the launching on July 23, 1972, of the ERTS (Earth Resources Technology Satellite) in a nearly circular almost-polar orbit about five-hundred miles above the surface of the earth. The stated objective of the ERTS program is "to establish a capability for responsible management of

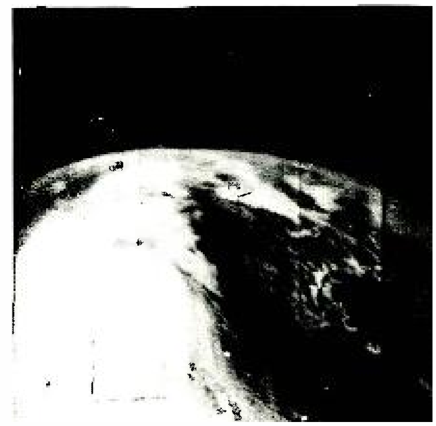

Fig. 2 — First television picture from space. TIROS I satellite. April 1, 1960.

the earth's resources and human environment." The first missions are to determine the feasibility of using satellites for acquiring data useful to earth scientists.

"However, the statements bear a resemblance to campaign promises"

The sponsors say "It is anticipated that the experimental satellites will lead to operational systems that can map the entire earth, assist farmers by detecting blight on crops, catalog water supplies, detect pollution, spot the best commercial fishing grounds, and provide a wealth of other useful data. It is hoped that ERTS will find oil and mineral deposits, bring better land use and map geological features." I hope so, also. However, the statements bear a resemblance to campaign promises.

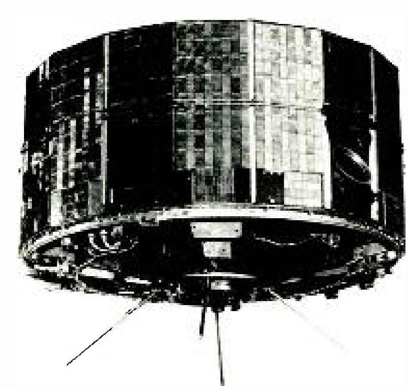

Fig. 3 — TIROS satellite.

In ERTS, three television cameras comprise a subsystem called the Return-Beam-Vidicon Three-Camera Subsystem. The cameras are identical electronically, but each operates in a different spectral band, one in the blue-green region, a second in the red region, and a third in the near infra-red.

The heart of the camera is the return-beam vidicon. This tube employs an antimony sulphide oxysulphide photoconductive surface and newly devised electro-optical configurations to achieve high resolution and high signal-to-noise performance.

To prepare the return-beam vidicon for picture taking, an erase cycle is initiated. This involves flashing four miniature lamps located on the periphery of the faceplate for approximately one-half second to erase any residual image left on the photoconductor. Next the target is prepared by scanning the photoconductor with the electron beam in order to bring the photoconductor down to cathode potential. The next step is the expose portion of the sequence, taking from 4 to 16 milliseconds, depending on the scene radiance. A focal-plane shutter is used to expose the photoconductor.

The camera images are recreated on the ground by means of very sophisticated equipment

The final sequence is the read period. Here the electron beam is used to read out the scene imaged on the photoconductor. The read-out sequence takes 3.5 seconds for each frame on each camera. With the Three-Camera Subsystem, the three cameras are erased, prepared and exposed simultaneously, but they are read out sequentially.

The three sequentially read-out pictures, containing 4000 scanning lines each, may be stored on either of two wideband video-tape recorders for later transmission to earth or may be transmitted directly to earth at the time of read-out. The camera images are recreated on the ground by means of very sophisticated equipment which includes a Laser Beam Image Reproducer. The final composite picture may be in a combination of any three colors desired.

For the present, deep-space probes have been reserved for Venus and Mars. The Soviets have had a virtual monopoly on Venus explorations. They have landed several capsules on this planet. The latest, Venus 8, was launched on March 27, 1972, and reached Venus on July 22, thirty-seven million miles from earth at landing time. Since the surface temperature of Venus is 880 ° F and the pressure is ninety times our atmospheric pressure, transmissions took place for only fifty minutes at which point the capsule disintegrated.

Mariner capsules carried ultra-violet spectrometers and infra-red interferometer spectrometers together with television cameras...

After a few aborted attempts, the United States launched Mariner IV late in 1964 and seven and one-half months later, on July 15, 1965, Mariner IV came within 6000 miles of Mars, one hundred and fifty million miles from earth. Twenty-two pseudo-television pictures were obtained by means of vidicons with electronic samplers and tape storage. Two hundred and forty thousand bits of information were sent for each photograph and it required eight hours to send each picture. Obviously, these were still pictures. The information was processed by huge computers on the ground in order to reconstitute the pictures.

Later Mariner capsules carried ultra-violet spectrometers and infra-red interferometer spectrometers together with television cameras in order to map the planet's surface and take atmospheric and temperature measurements. Mariner IX has been in orbit around Mars since November 13, 1971. Much more sophisticated methods and more complex equipment have been used and over seven thousand still pictures have been received. Mariner IX literally ran out of gas (attitude-control gas) on October 27, 1972, during its 698th orbit of Mars and, on command from earth, its radio transmitter was turned off.

Now to return a bit closer to earth. The moon in its elliptical orbit ranges between 221,000 and 253,000 miles from earth. It is our very own satellite and the attention given it is well deserved for the moon has never been known to turn its back on us.

In order to obtain detailed information concerning the lunar surface in anticipation of man's visits to the moon, as well as to gather other scientific facts, NASA's programs included Ranger, the Lunar Orbiter and Surveyor.

Ranger might well be considered the epitome of crash programs since it was fully intended to hurtle straight to impact with the lunar surface, hastily snapping pictures as it went to its demise. The first two spacecraft of this series were intended to test techniques for use on lunar and planetary spacecraft as well as to measure the particles and fields present in interplanetary space. The next three Rangers were to "rough land" a seismometer package on the lunar surface. The final four Rangers were designed to take closeup pictures of the moon's surface before crash landing. The Ranger VI mission failed, perhaps because the critical battery equipment was inadvertently turned on during the launch. Rangers VII, VIII and IX sent over 17,000 closeup pictures of the lunar surface, thus providing valuable data for the planning of moon landings of Apollo astronauts.

Ranger VII, launched on July 28, 1964, impacted on the moon on July 31. Ranger VIII followed on February 17, 1965, and Ranger IX came along on March 20, 1965.

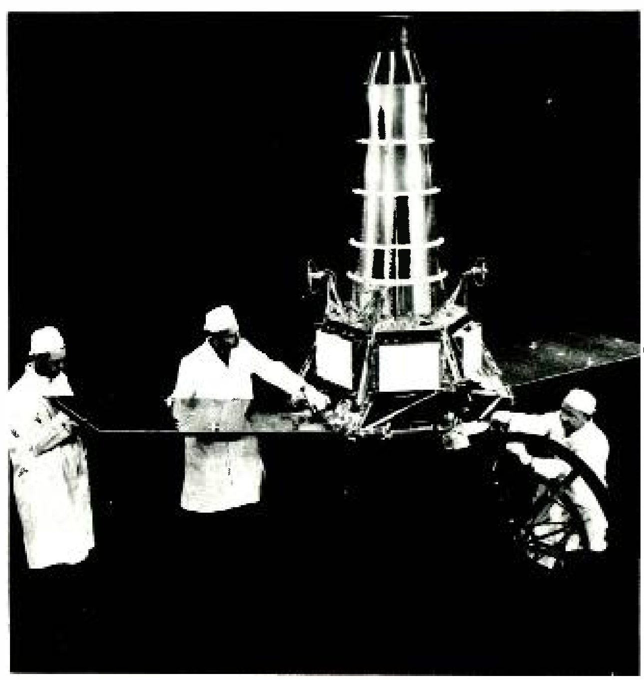

Fig. 4 — Ranger spacecraft with solar panels.

Fig. 5 — Ranger television cameras.

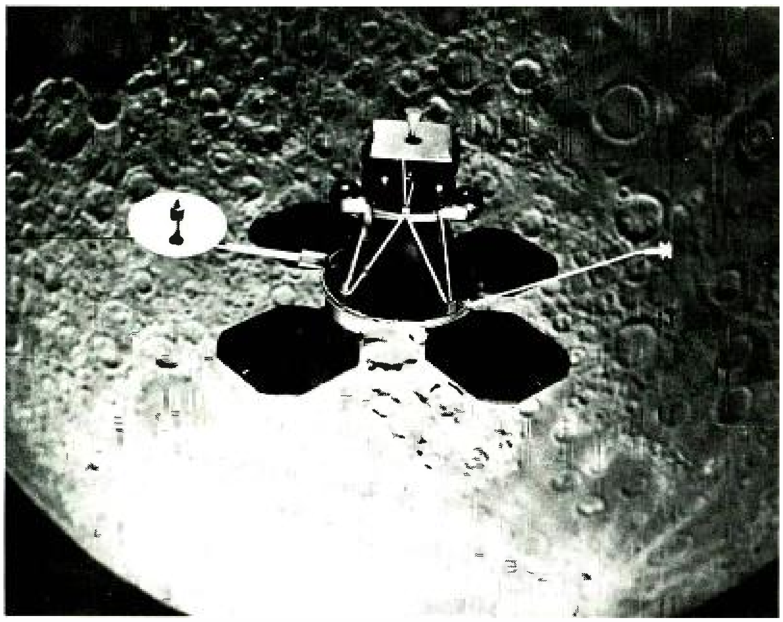

Fig. 6 — Lunar Orbiter against the moon background.

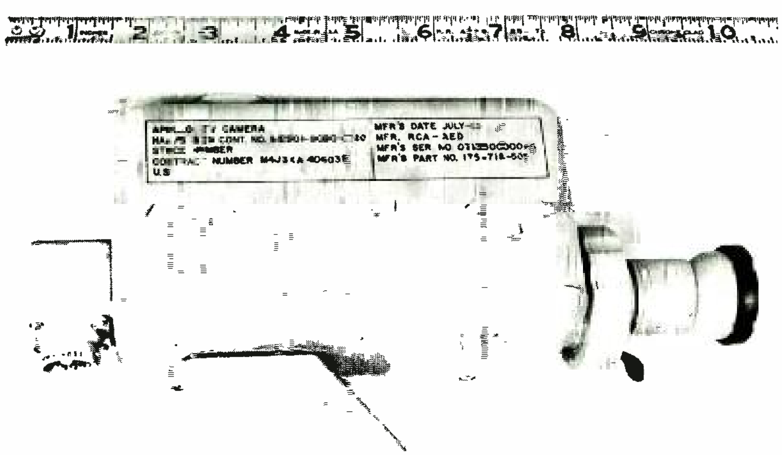

Fig. 7 — The hand-held black-and-white television camera used in Apollo flights.

Two of the cameras had 1132 scanning lines per picture

These latter Ranger vehicles each carried six television cameras. Each camera contained a one-inch vidicon camera tube. Since the bandwidth of the transmission channel to earth was limited to 200 kilohertz, a slow-scan television system was required. Two of the cameras had 1132 scanning lines per picture. To obtain high resolution, the readout frame time, after a 4.5 millisecond exposure of the vidicon surface, was 2.5 seconds. The scanned area in the vidicon was 0.44 inch on a side. These two cameras were designated "F-type" (Full Scan).

With the spacecraft traveling at nearly 9000 feet per second before impact, the readout time of the F-Type cameras would constrain the final picture to occur at two and one-half times this figure or at somewhat more than 22,000 feet of lunar altitude. For the final picture to be exposed at the lowest possible altitude, the four remaining cameras had a much shorter frame readout time.

These latter four cameras utilized 280 scanning lines with a scanned area of 0.11 inch and a frame readout time of 0.2 second. These partially scanned (P-Type) cameras allowed the final exposure to occur at an altitude of approximately 1800 feet. To insure complete coverage of the final moments before impact, the four cameras were so sequenced that while one was in the readout cycle the other three were in appropriate phases of the expose and fast-erase cycle.

It has been stated that the final pictures taken just before impact carried detail of about 2000 times greater than obtained from the best earth-based telescopes.

Lunar Orbiter carried, instead of the vidicon television systems used in other unmanned spacecraft, film cameras of very high resolution together with automatic laboratories for developing and fixing each picture and electronic scanning equipment to produce electrical signals for transmission back to earth.

Lunar Orbiter was designed to operate in conjunction with Surveyor. By photographing Surveyor sites from orbit, the detailed Surveyor findings could be extrapolated to other areas not available to Surveyor missions but easily recorded by orbital photography.

The first Lunar Orbiter was launched on August 10, 1966, and the missions continued for about one and one-half years. All five Lunar Orbiters were successful in producing over 1600 pictures. All potential Apollo landing sites were photographed with resolutions down to one meter. The last two Lunar Orbiters photographed the entire front face of the moon at resolutions perhaps ten times better than possible from earth and obtained detailed photography of many lunar features of particular interest, as well as doing photography of the far side of the moon.

The Surveyor mission consisted of a series of soft-landing lunar probes built to reconnoiter the moon's surface in preparation for an Apollo manned landing. The first Surveyors were primarily picture-taking spacecraft but later models conducted experiments in soil mechanics and analysis of the moon's surface composition.

The camera system consisted of two cameras, each using a one-inch vidicon

Surveyor I, launched on May 30, 1966, carried a camera system with a variable iris, changeable filters and a rotating mirror assembly which allowed the camera to look in almost any direction and take pictures under various lighting conditions, in either black-and-white or in color. Color pictures were obtained by exposing the camera to the same scene three times, each time using a different color filter, and reconstituting the picture on earth through similar filters.

The camera system consisted of two cameras, each using a one-inch vidicon. One camera used for a quick look produced 200 television lines at a 20.6-second frame time. The resulting signal was transmitted to earth at a bandwidth of 2.1 kilohertz. The other camera produced 600 television lines with a 1.2-second frame time and was transmitted with a bandwidth of 220 kilohertz. Most of the frames were digitalized on reception, processed on a computer to correct for the system frequency response and then converted back to image form.

Five Surveyors soft-landed on the moon. On command from the earth, they sent back scores of thousands of photographs ranging from panoramic views to high-resolution closeups of rocks and soil. Surveyor VII, launched in January, 1968, brought to an end the highly successful automated exploration of the moon in advance of man's first visit there.

Even before the Surveyor missions had been completed, the Apollo series began with a number of suborbital flights in order to check many performance features of the spacecraft and the launch vehicle. Then in October, 1968, Apollo VII set out on an eleven-day mission with three astronauts aboard. With them went a hand-held black-and-white television camera which provided the first live television pictures to home receivers from within a manned United States spacecraft, giving the American public its first view of life in an orbiting space vehicle.

Apollo VII, however, was only a prelude to the missions to follow...

This camera utilized a one-inch hybrid vidicon operating with a frame rate of 0.1 second and 320 scanning lines. The output signal, with a bandwidth of 500 kilohertz, was transmitted to earth. There the signal was converted to the line rate and the frame rate used for broadcasting television in the United States. The Apollo television signal, at its 0.1-second frame rate, was applied to a kinescope monitor and the picture formed on the monitor was focused onto a broadcast vidicon camera. In effect, the vidicon target stored the Apollo signal. For every third broadcast frame - which was once during each Apollo frame - the camera read out one frame of video signal at broadcast rates. For the next two frames, the scanning beam of the camera was gated *off* and no video was produced. The video from the camera was thus an interrupted video, one frame *on* and two frames *off*. The interrupted video was fed next to a magnetic disc recorder where the interrupted video was converted to continuous video. Each active frame was recorded on the disc, read out three times to fill the *off* frames, and then erased to make room for the next active frame. From the magnetic-disc recorder, the video was fed to a conventional stabilizing amplifier at the output of which the signal was ready for transmission over standard broadcasting facilities.

Apollo VII, however, was only a prelude to the missions to follow. On December 21, 1968, riding the most powerful rocket in history, three astronauts shot into a 100-mile-high orbit to prepare for a flight to the vicinity of the moon. After a few orbits of the earth, the spacecraft was given a velocity of more than 24,000 miles per hour in order to escape the gravitational field of the earth and head for the moon.

With a duplicate of the hand-held camera carried on Apollo VII, the Apollo VIII astronauts were able to send live television pictures of the lunar surface a quarter of a million miles to the American public on Christmas Eve, 1968. Apollo VIII proved that man had the equipment and ability to leave his own planet, navigate through the vast uncharted ocean of space, orbit the moon, and then find his way safely home.

Apollo IX tested the complete lunar module in earth orbit, by separating from the command module and joining it again in space. Before the flight of Apollo IX was finished, Apollo X was being prepared for launching. It completed a dress rehearsal of the lunar landing. After achieving lunar orbit, the lunar module separated from the command and service module, descended within 50,000 feet above the lunar surface, and then returned to a rendezvous with the command module in lunar orbit.

Apollo X carried a color-television camera in the command module. This camera used a secondary-electron-conduction picture tube together with a rotating color-filter wheel to produce field-sequential signals for transmission to earth. On earth, the sequential color signals were recorded on a magnetic-disc recorder and, after the application of a number of sophisticated techniques, a standard NTSC signal was available for broadcasting to the public.

The (SIT) silicon-intensifier-target tube is a low-light-level television camera...

This same method of producing broadcast-type color-television signals was used for command-module cameras in subsequent Apollo missions. However, Apollo XV and Apollo XVI each used a silicon-intensifier-target tube in the camera, since the secondary-electron-conduction tube proved to suffer catas-

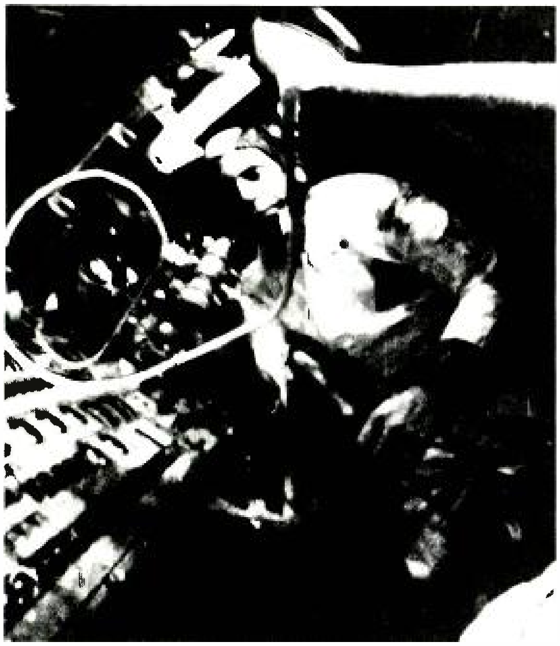

Fig. 8 — Television picture of the interior of the Apollo VII Command Module.

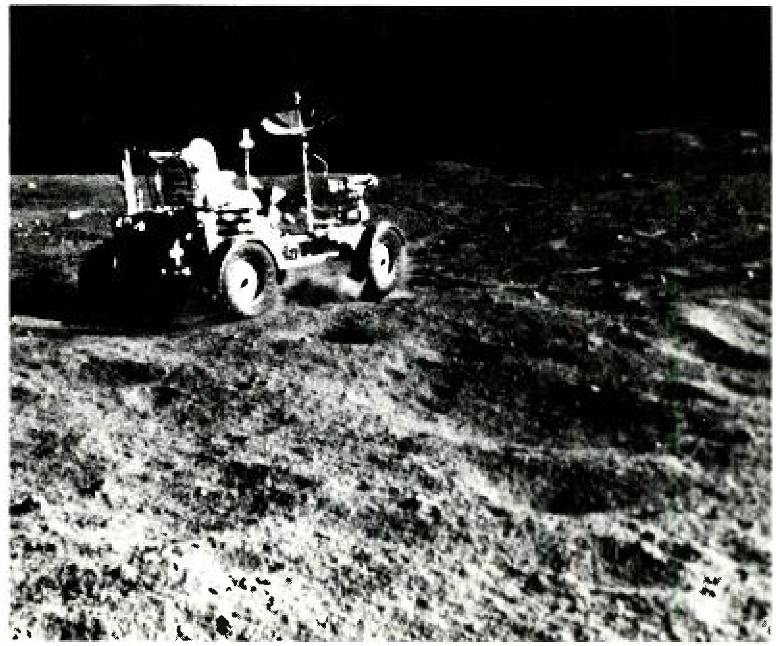

Fig. 9 — Lunar Rover speeding across the surface of the moon during the Apollo XVI mission.

trophic damage from very bright light or from a point of light in a dark field. The silicon-intensifier-target (SIT) tube is a low-light-level television camera tube consisting of a vidicon-type scanning electron gun and image-intensifier section separated by a very special silicon target with an integrated-circuit array of more than 600,000 p-n junction diodes. These features permit the tube to look directly into the sun without damage or to see in almost complete darkness.

In addition, Apollo XV carried to the surface of the moon a lunar rover equipped with a ground-commanded color-television assembly consisting of a field-sequential color-television camera with an SIT camera tube and a control unit which allowed controllers at the Manned Spacecraft Center in Houston, Texas, to operate the camera. This camera mounted on the lunar rover provided live television pictures from all the areas explored by the astronauts. As a further dramatic event, the color-television camera and control unit remained on the moon's surface to give the first live television coverage of a lunar module blasting off from the lunar surface for a rendezvous with the command module.

The drama of the eventful day of July 16, 1969, is difficult to describe. Apollo XI was ready to leave on its journey to the moon culminating in a manned lunar landing. The blastoff at Cape Kennedy occurred precisely on schedue, at 9.32 A.M. The modules disappeared through the cloud cover, went up to a circular parking orbit of 100 miles above earth and remained in this orbit for about three hours while numerous checkouts were conducted. Then the modules blasted off on a moon path at an initial velocity of a little more than 24,000 miles per hour. As the vehicle traveled along this path, the speed gradually dropped to about 2000 miles per hour due to the drag of the earth's gravitational field and then, about 34,000 miles from the moon, began to be accelerated by the gravity of the moon. NASA had scheduled the time for the outward journey from earth orbit to moon orbit to be 73 hours and 10 minutes.

I am sure that most of you saw the moon landing, the moon walks and the return to the command module. The television signals, in color from the command module and in black-and-white from the lunar module, were picked up on a large antenna at Parks, Australia, converted to standard United States television signals, transmitted to Sidney by microwave, thence via the Pacific Communications Satellite to NASA's control center at Houston for release to the television networks in the United States. And again, the signals were sent to Europe by satellite and subjected on arrival to another conversion to European television standards.

I read an essay in the New York Times, July 20, 1969, written by Walter Sullivan - an essay which I wish I could have written

Having been an observer of the awesome blastoff spectacle as Apollo XI left the ground and disappeared into the clouds, I must confess that I felt emotionally involved with history in the making. Only a few hours before the Lunar Module landed on the moon, I read an essay in the New York Times, July 20, 1969, written by Walter Sullivan - an essay which I wish I could have written. I should like to ask your indulgence for a few minutes while I share it with you.

"If the Lunar Module carrying two American astronauts lands safely on the moon this afternoon, it will indisputably be a landmark in human history. But it will also be unique in that such a large proportion of mankind will bear it witness.

"In the past, as a rule, only a few were aware of the great events that altered the course of man's destiny. Often centuries of perspective were needed before their significance became evident.

"There were scientific discoveries that set in motion new epochs of human thought, such as those of Archimedes, Pythagoras, Copernicus, Newton, Darwin and Einstein.

"There were great battles that turned the course of history, such as Marathon and Waterloo. And there were the great voyages, such as those that opened the new world to the old.

"But the world was in no real sense a witness to these events, and but dimly conscious - if at all - that it would never be the same again after them.

"The drama now coming to its climax as three American astronauts circle the moon, prior to a landing by two of them, represents a special kind of milestone in that it is the first voyage of human beings to another celestial body - and the entire world is watching.

"In some respects the Apollo 11 mission is reminiscent of early efforts to reach the North and South Poles. Then, as now, brave men set forth to penetrate an environment utterly hostile to man. Without their special clothing and supporting parties, they would have been lost.

"Yet Apollo differs from the brave feats of such past explorers in a basic way. Those who set forth across unknown seas and continents, from the Vikings to Columbus, the explorers of the North American hinterland and the polar regions, did so on their own.

"Anxious friends and supporters bade them farewell and waited months or years, aware that they might already have perished through some mishap that would never come to light.

"Now we ride all the way with the Apollo astronauts. Through an extraordinarily elaborate complex of monitoring systems, specialists here via radio telemetry keep track of hundreds of functions not only inside the spacecraft but inside the astronauts themselves.

"And finally, through television, almost the whole world watches. It was estimated that more than half a billion people witnessed the memorable start of the journey from Cape Kennedy Wednesday morning. The audience probably will be a good deal larger when astronauts Neil A. Armstrong and Edwin E. Aldrin Jr. step out onto the moon. A TV camera mounted on the outside of the Lunar Module, or LM, that will carry them down to the moon, will be aimed at the ladder by which Mr. Armstrong, in his bulging, tightly inflated space suit, will climb down to the lunar surface.

"One feature of this mission that sets it completely apart from all previous exploratory expeditions is the amount of preparation that went into it.

"If one includes the scientists, engineers and factory workers, as well as tracking personnel, it has taken hundreds of thousands of men and $24-billion to put two men today in a position to land on the moon.

"Furthermore, in contrast to earlier explorers who truly headed into the unknown, preliminary scouting by unmanned spacecraft has laid to rest many of the fears and uncertainties concerning a lunar landing, such as that the moon might be covered with a highly reactive cosmic dust, or that the landing craft might sink out of sight in a kind of lunar quicksand.

"As for the longer-term significance of the moon landing, we cannot say to what extent it is the start of a new era because we cannot estimate what man's ultimate capabilities will be. We can certainly establish bases on the moon to conduct scientific observations, as we have in the hostile environment of Antarctica.

"There are a number of such observations that could never be done under the earth's atmosphere - and a few, as in radio astronomy, that could not be done unless the great mass of the moon were interposed between the observing equipment and the noisy radio transmissions of earth.

"We may decide that it is worthwhile to send men to explore Mars and, perhaps, the great moons of Jupiter, although, as with the moon, reconnaisance by automated vehicle will almost certainly have to be done first.

"Far beyond the solar system lie other stars, presumably with their worlds, some of which may be inhabited - or habitable. Sober facts of distance and energy requirements, even given the most favorable fusion reactions, make travel to such worlds within a human lifetime seem problematical.

"Yet history has taught us (if we care to learn) that such arguments must be accepted with caution. We cannot foresee, beyond the obvious horizons, where technology and history will lead us. If two men successfully land on the moon, they will have taken a first step on a journey whose end no man can predict."

Over one-hundred years ago, science-fiction came rather close to present-day reality

Turning again to the past, one might note that Kepler and Newton, over three-hundred years ago, did all the basic research needed for these space shots and - if they had invented television and electronic digital computers as well as developed rocketry techniques - they could have done some startling things for their times, as well as ours. However, I wish to take a few minutes to tell you a bit about my own library researches on the subject.

Over one-hundred years ago, science fiction came rather close to present-day reality. In 1850, Cyrano de Bergerac wrote a series for French newspapers, called "The States and Empires of the Moon." Jules Verne followed in 1865 with his prophetic volume "From the Earth to the Moon in 97 Hours."

A study of this latter volume yielded this remarkable information:

1) In order to achieve the shortest path to the moon, one should aim vertically in order to catch the moon at the zenith. At the same time, the moon should be in its perigee, its closest point to earth, at the time of impact of the vehicle with the moon. Thus as much as 31,000 miles of transit could be saved. This required that the launch be no further north than twenty-eight degrees north latitude nor further south than twenty-eight degrees south latitude, for the moon never exceeds these bounds. Jules Verne picked Tampa, Florida, for Captain McNicholl's launch site and NASA picked Cape Kennedy, both sites very close to twenty-eight degrees north latitude.
2) Jules Verne calculated the escape velocity, neglecting the friction of the earth's atmosphere, to be 24,545 miles per hour. According to NASA, Apollo XI kicked out of its 100-mile earth orbit at "more than 24,000 miles per hour."
3) On the next item, I really had to dig because of some ambiguities which I discovered in two English translations of Jules Verne's work. The Princeton University library provided the original French version. Here it is stated "Il devra étre lancé le premier décembre de l'année prochaine, a onze heures moins treize minutes et vingt secondes." One is left slightly in doubt as to whether this is late in the morning or late in the evening until one encounters another phrase "a dix heures quarante-six minutes et quarante secondes du soir" which places the launch at one hour, thirteen minutes and twenty seconds before midnight on the first of December. Then one encounters "Il rencontrera la Lune quatre jours apres son depart, le quatre décembre a minuit précis." Here somebody made a mistake in arithmetic in arriving at the ninety-seven hour figure in the title of this book, for from a little before midnight on the first of December until precisely at midnight of the fourth of December is only three days plus one hour, thirteen minutes and twenty seconds for a total transit time of seventy-three hours, thirteen minutes and twenty seconds. According to NASA, Apollo XI used seventy-three hours and ten minutes from the time it was kicked out of earth orbit until it began its first circuit of the moon.

One can only conclude that there is nothing new under the moon

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Design considerations of binary PSK modems

B. E. Tyree

This paper presents both theoretical and practical aspects in the design of binary PSK modems. Of significance is a guide to determining the system implementation loss budget for predicting the degree to which a modem design performs with respect to theoretical bit-error-rate performance.

Bennie E. Tyree, Ldr., Satellite Terminal Engineering, Government Communications Systems, Camden, New Jersey, received the BEE from the University of Florida in 1957 and the MSEE from Drexel University in 1963. He joined RCA in 1957 participating in the Engineering Training program and then the PRC-35 transceiver program during 1958. Other major program responsibilities from 1959 to 1964 include the GKA-5 Data Link project, classified VLF program, the Dyna Soar X-20 SHF Ground Receiver and the AN/TRC-97 Troposcatter Communications Equipment. In November of 1964 he became project engineer for the development of an FDM equipment to meet DCA requirements and continued on this program through 1967 when he received the RCA Professional Excellence Award. He was promoted to Engineering Leader in June of 1967 on the TACSAT 1 program, responsible for developing two of a family of five Tactical Satellite Terminals, including a high speed Differential Encoded PSK Modem. In 1970 he was responsible for three other TACSATCOM programs including a simulation of FDMA accesses to a hard limiter resulting in the formation of spacing allocations based on intermodulation distortion. During 1971, he performed further work in the satellite terminal area, high speed modems, and error correction devices. He is a member of the IEEE and the Communication Technology group.

THE DESIGNER of present-day communication systems is faced with the problem of determining the most efficient way to process digital data (such as teletype, digitized voice, PCM, or high-speed digital data) through a system and recover the data at a distant station with sufficient accuracy to reconstruct intelligible information.

A modem (modulator-demodulator) of some type is used to impress the data on a carrier prior to transmission by the radio and, in a like but reverse manner, another modem is used at the distant receiving station to demodulate the data for use by the appropriate processing equipment.

This paper presents the theoretical and practical aspects in the design of one such type of modem: a binary-phase-shift-keying (BPSK) modem which offers the optimum method (when properly implemented) for transmitting digital data in terms of minimum error rate probabilities. Only uncoded transmission is considered, but the same generalized approaches are used when coding is required to achieve the system performance.

The paper is divided into two major sections: the first describes theoretical PSK techniques, and the second describes the factors that affect the systems implementation losses (*i.e.*, how close to theoretical a modem design can be achieved).

Theoretical PSK

Binary data communication systems use two symbols or states as a means of transmitting information. These symbols may be transmitted in a number of forms to combat noise and other channel perturbations. The figure of merit used to determine the quality of transmission is specified in terms of bit-error rate (BER).

PSK modulation techniques offer the optimum system(s) for transmission of digital data in terms of achieving minimum bit-error-rate probability. In general, it is assumed that the transmission channel is degraded only by additive white gaussian noise. In the practical situation this is not the case, especially if communication is through a hard-limiting satellite where spectral sidelobe interference (for unshaped phase-transition systems) and intermodulation distortion fall into the active channels. For reference purposes, the assumption is made that these interferences look like white noise in terms of their effect on a particular channel. Lawton[1] has shown that the minimum probability of error, P_e, for binary transmission in an ideal uncoded PSK system to be given by the expression:

$$P_e = [1-\text{erf}\sqrt{E(1-p)/2N_o}]\,/\,2 \qquad (1)$$

where E is the average energy per received symbol (bit); p is the finite time correlation (or correlation coefficient) of the two symbols $s_0(t)$ and $s_1(t)$ where $-1 \leq p \leq 1$; N_o is the noise power spectral density *i.e.*, noise power/Hz); and erf(x) is the error function of x, defined by

$$\text{erf}(x) = \frac{2}{\sqrt{\pi}}\int_0^x \exp(-y)^2 dy$$

Some discussion is pertinent at this point with respect to the assumptions underlying the derivation of Eq. 1. The factor, p, defines the likeness or unlikeness of two signals $s_0(t)$ and $s_1(t)$ which represent a logical 0 or a logical 1, respectively. Notice that the form and type of signals, their bandwidth, *etc.*, is not explicit in the equation except for their relationship to p.

Coherent PSK

By inspection of Eq. 1, the optimum value of p is determined to be -1 for minimum error rate probability. This case (for $p =$

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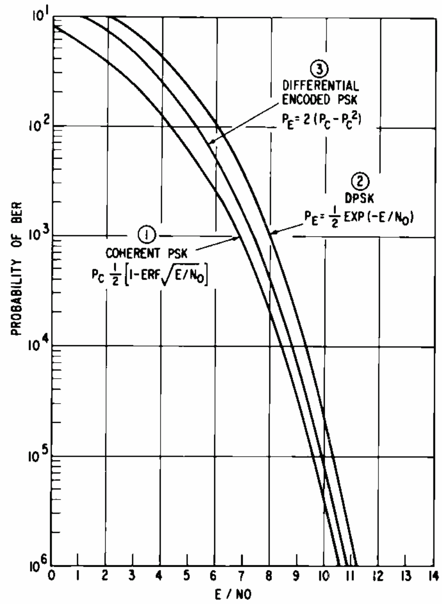

Fig. 1 — Theoretical comparison of PSK techniques.

−1) occurs when the two signals $s_0(t)$ and $s_1(t)$ are antipodal; substitution of $p=-1$ in Eq. 1 results in the well known relation for coherent PSK:

$$P_e(\text{CPSK}) = [1 - \text{erf}(\sqrt{E/N_o})]/2 \quad (2)$$

Application of Eq. 2 in a practical situation requires that the receiving modem be: 1) perfectly synchronized with the received signal, 2) use a noise free carrier reference, and 3) employ correlation detection or, equivalently, matched filter detection. In addition non-linearities should not exist in the system path prior to demodulation (since these affect the statistics of both signal and noise) nor any memory from pulse-to-pulse since the derivation of Eq. 2 is based upon isolated pulse reception.

In the transmitter, the requirement that $s_0(t)=-s_1(t)$ is accomplished by reversing the phase of the transmitted carrier (*i.e.*, the relative phase between a 1 and 0 is 180°) thereby providing the required correlation coefficient ($p = -1$).

To accomplish true coherent PSK, a receiver carrier phase reference must be known with respect to that which is transmitted. If this carrier reference is not available, a known phase indication (or sync signal) must be provided from the transmitter to allow the received data to be properly demodulated. If this does not occur, the receiver reference may be inserted out of phase with the incoming modulated carrier and the information demodulated in an inverted state resulting in the 1-0 ambiguity problem (*i.e.*, a 1 is demodulated as a 0 and vice versa).

Thus, the basic modem design problem then lies in how to establish the receiver carrier reference. Since the transmitted phase-reversed signal is of a double-sideband suppressed-carrier format, there exists no carrier component of sufficient magnitude which may be used in the receiver as a reference. Thus, the case of a pure coherent PSK system in reality does not exist, but, CPSK provides a base upon which all other techniques may be compared and evaluated.

Fig. 1, curve 1, shows the theoretical attainable error rate *vs.* E/N_o for uncoded CPSK. This curve will be used as the basis for comparing the PSK implementation techniques discussed in the following paragraphs.

Pilot tone — auxiliary carrier

There are two obvious methods of achieving a receive-carrier reference: transmit a residual carrier or transmit a pilot-tone frequency which is near that of the data signal from which a receiver reference can be obtained. The pilot tone frequency is derived in the transmitter in such a manner that a correct phase relationship is established with the received data thereby avoiding the 1-0 ambiguity problem in the receive reference and demodulated data.

To provide a proper frame of reference for comparing types of PSK techniques, we assume that the total transmitted power for all cases is identical. It is rather obvious that when some of the power is removed from the information and used by the pilot-tone signal, the expected probability of error will be degraded by a movement along the E/N_o axis of Fig. 1. Van Trees [2] has shown that the best approach is to devote all the available energy to the modulation and obtain the carrier reference information by operating on the incoming signal in such a manner to remove its dependence on the data.

PSK — extracted carrier

Since the pilot-tone system results in appreciable degradation from the theoretical coherent PSK case, other forms of carrier reference extraction techniques are used.

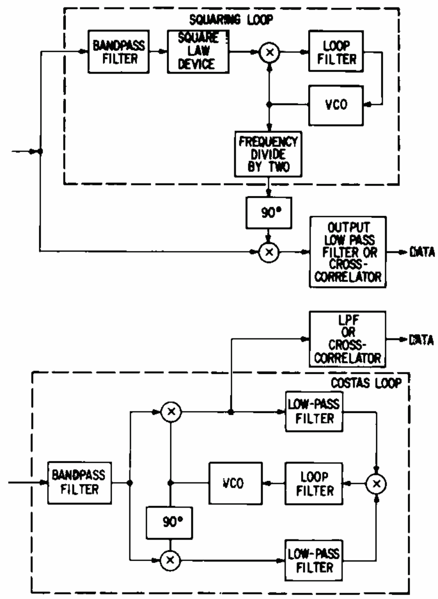

Fig. 2 — Carrier extraction techniques.

Both Van Trees [2] and Lindsey [3] treat the pilot-tone and the carrier-extraction from-modulated-signal cases in depth. The extraction from the modulated signal or self-synchronizing scheme operates on the modulated IF signal.

This operation is performed without degradation to the signal in the data channel. One of two non-linear operations is used: 1) the squaring loop or 2) the Costas phase-lock system, as shown in Fig. 2. Van Trees [2] has proven that these two carrier-extraction techniques are identical in operation.

The basic operating principle for these schemes is as follows: The modulated signal is of a double-sideband suppressed-carrier format; thus, the data transitions must be removed to allow tracking. In the squaring loop, this is accomplished by the frequency doubler which produces a continuous-phase signal at twice the input IF frequency. By proper filtering, the output is tracked by a phase-lock loop and smoothed as required. However, since frequency multiplication is used (in both the squaring loop and the Costas loop) the 1-0 ambiguity problem exists in the receiver carrier-reference signal. This occurs since multiplication of a 0° or 180° data signal results in a 0° or 360° (0°) doubled frequency reference. This problem can be resolved by transmitting a sync pattern (a number of recurring bits of known relationship over a given time interval) to assure proper phase synchronization in the receiver. This requirement increases the transmission rate and reduces the effective information on a per-frame basis. Until correct phase synchronization is achieved, erroneous data is supplied or no data at all. Even with this limitation the extracted carrier technique provides the simplest method of supplying a "noiseless" receiver reference signal. In addition, differential techniques can be employed to resolve the 1–0 ambiguity at a small penalty. Analyses by Lindsey[3] and Stiffler,[4] based upon prefiltering and loop-filter requirements, indicate that the noise contribution will be negligible when proper constraints are employed on the filter bandwidths.

Differential systems

To avoid the transmission of either a carrier pilot, pilot tone, or synchronizing pattern, differential schemes have been developed. The differential schemes are such that even if the receiver reference is out of proper phase with the transmitted information, the data will be processed in the correct form. In these schemes, a space (0) is generally represented by a phase reversal while a mark (1) represents no reversal. Either state can be chosen as long as the convention is maintained in the system. In essence, the transmitted data has been encoded so that a change in state of the carrier phase represents a 0. At the receiver, one of two techniques is employed to convert this type of transmission into binary data 1) at RF or 2) at baseband after demodulation.

Differential PSK (DPSK)

A block diagram of a typical DPSK system is shown in Fig. 3. The data is encoded initially into phase reversals of the carrier only when a space or logical 0 occurs. In the receiver, a delay line is employed at IF frequencies to delay each data bit by one baud interval. This delayed information is then used as the receiver reference and compared with the next baud to detect data phase transitions. Each subsequent baud is then compared with its adjacent baud and the

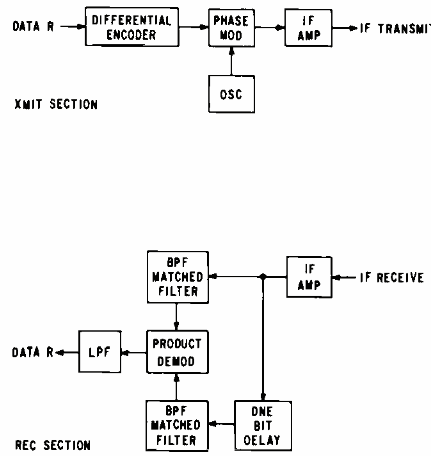

Fig. 3 — Differential PSK (DPSK) system.

output digital data derived from the comparison. Two inherent drawbacks result from this type of detection; first, the reference is perturbed by the same content of noise as the desired signal; second, since comparisons are being made on adjacent bits, adjacent symbol dependence affects the bit error probability and, as one would expect, the errors tend to occur in pairs.

Lawton [1] gives the expression for the BER probability of differential PSK as:

$$P_e\,(\text{DPSK}) = \exp\,[-E/N_o]/2 \qquad (3)$$

Fig. 1, curves 2 and 1, present the comparison of the DPSK system and coherent PSK reference system. For BER probabilities of less than 1×10^{-5}, DPSK requires about 0.7 dB more signal-to-noise ratio (E/N_0) than that for CPSK; however, at a BER of 1×10^{-2}, the difference is 1.6 dB

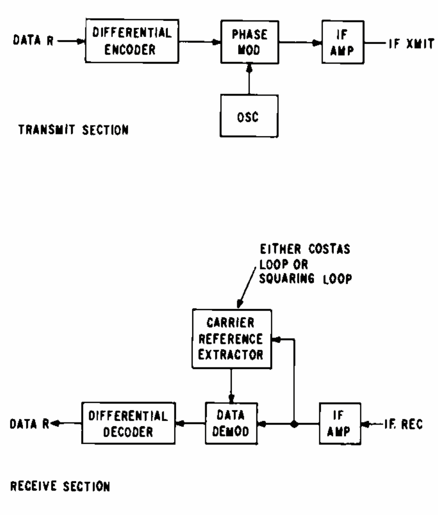

Fig. 4 — Differential encoded PSK (DEPSK) system.

Differential encoded PSK (DEPSK)

In the differential encoded PSK schemes, the encoding and decoding is performed at baseband, *i.e.*, at the digital level (see Fig. 4). This scheme is of primary significance with regards to the 1-0 ambiguity problem. With the known fact that a change of state in the transmitted carrier occurs only when a space is present in the data stream, the receive decoder senses the change of state and provides a correct output data stream under a non-noisy environment. This occurs even if the carrier reference extraction locks in the wrong phase (1-0 ambiguity) since the decoding process provides an output (space) only when two adjacent bits are of different polarity.

The receiver reference extractor used for this type of system is derived by either the squaring loop or Costas loop given in Fig. 2. The parameters of these carrier extraction techniques are assumed to be of such a nature that the receiver reference does not contribute to the overall error rate. However, in a noisy environment where single errors occur in a straight binary channel, errors tend to occur in pairs where differential encoding/decoding is used. This loss in equivalent energy per bit is generally small. Martin [5] gives the probability of BER for differential encoded PSK as:

$$P_e(\text{DEPSK}) = 2P_e(\text{CPSK})\,[1-P_e(\text{CPSK})] \qquad (4)$$

Curves 1,2 and 3 of Fig. 1 indicate the BER performance of DEPSK compared to CPSK and DPSK. Where low BER's occur, DEPSK has an error rate of 2 to 1 over CPSK. This amounts to an increase of about 0.3 dB in signal energy at a BER of 1×10^{-5} compared to 0.9 dB for DPSK. At a BER in the range of 1×10^{-2}, DEPSK requires 0.9 dB increase in signal power for the same performance as CPSK while a DPSK requires 1.6 dB. Therefore, DEPSK provides the better PSK technique as compared to CPSK.

Comparison of PSK techniques

The various PSK techniques discussed above are compared in Table I in terms of 1) the error rate performance equation, 2) the type of receiver reference, and 3) the inherent problems. In a particular system environment, any one of the practical

Table I — Comparison of PSK techniques.

Type	Error* rate expression	Receiver reference	Basic problems	Comment
1) CPSK	$[1 - \text{erf}\sqrt{E/N_o}]/2$	None	Pure receiver reference does not exist.	Used as basis for comparison (based on equal transmitted power).
2) PSK — pilot tone	$[1 - \text{erf}\sqrt{E'/N_o}]/2$	Pilot tone	Loss of energy from data to pilot tone carrier reference.	Increased power required to achieve same error rate performance as CPSK. $E' = E - Ep$
3) PSK extracted carrier	$[1 - \text{erf}\sqrt{E/N_o}]/2$	Extracted from modulated carrier	Phase ambiguity 1–0	Resolve by transmitting sync pattern. Increases total transmission rate, therefore, increased error-rate performance.
4) DPSK	$\exp(-E/N_o)/2$	One baud delayed modulated carrier.	Carrier reference corrupted by same noise in chan. as data.	Higher error rate performance than other techniques.
5) DEPSK	$2[P_e(\text{CPSK}) - P_e^2(\text{CPSK})]$	Extracted from modulated carrier.		Performs closest to CPSK in terms of BER.

*Based on equal transmitted energy for each case.

schemes may satisfy the requirements. In the overall analysis, however, DEPSK offers the better PSK approach since it inherently eliminates most of the basic problems associated with modem design with little penalty involved.

Modem design factors and system implementation losses

In implementing a particular modem, the system design engineer should know to what degree a given design performs with respect to theoretical in terms of bit error rate. Once the selection of the modulation technique is effected, a modem-implementation loss budget is prepared which permits a comparison to be made against given system BER, C/N_o (carrier-to-noise/Hz), and E/N_o requirements.

In cases where the allowable system implementation loss is exceeded by the loss budget, design tradeoffs are conducted with the modem and terminal parameters to achieve the allowable system loss (in some cases, coding of some form may be required).

The following section describes 1) the factors that contribute to the implementation loss and 2) the methods for calculating the loss attributable to each factor.

Matched filter considerations

Theory

In designing a PSK system for optimum performance, matched filter detection or cross correlation is used in the receiver to maximize the output signal-to-noise ratio when its input consists of a known signal plus random noise

It can be shown[6] that the transfer function, $H(W)$ of a matched filter in the presence of white noise (flat power spectrum, N_o W/Hz) is the complex conjugate of the spectrum of the signal, $S(W)$, to which it is matched.

The maximum output S/N for a matched filter receiver then is:

$$S/N(\text{max}) = 2E/N_o \qquad (5)$$

where E is the total energy per bit of input signal, and N_o is the noise spectral density in W/Hz (*Note*: double sided noise density).

This expression indicates that the shape of the signal or its fidelity is of no importance in determining the maximum S/N as long as a matched filter is used; only the total energy matters.

Implementation of matched filter

In implementing a matched filter, one first consideres the type and spectral distribution of the transmitted signal. In a practical situation, there exists some finite loss in shaping the matched filter response to match the transmitted signal.

$$n = \frac{\text{actual } S/N}{\text{theoretical } S/N_{MF}} = \frac{|S_o(t)|^2 max/N}{2E/N_o} \qquad (6)$$

In addition, other design constraints and factors in the system tend to distort the transmitted waveforms resulting in further mismatch between the received signal and the matched filter response resulting in some degree of performance degradation. These factors are primarily from filter distortion (associated intersymbol interference) and truncation (see Jones[7]).

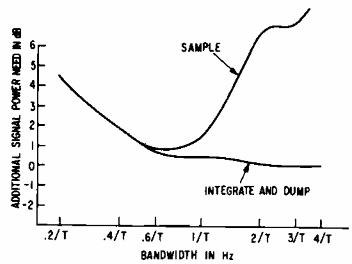

Fig. 5 — Average effect of band limiting on the detection of NRZ binary.

Two types of practical filtering arrangements are generally used in implementing a matched filter: 1) integrate, sample and dump and 2) sampled filter. Either arrangement is used in pre-detection or post-detection filters; however, the following discussion considers only post-detection processing using square-wave PSK modulation (without amplitude or phase-transmition shaping).

The integrate, sample, and dump (IS&D) implementation, under the environment of white noise and infinite bandwidth (no truncation), is the optimum matched filter. In an actual system, unlimited bandwidth is not achieved due to system noise, spurious noise, and interference limitations. The actual degradation in this case is threefold: 1) restricted bandwidth results in loss of signal energy; 2) the received signal is rounded and mismatches the integrate LPF response; and 3) extreme restriction of the bandwidth, $B_{IF}/R \leqslant 2.0$ (where R is the data rate and B_{IF} is the IF bandwidth) results in high intersymbol interference (for $B_{IF}/R \geqslant 2.3$, the intersymbol interference is $\geqslant 20$ dB).

However, even with these limitations, the IS&D approach provides the better matched filter as shown by Park[8] (Fig. 5). For detailed discussion of the sampled filter case, see Schwartz[6].

Matched filter — loss considerations IS&D

In addition to the IS&D imperfect integration loss, another filter loss occurs for band-limited signals since the received waveform does not match the integrator transfer function as in the optimum case. This contribution is analyzed in the following manner. [This analysis conducted per communication with Dr. I. M. Jacobs of the Linkabit Corporation, San Diego, Calif.]

Given the system model shown in Fig. 6 the probability of error for antipodal signals for the optimum case is given by Eq. 2 in terms of the available E/N_o.

In Fig. 6, $S_1(t)$ is a biphase signal having energy, E, over the symbol period and $S_2(t)$ is a biphase signal have energy, $E_2 = BE$, over the symbol period with loss B occurring from truncation.

Referring to the system model and considering the signal $S_2(t)$ after the filter, F_1, the available energy to noise density becomes E_2/N_o at the data detector. This means an effective energy loss, (function of B) occurred through the system filter and a shaping of the waveform which results in a mismatched spectrum at the integrator filter.

The integrator now effectively multiplies $S_2(t)$ against a stored replica of $S_1(t)$ and results in an additional loss factor in terms of the ratio E_2/E. Therefore, the probability of error for the truncated signal and the optimum filter becomes:

$$P_e \propto f\,[E/N_o]$$
$$P_{e2} \propto f[(E_2/N_o)(E_2/E)] \propto f[(E_2)^2/N_oE]$$
and $E_2 = BE$
$$P_{e2} \propto f\,[(BE^2/N_oE] \propto f\,[B^2\ E/N_o]$$

Thus, the overall effect of truncation with the IS&D filter is to basically double the band limiting loss if a matched filter is used which matches the original $[\sin x/x]^2$ distribution. For example, if an 0.1-dB loss is incurred from truncation, a like loss of 0.1 dB occurs from mismatch in the integrator filter, and a total transmission loss of 0.2 dB. Therefore, for budgeting purposes, matched filter losses for the IS&D filter should contain losses due to: 1) imperfect integration and 2) an equivalent loss equal to any truncation loss.

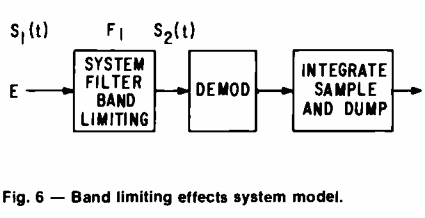

Fig. 6 — Band limiting effects system model.

Bandwidth limiting effects — truncation loss

In a modem design using an integrate, sample, and dump matched filter, band-limiting causes an energy loss and consequently degradation of system performance. This is a result of the significant energy in the sidelobes of a square-wave-modulated PSK signal. This type of signal exhibits a power spectral distribution which follows a $[\sin x/x]^2$ form with some 10% of the total energy in the spectral sidelobes and the remaining energy (90%) contained in the main lobe. To accomplish system filtering requirements, the system filters remove or truncate sidelobe energy in some fashion depending upon the narrowest filter in the system. Table II lists the losses due to truncation for unshaped BPSK signals containing a given number of sidelobes. The signal in each case is considered to be symmetrically centered in the system filter with both sidelobes of a given number truncated. For example, if all sidelobes are truncated leaving only the main lobe, a loss of 0.45 dB in system performance results while a signal containing four sidelobes results in a 0.1-dB degradation. For a given sytem design, one determines the truncation loss of the narrowest bandwidth filter in the system and allocates this loss in the system implementation loss budget.

Phase-distortion effects

Quadratic and linear phase distortion are the primary types of phase distortions that influence the BER performance of a given modem design. Quadratic-delay distortion results from sharp cut-off filters while linear delay distortion results from operation to either side of center frequency in a given filter. In addition to these two effects, amplitude slope from system and modem filters affect performance. Sunde[9] presents analyses (for raised cosine pulses) which predict the degradation for given amounts of linear and quadratic delay distortion as

Table II — $[\sin x/x]^2$ function.

Lobe	*Accum. energy level*	*% of total energy*	*Energy loss (dB)*
1. Main	2.8296	90.0	0.45
2. 1st	2.9776	94.8	0.23
3 2nd	3.0294	96.4	0.16
4. 3rd	3.0556	97.3	0.12
5. 4th	3.0714	97.8	0.1
6. 5th	3.0820	98.1	0.08
7. 6th	3.0896	98.3	0.07
8. 7th	3.0952	98.5	0.06
9. 8th	3.0996	98.7	0.055
10. 9th	3.1032	98.8	0.05
11. 10th	3.1060	98.9	0.04
All ∞	3.1416	100.0	0.00

Total energy ($-\infty$ to $+\infty$) = π = 3.1416

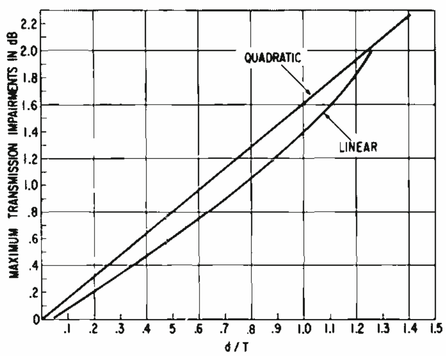

Fig. 7 — Transmission impairment versus delay distortion.

given in Fig. 7 where the delay and data rate period are designated d and T, respectively. While his analyses are for raised cosine spectra pulses and sampling at pulse peak, it is expected that his results are sufficiently valid for square-wave modulation.

The general design procedure is: 1) set the amount of degradation (implementation loss); 2) Use fig. 7 to determine d; and 3) design the various terminal and modem filters to obtain the allowable delay factor. For amplitude slope effects, Sunde concludes that, for slopes as high as 12 dB over the signal band, the loss is only 0.7 dB. Therefore, it is reasonable to expect that a given slope over the signal band will degrade roughly proportional to the amplitude slope. Losses from these three factors are generally combined on an RSS (root-sum-square) basis to arrive at a total factor in the loss budget.

Demodulator and carrier extraction losses

In the demodulation of the data impressed on the received carrier, some performance degradation is incurred because of imperfect carrier reference from the carrier extractor. For optimum demodulation, the receive carrier reference must be in exact phase coherence (0° phase error) with the received signal. Two sources exist in the carrier extraction which result in a phase error at the data demodulator: 1) thermal noise and 2) long-term or slow-frequency variations.

Thermal noise effects

In general, the Costas or squaring loop is used for carrier extraction and are the designs considered with the squaring-loop extractor used for discussion purposes.

The input to the carrier extractor is specified in terms of C/KT (or C/N_0) at some specified BER. The important factor under these conditions is to determine the required S/N in the phase-lock loop (and consequently the S/N of the extracted carrier) to minimize the degradation to the available E/N_0. It has been shown by Jacobs[10] that this degradation factor takes the form of $\cos^2\phi_1$ (E/N_0) for second order PLL; where ϕ_1 is the effective phase offset (in degrees) between the reference and the incoming signal due to phase noise variance or jitter.

Fig. 8 [10] indicates BER performance for various carrier reference S/N. Using this figure and realizing that in the actual PLL the S/N is 6 dB worse than the S/N of the carrier reference (because of divide-by-2), one can establish the degradation for a given condition.

First, the losses in the input filter and the ×2 (doubler) are established. In the ideal case, the input filter is a matched filter to the input signal spectrum thereby maximizing the S/N in the PLL. In general, a conventional maximum flat Butterworth filter is used thereby incurring some loss of side-lobe energy due to truncation. This loss is generally negligible, but in a system operating near threshold it must be considered. The doubler loss is then 6 dB plus a carrier suppression factor given by Lindsay[11] as:

$$L = 1/[1 + (N/4C)] \quad (7)$$

where L is a power ratio. [The *suppression factor* is a function of the predetection C/N_0 (carrier-to-noise) and results from the product formations in the non-linear device.]

These losses are then subtracted from the available C/KT and the S/N established in a given PLL bandwidth. From this information, the implementation loss from the carrier reference noise is then determined from Fig. 8. If this degradation is excessive, the loop bandwidth must be reduced to meet the allowable degradation.

Frequency offset effects

In the use of a second-order PLL, the reference signal is pulled into frequency

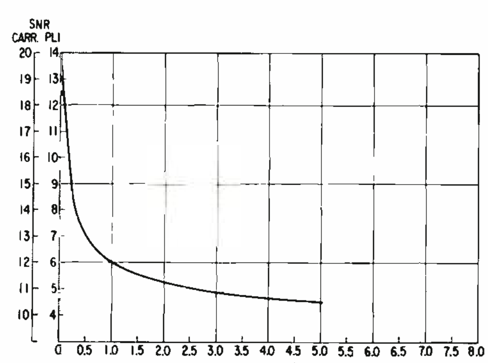

Fig. 8 — Carrier S/N versus degradation in E/No.

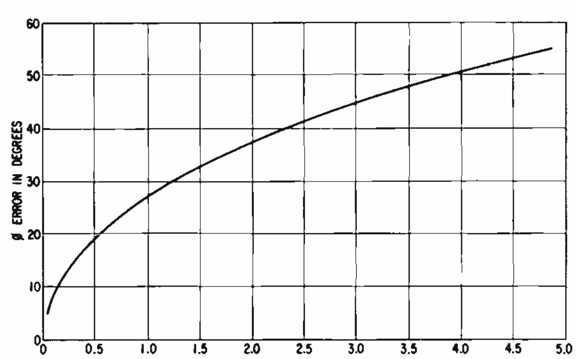

Fig. 9 — E/No degradation versus phase offset error.

synchronism with the received signal. However, exact phase coherence is not necessarily effected and some residual static-phase offset exists depending upon the loop gain, K. When a signal is received which is offset from the center frequency (of the IF) because of long-term or short-term system instabilities or slowly changing doppler frequency shifts, an additional phase offset occurs. These phase offset effects are calculated from the relationship:

$$\phi = 2\pi\Delta f / K \qquad (8)$$

where ϕ is the phase offset (radians); Δf is the frequency offset (Hz); and K is the loop gain (ratio).

The loss from the phase offset degradation is then calculated using the expression:

$$\textit{Offset degradation} \text{ (dB)} = 20 \log(\cos\phi_e) \qquad (9)$$

where ϕ_e is the phase offset in degrees.

Fig. 9 indicates the effective degradation to the available E/N_o versus phase offset in degrees.

Hence, long-term frequency offsets resulting from system frequency instabilities affect the PLL design in terms of the loop gain and minimum error-rate degradation. This loss is included in the system implementation loss budget where frequency instabilities are not corrected either by automatic or periodic adjustments.

Timing extraction effects (symbol synchronization)

For proper processing of detected data, symbol synchronization is required in the receiving section of the modem.

Timing information, sampling, and integrator dumping signals are derived by some form of extraction technique using

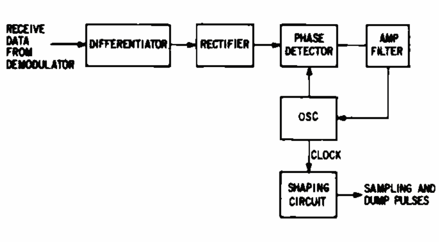

Fig. 10 — Typical timing extractor configuration.

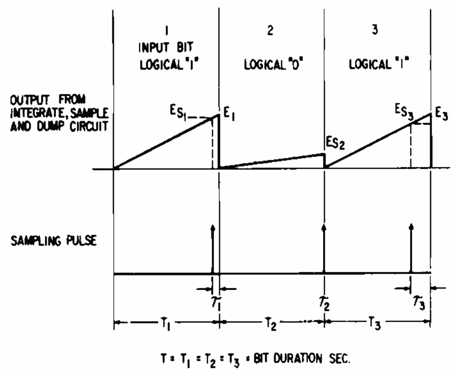

Fig. 11 — Sampled output from matched filter (IS&D).

the received data. A typical timing extraction configuration is shown in Fig. 10. The operation of this technique depends upon the data format, *i.e.*, the number of transitions or zero crossings in the data stream. Differentiation of the transitions and subsequent rectification produces a series of spikes that contain a line frequency component at the data rate. This line frequency is used by a phase detector and compared to the phase of a VCO or VCXO and the phase error signal used to pull the VCO in frequency synchronization with the received data stream. The output of the PLO is processed to provide the required sampling, integrator dump, and timing signals needed by the modem.

Since the basic mode of operation depends upon the data format, a degree of coasting (holding time) is required in the PLO. This coasting factor represents an effective loss in C/N_o by the ratio of the expected number of transitions over a given number of data bits. For example, a timing extractor designed to perform with one transition in 10 data bits has its available C/N_o ratio reduced by 10 dB.

Consequently, the PLO loop parameters are adjusted to operate with the lower C/N_o. In addition, the non-linear process of differentiation and rectification represents a doubling function thereby further reducing the available C/N_o by 6dB plus some suppression factor relating to the C/N at the input to the doubler (see Eq. 7).

Considering these factors, we are then ready to evaluate the performance of the timing extractor with regards to transmission impairment (implementation loss). Depending upon the input S/N to the timing extractor and its filtering properties some timing jitter appears on the sampling pulses causing the sampling to occur earlier or later than the end of the data bit. This jitter results in the sampled output from the matched filter to be of less magnitude than that of the ideal case (see Fig. 11), thereby effecting a loss of energy. This timing jitter occurs from two sources (similar to the case of the receiver carrier reference extractor): 1) thermal noise and 2) static phase error due to frequency offsets.

Thermal noise

Stiffler[4] gives the transmission loss due to thermal-phase noise jitter on the timing reference in terms of timing pulse variance $\pi\sigma_e$ and E/N_o as shown in Fig. 12.

$$\text{Since } \sigma_e = t_n / T_S = \phi_n / 2\pi \qquad (10)$$

$$\text{then } \pi\sigma_e = \phi_n / 2$$

where ϕ_n is the timing-phase error (radians) due to noise in the extraction loop $= \sqrt{N/C}$; t_n is the timing-pulse time variation due to noise (seconds); and T_S is the symbol bit duration (seconds).

The method of design is to select a given implementation loss per Fig. 12 at the desired BER, thus determining $\pi\sigma_e$. From a given $\pi\sigma_e$, the timing phase error is determined and, consequently, the PLL C/N ratio. Using the coasting factor loss

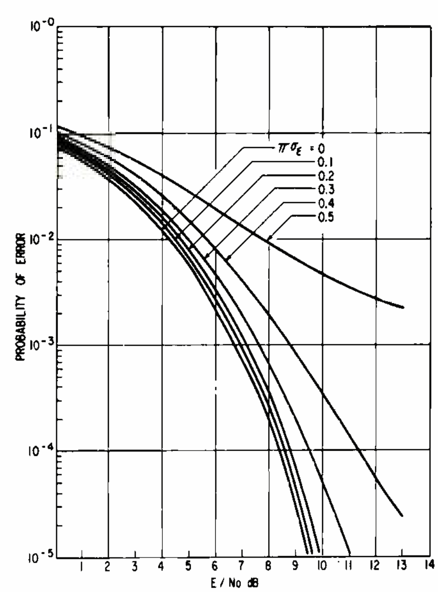

Fig. 12 — Binary PSK symbol error probability.

and the doubler loss, the PLL bandwidth is then determined. Some tradeoffs between the implementation loss and the PLL bandwidth may be required.

Static phase offset

Long-term frequency instabilities affect the timing extraction similar to the case of the carrier reference extraction. However, the main concern is the frequency instability of the timing extractor VCXO instead of system instabilities. Stiffler[4] shows the transmission loss due to static phase error in the loop to be given by:

$$Loss = 20 \log (1 - 2\tau / T_S) = 20 \log (1 - \phi / \pi) \quad (11)$$

where τ is the timing jitter (seconds); T_S is the symbol bit duration (seconds); and ϕ is the phase error (radians).

This loss is calculated and contained in the loss budget unless periodic adjustments can be made to minimize its contribution.

Dump pulse width effects

In a modem using a single channel IS&D filter, some loss of energy occurs due to a finite dump pulse width in the ratio of the dump pulse width to the data pulse width. This loss is calculated from:

$$Dump\ pulse\ loss\ (\text{dB}) = 20 \log[1 - (P / T_s)] \quad (12)$$

where P is the dump pulse width; and T_s is the symbol bit duration;

This loss can be overcome by using dual IS&D channels and alternating information bits to each channel with dumping accomplished after the bit interval. If a single channel is used, then this loss must be considered.

Phase noise, spurious noise, and short-term-stability effects

Terminal phase noise, spurious components, and short-term-stability effects have to be considered in a digital modem design with regards to system implementation losses. No rigorous rules can be formatted for these factors since the data rate and carrier extractor phase-lock-loop parameters and terminal characteristics vary. However, some generalized comments can be stated with regard to allocating losses for these factors.

Two effects are generally noted in the modem. Near the carrier, *i.e.*, within the natural frequency (W_n) of the carrier extractor loop, the $1/f$ noise from the standard stresses the performance of the PLL. This effect appears as a slowly varying phase offset, thereby resulting in some loss depending upon the loop gain. At the data-phase detector output, the PLL effectively subtracts the $1/f$ phase noise approximately 40 dB/decade from W_n down to DC frequency and passes the synthesizer spectrum unfiltered from W_n to $f = \infty$. When an integrate, sample, and dump matched filter is used, the higher frequency phase noise density is modified by the shape $[\sin x/x]^2$ with nulls at the data rate. The impact of these two effects on the modem design as follows: 1) The integrated phase noise spectrum including spurious noise adds to the overall thermal noise thus affecting the available E/N_0; and 2) The $1/f$ noise distribution of the synthesizer to W_n of the carrier-extractor loop results in a phase offset.

Some allowance of these factors must be considered in the implementation loss budget.

Summary of system implementation losses

As discussed above, a number of factors contribute to the system implementation loss. As an example, a typical loss budget is given in Table III for a DEPSK modem at 288 kB/s illustrating typical contributions and the overall implementation losses. The truncation loss assignment is based upon a modem pre-detection bandwidth which passes the fourth sidelobe of the biphase signal and allows a reasonable signal-to-noise ratio to the data demodulator. Total phase and amplitude distortion allocation is set at 0.1 dB, and the filter parameters are set to accomodate this budget allocation.

Phase noise and short-term stability contributions from the terminal synthesizer amounts to a 0.1-dB degradation.

The carrier extractor is designed to provide a loop S/N of 12 dB which results in reduction of the available E/N_0 of 0.1 dB. In addition, the carrier-extractor loop is designed for sufficient gain to permit long-term frequency-drift degradations of no more than 0.05 dB.

Table III — Typical loss budget for a DEPSK modem at 288kB/s.

Loss factor	*Loss (dB)*
Truncation loss	0.10
Phase distortion	0.10
Linear	
Parabola	
Amplitude slope	
Phase noise/short term stability	0.10
Carrier-extractor loss	0.10
Long-term offset	0.05
Timing loss	0.20
Matched filter	
Design	0.25
Signal mismatch	0.10
Total implementation loss	1.00 dB

In a similar manner, the timing-extractor-loop parameters are designed to maintain the timing jitter and oscillator stability losses to no more than 0.2 dB.

The matched filter loss consits of an imperfect integration loss of 0.25 dB and a signal mismatch loss due to truncation of 0.10 dB. Then the total system implementation loss becomes 1.0 dB.

For this case, to achieve a BER of 1×10^{-5}, theoretical DEPSK requires an E/N_0 of 9.9 dB (see Fig. 1, curve 3). Then the required E/N_0 for the given implementation loss is 10.90 dB or a C/N_0 of 10.90 + 54.6 = 65.50 dB.

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A buffered printer computer terminal

J. Tults | C. M. Wine

A buffered printer computer terminal is one that contains a local memory to store the messages entered from the keyboard or received from the computer. The use of a memory permits great flexibility in message formatting, message editing, and matching transmission rates to printing device speed.

THE BASIC STRUCTURE of the computer data terminal is built around hardware modules that interface through a byte-organized data-bus structure. The memory of the buffered printer is modular with a capacity of about 2000 bytes. As the functions of this terminal are character string manipulation and transmission, a serial shift-register memory organized as a double-ended stack is employed and has been found very suitable in this application. The printing mechanism may be anything from a Model 33 to a Model 37 Teletype, or an IBM Selectric typewriter. The local editing features include character insertion and deletion and message verification. A format feature is provided with fields of information that are protected from being changed by the operator. The format feature also provides some guidance to the operator in filling out forms. For this terminal, the overriding functional specification was low cost.

General discussion

The main building blocks of the data terminal are shown on the system diagram in Fig. 1. The data terminal is organized around an 8-bit parallel data bus system. The data sources and sinks, in this case the teletypewriter at left and the computer at right, supply and receive serial data, and they must, therefore, be connected to the bus system through sets of serial/parallel and parallel/serial converters. The 2048-character buffer

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memory serves two functions: First, its use is essential to accommodate the different data handling rates of the teletypewriter and the communication link to the computer, *i.e.* 10 and 120 characters/s, respectively, in this particular case. Second, the buffer memory makes it possible and convenient to edit and verify messages prior to transmission. All data handling and editing functions are performed by central control logic which is actuated by signals from a 12-key command cluster.

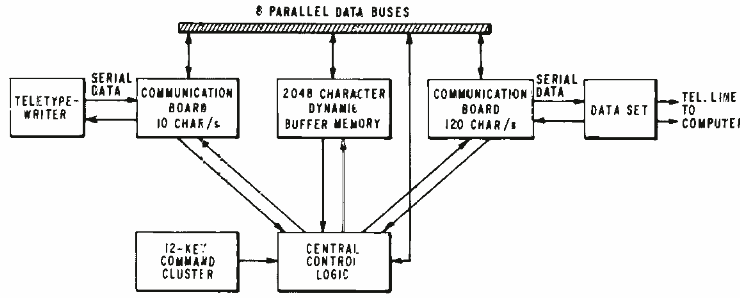

Fig. 1 — System diagram of computer data terminal.

Fig. 2 shows the experimental data terminal. The Teletype Corporation Model 33 teletypewriter is the local data source and produces a hard copy of locally generated as well as received data. The teletypewritter is also an integral part of the message editing system which receives commands from the 12-key cluster mounted on the cover plate of the teletypewriter to the right of the data entry keyboard. Next to the teletypewriter is a home-built data set to provide a two-way communication link via a telephone line between the data terminal and the time-shared computer. The circuit rack mounted under the table contains the buffer memory, central control logic, communication circuitry, and the power supplies for these units.

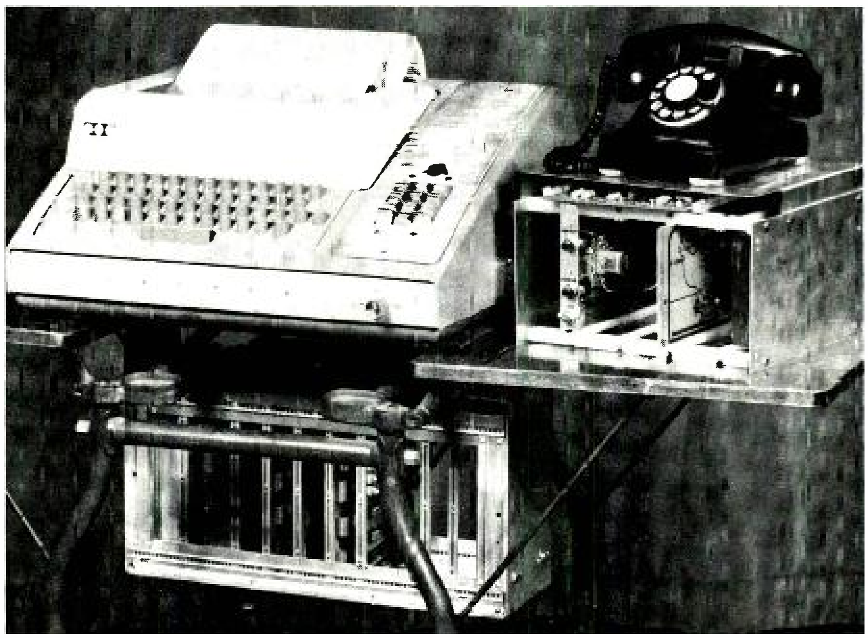

Fig. 2 — Laboratory model of computer data terminal.

The photograph in Fig. 3 is a close-up view of the circuit rack with two of the printed circuit cards removed. The card at front left is one of the two communication circuit boards used in this system. The circuit consists of a pair of serial/parallel and parallel/serial converters to communicate with the time-shared computer at the rate of 120 characters/s via a data set. It provides the control signals necessary at the interface of the data set, and supplies outgoing messages with STX and ETX characters (start and end message indicators, respectively).

The other communication board, the second one from the right in the rack, links the teletypewriter to the parallel data bus system. It is essentially identical to the first board, except that it is adjusted to operate at a speed of 10 characters/s and does not have to perform the auxiliary functions mentioned above.

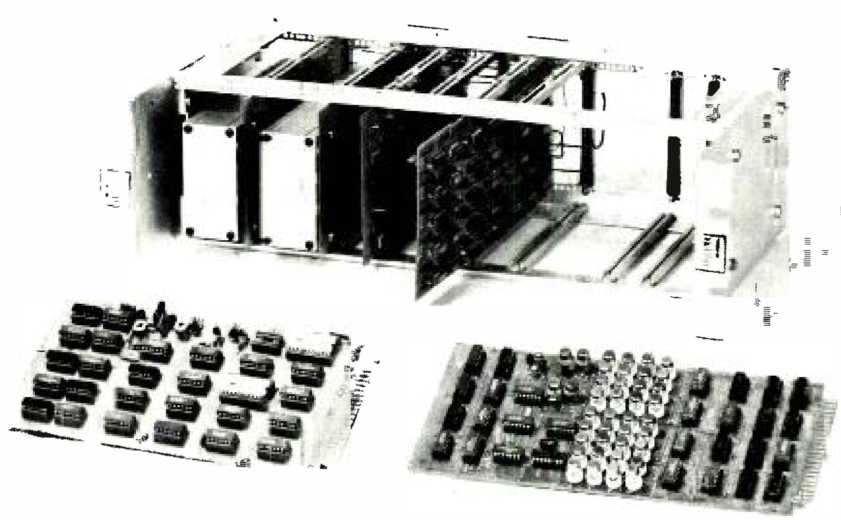

Fig. 3 — View of partially disassembled circuit-rack.

The circuit card shown at front right in Fig. 3 contains the 2048-character memory and the logic associated with the write-in and read-out operations. This is a dynamic memory driven by 1-MHz clock waveforms. The write-in and read-out functions can be performed asynchronously with an access time that is variable, but always less than about 2 ms.

The board mounted at the extreme right in the circuit rack contains the central control logic and consists of 40 DTL and TTL integrated circuits including NAND gates, inverters, one-shot multivibrators, and D-type flip-flops.

The two cards at the far left in the rack carry low-voltage power supplies for all the circuit boards mounted in this rack.

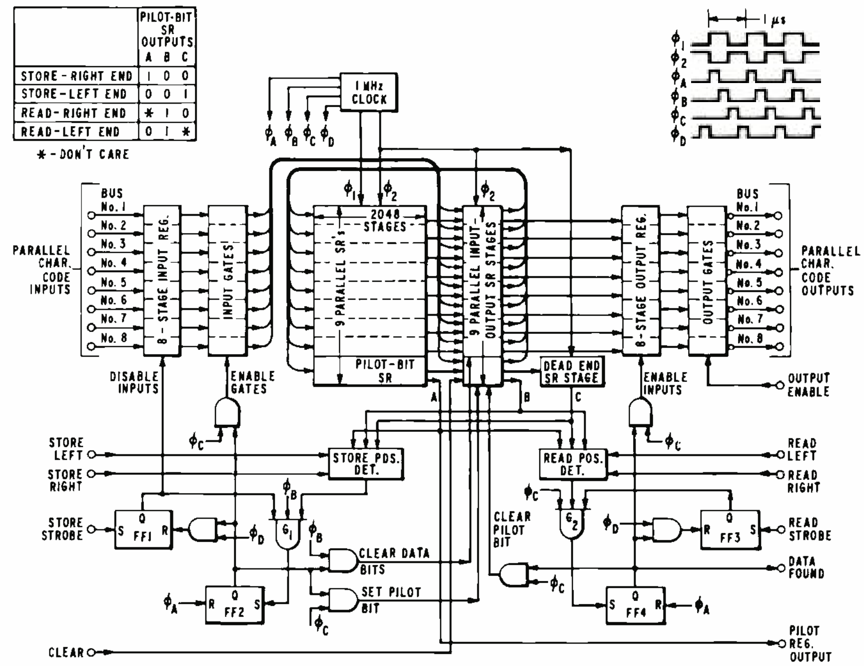

Fig. 4 — Simplified logic diagram of 2048-character dynamic memory.

Dynamic buffer memory

The data terminal is noteworthy primarily because it incorporates a type of buffer memory especially well suited and economical in this particular application. The memory is a self-contained unit that may be used in a variety of data-handling systems. The memory is basically of serial type, rather than random access. It resembles a stack where new data is added on the top and stored data is read out at the bottom. By changing the level of a control signal this so-called first-in/first-out (FIFO) operating mode can be changed into first-in/last-out (FILO) mode. In this memory, data can be written into as well as read out at either end of the stack. The read-out operation is always destructive, but this problem is overcome by writing the character just read out back into the memory at the other end of the data stack. Operating in this manner makes it simple to edit data stored in such a memory. Another advantage of this memory is its relatively low cost of only about 1 cent/bit.

Fig. 4 shows a condensed circuit diagram of the buffer memory. The system consists of the following main sections: a) clock signal generator, b) main memory, c) input and output registers, d) write-in logic, and e) read-out logic. All these circuits are located on a single printed-circuit board that is 10 in. long and has a standard width of 4-1/2 in.

The free-running clock operates at 1 MHz and generates the various clock phases illustrated in the upper right-hand corner of Fig. 4. Clock phases ϕ_1 and ϕ_2 are used for the shift registers, and the respective clock-line drivers must, therefore, be capable of driving a load with an equivalent capacitance of about 5000 pF. Clock phases ϕ_A through ϕ_D are employed in the write-in and read-out logic.

The main memory consists of nine dynamic shift registers operating in parallel. Each register is made up of four National Semiconductor Type MM5016 512-bit dynamic shift-register packages and one discrete stage in the form of a J-K flip-flop, where all these units are connected in series to form a loop. Eight of the nine shift registers are used to store character information, typically in the form of 7-bit ASCII codes with the parity bits stored in the eight register. The eight code bits of a character to be stored are applied simultaneously at the appropriate instant to the input stages of the corresponding composite shift registers Since the contents of these registers are recirculated synchronously, the code of the stored character will appear at the output terminals of the eight composite shift registers at fixed intervals of about 2 ms. This interval is equal to the product of the clock period and the number of shift-register stages.

The ninth composite shift register, called here the pilot-bit register, operates in synchronism with the other registers. Its function is to mark the beginning and end of the character string stored in the memory to facilitate storing and reading operations. Initially this register is cleared. Whenever a new character code is stored, the corresponding bit in the pilot-bit register is set to 1, and when a character code is read the corresponding bit in this register is set to zero. Storing and reading operations are permitted only at the left- and right-hand ends of the single string of characters stored in the memory to maintain meaningful organization and ensure proper recovery of the stored data. The ends of the stored character string are detected by monitoring the outputs A, B, and C of the pilot-bit register. The table in the upper left corner of Fig. 4 indicates what the states of these register stages must be for permitting a particular type of storing or reading operation.

Control logic for data editing and communication

New data is generated locally by operating the keyboard of the teletypewriter. This data is temporarily stored in the buffer memory. The editing of this data and data interchanges with the remote computer are controlled by logic circuitry activated by pressing the appropriate key on the 12-key cluster mounted on the side-panel of the teletypewriter. The functions assigned to these keys are described in Table 1.

Every one of the 12 command keys triggers a monostable multivibrator. This eliminates the usually undesirable effects resulting from bouncing contacts in key-switches, and it also provides a convenient way to establish accurately the time interval the switch will appear to be activated. Furthermore, most of these monostable multivibrators are rendered non-triggerable by a control signal to inhibit starting a new operation in case one is still in progress. The operator is informed of this condition by a light-emitting diode above the 12-key cluster that stays lit until a command has been fully executed. With the exception of "Clear" and the single character operations of "Print Character" and "Erase Character", the output pulses of the monostable circuits are used as set-inputs of corresponding D-type flip-flops. The outputs of these flip-flops gate various status signals supplied by other building blocks of the data terminal to initiate a sequence of events appropriate for executing any given command. The flip-flops are automatically reset after the commands have been fully executed.

Most of the editing functions involve reading a character from one end of the stored character string, then perhaps channeling this character to the teletypewriter or to the telephone circuit through one of the communication boards, and finally restoring the character string comprising the stored message. The last two steps are omitted during erasing operations, and the second step is omitted in all data skipping operations including the "Re-Index". The sequence described above is repeated until the character read from the memory signifies that the operation is complete. When performing line-oriented functions, e.g. "Print Line", the CR (carriage return) character serves this purpose. In message processing operations, the NUL character signals that the command has been executed.

Execution of printing commands takes a relatively long amount of time since 100 ms is consumed by the teletypewriter for printing one character. The data converters on the communication board serving the computer operate at a speed of 120 characters/s, and characters can, therefore, be read from the memory at intervals of about 10 ms. All the other functions which involve the handling of the character string stored in memory can process one character in a time interval of only about 2 ms.

The control logic provides for special handling of formatted data during editing. Sections of the message bracketed by SI and SO characters are defined to constitute formatted data. Usually the computer is the source of this type of data, e.g., it may send to the data terminal a questionnaire-type message where the individual questions are formatted. Upon a "Print Message" command at the data terminal the control logic will interrupt the printing operation whenever it detects the SO character at the end of a question. The user is then expected to respond by typing in an answer which will be stored in the buffer memory as non-formatted data. By pushing the "Print Message" key, printing starts again and continues until the end of the next question stored as formatted data in the memory is detected. While editing his answers, the user is prevented from making any changes in the formatted portions of the message.

Table 1 — Buffered teletype operation.

Command	*Function*
Clear	Wipes out the memory and then stores a NUL character as a head-of-message marker
Transmit	Sends the message, stops at the marker, waits for the response, deletes the old message, and starts to print the message*
Re-index	Skips to the character that follows the marker
Print char.	Prints one character, or interrupts Print Line and Print Message operations
Print line	Prints until a carriage return (CR) has been performed
Print message	Prints until marker is passed
Char.	Backs up one character
Line	Backs up till CR is passed
Line	Skips to a CR
Erase char.	Erases the next character**
Erase line	Erases until it passes CR**
Erase message	Erases until it reaches the marker, then does a Print Message**

*Only unformatted data, SI, and SO are transmitted. A formatted message segment is one starting with an SI and ending with an SO character.

**Formatted data is protected and cannot be changed by Erase keys.

A message sent to the computer by pressing the "Transmit" key is also monitored by the SI and SO detectors. Only the non-formatted sections of the data stored in the memory, i.e., the information generated by the user, is transmitted to the computer. As it is read out of the memory for transmission, this non-formatted data is not restored into the memory. However, even though the formatted sections of data read out of the memory are not transmitted, they will be stored back into the memory to save the message originally sent by the computer.

In most cases after data-editing operations, the ends of the character string in the memory do not correspond to the true end-points of the message represented by this string. This inconsistency can be quickly corrected by the "Re-Index" operation. The "Re-Index" command simply causes characters to be read out at one end for storage at the other end of the character string in the memory until the NUL character marking the end point of the stored message is detected. The "Transmit" operation should be preceded by "Re-Index" to ensure that the complete message generated by the user is sent to the computer. Data received from the computer over a telephone line is permitted to enter the data terminal only during the period immediately following the completion of the "Transmit" operation. This provision protects the data terminal against noise and stray messages that may occasionally appear on the telephone line.

Conclusions

The machine developed at RCA Laboratories provides all the necessary functions of a buffered printer terminal and has many desirable features. The concepts we intended to demonstrate and evaluate are incorporated into the prototype model. The gap between simple unbuffered teleprinters, and relatively costly mini-processor-based multi-function terminals, is eliminated by this kind of terminal.

Recent advances in color tv cameras for space

M. H. Mesner

The unique requirements of some of our space missions, placing unusual demands on resolution, sensitivity, and reliability, have been filled by miniature cameras using newly developed image sensors. The Silicon Intensifier Target sensor has been used in combination with a small color wheel to provide the color pictures transmitted from the moon on Apollo 15, 16, and 17. The 2-inch Return Beam Vidicon has been used in a three-camera system flown on the Earth Resources Technology Satellite to provide multispectral signatures of key earth resources. Similarly, scanning radiometers have been employed to extend multispectral data collection into the IR spectrum.

COLOR tv — a versatile tool for the exploration of space! Yet its first prime use was to view a scene which is probably more devoid of color than any area from the center of the earth to the extremes of the solar system. Television viewers the world over clung to their color sets to identify an astronaut by the tiny red band on his space suit. This does not depreciate the value of color television in space, but rather points up the degree to which the medium has penetrated our lives. From a scientific point of view the reward is rich, particularly if the technique is considered as multispectral television.

Multispectral imaging

In a broad sense, the concept of multispectral tv is more than the reproduction of color by tri-stimulus methods such as the conventional red, green, and blue mixing, but rather involves a process of tele-instrumentation providing an additional dimension in measurement of scientific data. This has been ably demonstrated by the camera system on the Earth Resources Technology Satellite. Much earlier, on the Ranger moon probe, a technique originally was planned in which the generation of images through specific spectral filters was to be accomplished by cycling three filters in front of the lens. Multispectral pictures of the surface of the moon would have been produced as the spacecraft approached impact. The opinion of scientists was that the different spectral images of the moon's surface would not yield scientific results commensurate with the added risk to reliability from the use of moving parts. Therefore, the color wheel and actuator, which had actually been installed, were removed.

M. H. Mesner, Member of the Engineering Management Staff, Astro-Electronics Division, received the BSEE from the University of Missouri in 1940. Since his association with RCA, Mr. Mesner has concentrated on research and development of special tubes, circuitry, and color television. From 1940 to 1958, Mr. Mesner was a research engineer on the technical staff of the RCA Laboratories. He was active in the development of color television, contributing to the development of receiver encoders, special color cameras and tri-color vidicons involving line-screen techniques using external gratings, and line-screen kinescopes and receivers using line-screen techniques. Upon the formation of AED in 1958, Mr. Mesner assumed responsibility for directing the development of miniature tv cameras for spacecraft including those on the highly successful TIROS and ESSA (ITOS) satellites. Mr. Mesner's association with TIROS also included responsibility for system checking and environmental testing for the TIROS prototype payload. He also directed the development of miniaturized tv cameras for the Ranger and Nimbus spacecraft. The hand-held tv cameras for Apollo 7, 8, and 10 were designed under his direction. This camera design used integrated circuits extensively to reduce size and weight; it has the added requirement of operating through both launch and post-launch environments. Mr. Mesner also had technical responsibility for the development of the color camera using RCA's silicon intensifier target (SIT) sensor which was used in the ground commanded television assembly for the last three Apollo missions. He has 14 issued patents in the field of television, and has been a frequent contributor to technical publications. Mr. Mesner is a fellow of the IEEE and a member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and the Society of Photometric Instrumentation Engineers.

On Surveyor, the next lunar mission, color pictures of the legs of the spacecraft and surrounding lunar surface were made after Surveyor made a soft landing. This camera used a vidicon with appropriate filters.

Later, multispectral television pictures of the earth's surface were obtained by NASA's Advanced Technology Satellite (ATS-III). The imaging device was a spin-scan camera consisting of 3 photomultiplier tubes with a narrow field of view which scanned the earth mechanically, using the rotational motion of the spacecraft for scanning in one direction. Scanning motion in the other axis was accomplished by the stepping of the mirror angle after each spacecraft revolution. This camera, operating from a 22,300-mile altitude, provided multispectral images in 3 bands: 390 to 490 nm, 480 to 580 nm, and 560 to 700 nm.

Observation of earth resources

It was on ERTS, the Earth Resources Technology Satellite, that multispectral imaging was brought to fruition. Studies by the University of Michigan and other university research groups showed how multiple images of a scene taken from airplanes or earth-orbiting satellites could develop a spectral signature of growing agricultural crops or forested areas. With this information, scientists could identify which type of growing plants were being observed and their state of health. This is particularly true if one of the spectral separations is in the near infrared band, where reflectivity is highly dependent on the chlorophyll content of the growing plant.

ERTS camera system

The ERTS camera system has been designed to make possible the iden-

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tification and recording of these spectral signatures from an altitude of 570 miles. In addition, the tv resolution was increased by a factor of 10 over that normally ascribed to tv images, that is, 4500 tv lines. These images are created in two ways: (1) by three return-beam vidicon cameras, and (2) by the multispectral scanner, a four-channel, scanning radiometer.

The three RBV cameras, which take simultaneous, registered pictures in the spectral bands of 475 to 575 nm, 580 to 680 nm, and 690 to 830 nm respectively, are shown in Fig. 1 With the information available from three simultaneous pictures taken by the three camera system the crop designation and quality may be readily identified. Furthermore, geological features may be seen and cataloged, and the level of water in reservoirs and rivers may be quickly assessed. Oceanographers also find these pictures valuable for examining submerged coastal shelves and locating temperature zones in the water — useful for anticipating fish-school movements.

Fig. 2 is an RBV camera picture taken of the California coast looking South from Monterey, showing forested and farm areas. While the figure shown is in black and white, it is normally a composite of the three spectral images, the 475 to 575-nm band reproduced on paper with blue dye; the 580 to 680-nm band, with green; and the near-IR band (690 to 830 nm) printed in red. The red areas indicate high reflectance by the dense forests and growing crops which are high in chlorophyll.

Two-inch return-beam vidicon

The cameras for ERTS are the result of a number of years of research at the Astro-Electronics Division and at Electronic Components, Lancaster, Pa. Much of the basic tube design was done by Dr. Otto Schade at Harrison. The high resolution obtained, 90 line pairs/mm limiting resolution (4500 tv lines across the picture), is made possible by improvements in several areas. The scanned area was increased in size over most vidicons, to one by one inch; and the spot diameter was reduced by lowering the diameter of the limiting aperture to less than 1 mil and by careful control of the electron optics. Fig. 3 shows one of these image sensors. The signal is taken from the return beam and amplified by an electron multiplier. This accomplishes several things: it lifts the level of the signal current above the noise level of the amplifier, and it permits operation with the reduced beam current inherent in the smaller aperture. Also, it reduces the problem of microphonics (generated in the amplifier input due to the motion of the target mesh which acts like a condenser microphone). In the return-beam operation, the direct connection from the target is eliminated, minimizing the "condenser microphone" effect on the video signal.

A significant improvement in resolution was obtained by the use of precision-wound focus and deflection coils. A shaped focussing field was obtained by a segmented focus coil, in which the field strength along the axis of the tube was graduated according to values computed for maximum resolution.

The vidicons used have an ASOS (Antimony Sulphide-Oxysulphide) photoconductive surface, capable of storing a signal capacitively for a number of seconds. In the ERTS cameras, exposures are made simultaneously, but each vidicon is read out and erased in sequence. The total picture period is 25 seconds, permitting overlapping pictures to be taken as the spacecraft orbits the earth.

The lenses have a 126-mm focal length and $f/2.8$ aperture ratio, the shutter provides a selectable exposure between 4 and 16 ms, and the video baseband width is 3.2 MHz.

Scanning radiometers

The multi-spectral scanners used on ERTS have six sensors in each of four spectral bands: 500 to 600, 600 to 700, 700 to 800, and 800 to 1100 nm. The scanning is done mechanically, which limits the picture-taking to lower rates than can be accomplished electronically. Orbit motion provides scanning on one axis, and an oscillating mirror on the other.

The recently launched NOAA-2, a weather observation satellite, also uses a scanning radiometer sending back picture information gleaned from an IR channel (10.5 to 12.5μm) as well as pictures of the scene derived from common optics in the visible portion of the spectrum. This device is shown in Fig. 4.

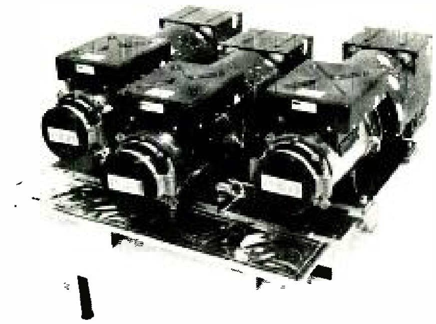

Fig. 1 — System of three RCA cameras used on the Earth Resources Technology Satellite.

Fig. 2 — Picture of California coast taken by the RBV camera system on ERTS.

Fig. 3 — ERTS image sensor, the two-inch RBV.

Fig. 4 — Scanning radiometer on NOAA-2 (visible and ir spectrum).

Apollo tv color study

Initial studies

Early during planning for the Apollo mission, NASA was well aware of the value of color pictures in lunar exploration and, as far back as 1965, they awarded RCA a contract to study various ways and means of accomplishing color transmission from the moon and vicinity.

In this study, it was emphasized that for the transmission of video data from the moon, in which the available bandwidth was necessarily limited, many methods of generating color pictures and encoding them for transmission were conceivable. The transmission techniques were not restricted by commercial television standards. Thus, the constraints of light weight, low power, and narrow baseband imposed by a space mission were offset by a broader selection of color generating methods. Thus, methods which came to light in the formative years of color television research of 1945 to 1952, when the ground work for NTSC Standards was accomplished, came under consideration.

Field sequential color

After reviewing the RCA study, NASA selected a field-sequential system for color-picture generation. This permitted transmission on a limited bandwidth, (less than 900 kHz on some missions). The received data was converted by magnetic disc recorder from field-sequential signals to a simultaneous red, green, blue format. This is done by recording the three fields on the disc recorder in sequence, but, by the arrangement of the playback heads, reading out the signals simultaneously. The three-channel data was then fed into an NTSC encoder for transmission on the commercial networks.

On the Apollo 12 mission, a field-sequential camera made by Westinghouse was used to bring the astronauts' pictures in color in real-time to tv audiences. This camera used a secondary emission conduction (SEC) vidicon. Unfortunately, it was inadvertently pointed at the sun, causing the internal structure to rupture.

Fig. 5 — SIT sensor used in Lunar color cameras for Apollo.

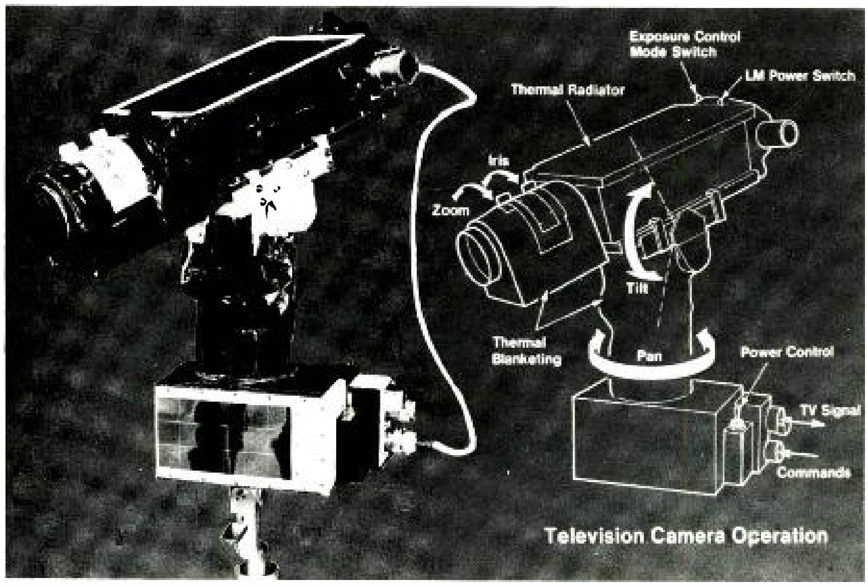

Fig. 6 — Ground Commanded Television Assembly for Apollo 15, 16, and 17.

Color camera with SIT tube

In an effort to produce a lunar color camera which had a higher probability of surviving the anticipated rough treatment to be experienced in a typical extra-vehicular activity, RCA had been developing a silicon intensifier target (SIT) sensor. Tests had shown that a camera using a SIT tube could be pointed directly at the sun without being damaged. Another feature of interest was the high signal gain of 1600:1 which could be achieved, yielding high insensitivity. The 16-mm SIT tube used during the Apollo 15 and subsequent missions is shown in Fig. 5. For the surface of the moon, bathed in bright sunlight, higher sensitivity is not a requirement, but for maximum flexibility of use (that is, in deep shadows, lunar twilight, and the interior of a spacecraft), a higher sensitivity is desirable. A very important advantage of the SIT, made possible by the use of the high gain of the image section and target, lies in its adaptability to automatic sensitivity control as a function of light, normally referred to as automatic light control (ALC). The gain of the target is a function of bombardment velocity, or accelerating voltage, which may be controlled by the amplified video signal. This produces a controlled loop, in which the video may be controlled within narrow limits through a range of input luminance of greater than 1000:1. The sensor itself has an intra-scene dynamic range of 100:1. With ALC, the total range for minimum detectable signal to maximum signal is 100,000:1. This automatic feature relieves the operator, who may be either an astronaut or a ground controller, from attention to illumination except under unusual circumstances.

Fig. 6 shows this camera, along with control devices which form the ground commanded television assembly (GCTA). This tv system was remotely controlled from the control center in Houston on the Apollo 15, 16, and 17 missions, with four functions being varied: elevation, azimuth, lens aperture, and lens focal length (zoom).

On later transmissions, the communication bandwidth was extended, resulting in picture quality not incompatible with network standards.

The photo-sensitive area of the SIT tube is an S-20 photocathode as part of an image section with anode voltage which may be varied from about 2000 to 9000 V. The accelerated electrons bombard a silicon-diode array in which electron bombardment induced conductivity (EBIC) produces a gain in the signal charge mentioned earlier. This places the signal current considerably above the typical preamplifier noise level. This accounts for the high-sensitivity achievable by a SIT tube.

For color separation, a small color wheel is driven by a 420-Hz synchronous motor. The motor frequency is generated from synchronizing pulses, and a color flag signal generated by the wheel calls for motor slippage, in the case of error, until each color segment reaches a phase which will cause the proper color to be reproduced. The camera is miniaturized by use of integrated circuits and high density printed circuit boards. An interior view of the camera is shown in Fig. 7.

The camera weight is 11.2 lbs., and it requires 12.5 W of power for operation. The limiting resolution is about 600 tv lines for the camera itself, but is limited to a lower value by the bandwidth constraint of about 2.5 MHz.

Small broadcast cameras

A commercial spinoff from space-age technology was evidenced in the small color camera designed at the Astro-Electronics Division for NBC's coverage of political conventions. Rather than using a color wheel, this camera used three small vidicons. This camera was described in an earlier issue of the *RCA Engineer*.[1]

By the substitution of SIT tubes for the conventional vidicons, a camera may become much more sensitive and operate at low illumination values. As cameras are miniaturized by the introduction of integrated circuits and modern packaging techniques, the camera becomes small compared to the lens. A large lens and a small camera still may leave a severe problem of weight and size. The way out of this constraint lies in increased sensitivity of the sensor which will permit the adequate use of lenses of higher *f*/numbers; that is, smaller apertures. This means the use of glass elements which may be comparatively very small.

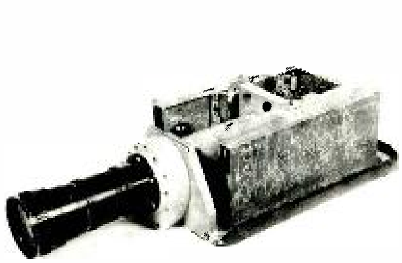

Fig. 7 — Interior of Apollo camera using SIT sensor and color wheel.

The total camera may be truly miniaturized by the use of SIT sensors with lower noise level or higher sensitivity. This restores the balance between camera and lens.

Single-tube color cameras

If a single-tube camera can be employed for color, the camera size may be further reduced. One way of doing this is to employ the sensitivity of the SIT combined with striped-filter techniques.

This is a technique of producing an encoded signal as a result scanning a series of colored stripes which may be mounted externally, or within the tube. The stripes provide an individual spatial frequency for each selected color band. The tv signal is thus automatically multiplexed with color and video information.[2]

The use of striped-filters provides a means of producing a small camera without the disadvantage of a color wheel and disc scan converter for converting sequential to NTSC standards, at the same time taking advantage of SIT sensitivity. Laboratory experiments using this combination have produced results demonstrating the feasibility of this method of producing a small color camera with low light capability.

New devices

The use of charge-coupled silicon-diode arrays also promises improvements in miniaturization and high sensitivity, permitting the use of a small lens. While these techniques are still considered to be in a state of development, the high quantum efficiency and broad spectral range of silicon offer an approach which will one day, no doubt, be competitive with the SIT sensor.

Future missions

With the landings on the moon by U.S. astronauts already accomplished, the next giant steps in space lie further out in the solar system, and because of those great distances, missions of long duration must be planned. Because of their long duration, it is of greater practicality in the foreseeable future not to send astronauts, but to explore space by remote control and remote observation. Also, a minimum number of moving parts is a necessity. This means that miniaturized color cameras, extremely small and highly reliable, must be developed; and on the missions to Mars, Jupiter, and Saturn, these multispectral cameras must be radiation-proof, rugged, and have unattended lifetimes of 10 to 20 years.

Studies have already been conducted laying the groundwork for the Grand Tour, now temporarily shelved, and for orbiting vehicles to closely approach Jupiter or Saturn.

These studies have shown that presently available sensors can perform these photographic missions. Also, a study by NASA has been conducted on the feasibility of a large space telescope in which an observatory with a large telescope may be placed in an earth orbit. This will be active for many years, making measurements useful to astronomers from the vantage point of space, removing the limitation of atmospheric aberrations.

Thus, it seems that the landings on the moon with reporting by color television has not ended its use, but rather set the pace for future development.

Conclusion

Due to the requirements of space, miniaturization and ruggedization of tv sensors has reached fruition. In addition to the environmental constraints and the need for unattended operation, the tv sensors have been required to meet the new standards imposed by performance as instrumentation devices. The added dimension provided by the analysis of multispectral signatures further enhances their value in mensuration.

As the environment becomes more severe, the reliability specifications more rigid, and as the need for precise measurements intensifies, television techniques must take on the aspects of a science, rather than an entertainment medium.

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Functional flow diagrams and descriptions for AEGIS—a systems engineering management tool

E. G. Lurcott

The AEGIS Weapon System currently being developed for the U. S. Navy is an advanced shipboard missile system characterized by the rapid reaction and high fire power required to defend the fleet against hostile aircraft, missile, and surface threats of 1975 and beyond. Seven major systems constitute the AEGIS Weapon System: the AN/SPY-1 Radar System, Command and Control, Weapon Direction System, Fire Control System, Operational Readiness Test System, Guided Missile Launching System, and the Missile System. Although each of these systems has a rigidly specified function, the functions interact strongly when the systems are integrated and in the operational mode. To ensure that all systems operate together as an entity and meet specified AEGIS functional and performance requirements, it is critically important that all system-to-system and system-to-ship interdependencies be completely identified and defined during the development and test of the systems and interfaces. In a program such as AEGIS, several specialized management tools are being used to provide this detailed level of visibility. Of these, the use of Functional Flow Diagrams and Descriptions (F^2D^2), which have been developed and implemented by AEGIS, provides the most effective means of depicting the functional interrelationships and interdependencies of the systems. F^2D^2 represents a significant expansion of the usual flow diagram applications. Rather than serving only as a design tool, it enables the complete functional definition, control, and audit of the entire AEGIS development effort. Its use also ensures that the program development is logically complete and consistent, and that the established interrelationships are adequate to meet all Weapon System requirements.

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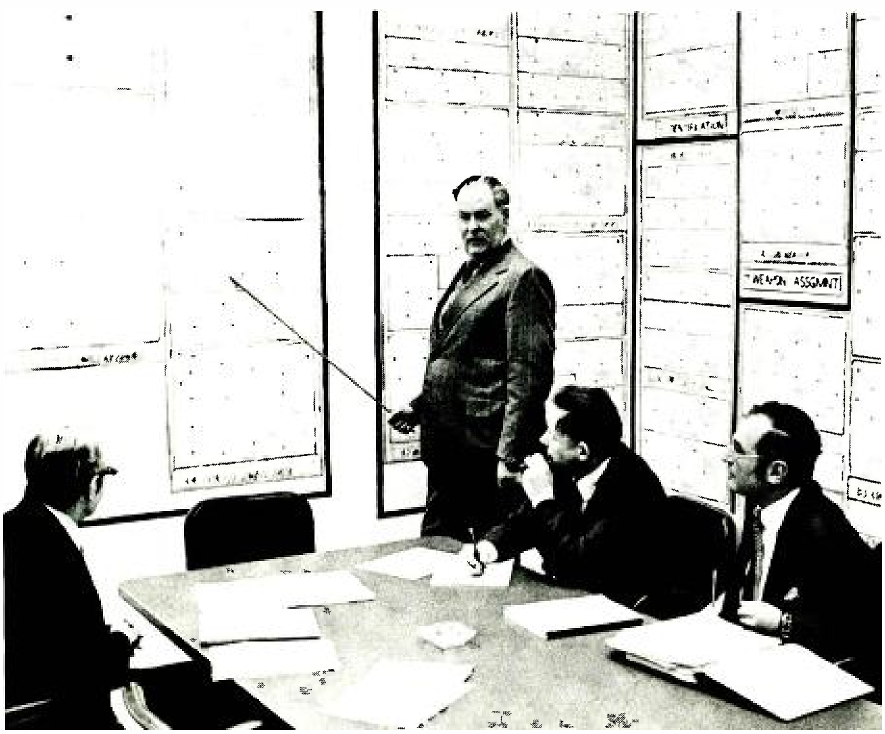
attended Drexel Institute of Technology and was a member of the RCA Photophone Division from 1940 until 1942. After his discharge from the U. S. Navy in 1946 he rejoined RCA as a member of the Teleran activity where he developed an airborne television receiver He did advanced development on applications of Graphicons. Direct View Storage Tubes and large screen television. He worked on display subsystems and techniques for such systems as ATLAS, MINUTEMAN SAM-D, FPS-95 and AEGIS. Mr. Lurcott is a member of the group responsible for functional definition of the AEGIS weapon system. For his role in the application of this functional analysis to the Command and Control System of AEGIS, Mr. Lurcott received a Chief Engineers Technical Excellence Award for the first quarter of 1972. He is a registered Professional Engineer in New Jersey and has four issued patents. He is a senior member of the IEEE and a member of the Society for Information Display.

Author, Gene Lurcott, reviewing F^2D^2 documentation displayed on the walls of a room that is used specifically for such reviews.



FUNCTIONAL FLOW DIAGRAMS AND DESCRIPTIONS F^2D^2 are flow diagrams (*i.e.*, schematics) and narrative descriptions that collectively define and interrelate the functions of the electronic and mechanical equipment, computer programs, facilities, and personnel that constitute the AEGIS Weapon System as defined in the AEGIS Weapon System Specification, WS7833(R)/1A (EDM-1). These diagrams depict the allocated baseline of the Weapon System at four levels, or tiers, of functional detail.

Tier 0

The highest-level flow diagram, Tier 0 (Fig. 1), shows the basic sequence of events and relationships associated with the three-phase engagement function, *i.e.*, pre-engagement, engagement,

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Final manuscript received September 1, 1972.

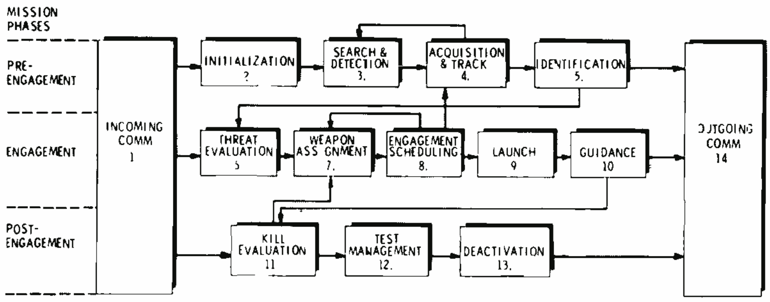

Fig. 1—Tier 0 functional flow diagram.

and post-engagement. It defines the system in terms of fourteen events and assigns (*i.e.*, allocates) them to the three mission phases. The numerical designation assigned to each of the fourteen events shown in Fig. 1 is used to key the user into appropriate lower, and increasingly detailed tiers of flow diagrams.

Tier 1

Tier 1 flow diagrams depict the system-to-system interdependencies and subfunctions that are involved in accomplishing each of the fourteen Tier 0 events. For example, as shown in Fig. 2, the AN/SPY-1 Radar System and Command and Control are involved in accomplishing the Tier 0 Acquisition and Track function (event No. 4). Also identified at the Tier 1 level are the inputs, and their sources, that initiate the required functions, and the resulting outputs and destinations. Again, each function, as well as each input and output, is numerically identified; the first digit keys back to the related Tier 0 event, and the second is assigned at the Tier 1 level to identify the particular function being depicted.

Tier 2

At the Tier 2 level, subfunctions of Tier 1 are displayed. This tier shows the functional requirements, interrelationships, and interdependencies and defines the functional baseline of each Tier 1 system. These baselines are established by identifying all system functions that must be accomplished, and allocating them to either a computer program, an equipment item, or a manned operator station (console).

The functional flow across interfaces also becomes apparent at this level. This enables the mutual audit of both functions and interfaces, thus ensuring that they are complete, compatible, and in accordance with specified requirements. An example of this level of detail is shown in Fig. 3, which is an expansion of the "MANAGE SYS TRK" (4.4) function identified at the Tier 1 level in Fig. 2. The first two digits of the three-digit number shown in Fig. 3 for each input, output, and function enable the user to identify which Tier 1 system function is being detailed. The third digit is assigned at the Tier 2 level. The resulting three-digit identifier is used to track the function into the more detailed Tier 3 flow diagrams. As in Tier 1, and particularly in the Tier 2 and 3 flow diagrams, all functions, inputs, and outputs are organized across the diagram to depict inputs flowing in from the left and outputs flowing out at the right.

At the Tier 2 level and below, symbols are used extensively. The many types

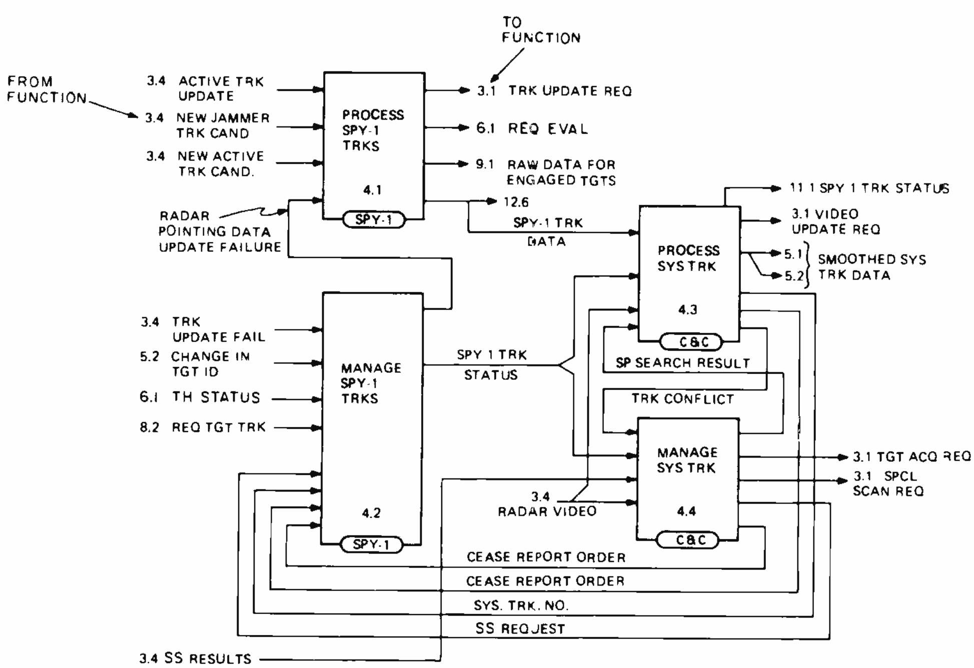

Fig. 2—Tier 1 functional flow diagram (example).

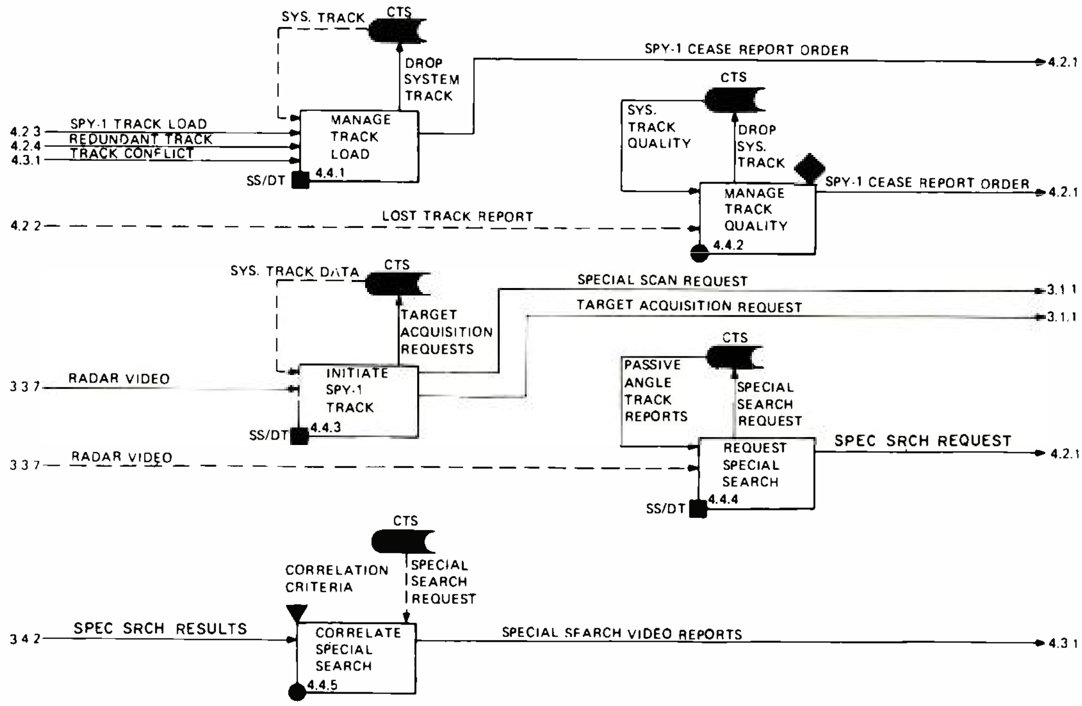

Fig. 3—Tier 2 functional flow diagram (example).

of input data that are frequently required to define and/or control a function, and the allocation of these functions to equipment, operators, or a computer program are represented in F^2D^2 by the symbols shown in Fig. 4. The input data that may be utilized by a particular function is characterized as current input data, supporting data, or control data (i.e., criteria). These categories are defined as follows:

Incoming data—data that initiates the performance of a function.

Outgoing data—Data that results from the performance of a function.

Support data—data pertaining to variables (*e.g.*, weather, ship speed and heading, etc.) that is needed or desirable in the performance of a function. It neither initiates the function nor dictates how it is accomplished.

Criteria—data (*e.g.*, alpha-beta filter constants, missile dynamics, processing constants, etc.) that dictate how a function is to be performed.

Allocation—the system (Tier 1), or man/equipment/computer program (Tiers 2 and 3) to which a function is assigned (*i.e.*, allocated).

Tier 3

Tier 3 functions are subfunctions of Tier 2. At this level each function, as it flows down from Tier 2, is quantitatively expressed in terms of general performance requirements, *e.g.*, rates, capacities, bandwidths, time delays, etc. Additionally, each function is further defined by being uniquely assigned to one of four conceptual areas: data acquisition, analysis, decision making and control, or action. These conceptual areas are then allocated to a computer program module or submodule, an equipment unit or assembly, an operator, a pushbutton, or a digital keyboard. Also shown are actual console button labels and operator tasks. The manual functions may thus be compared with the interfaces and human factors requirements and audited for completeness. Fig. 5 is a typical Tier 3 flow diagram showing the further breakdown of the "INITIATE SPY-1 TRACK" (4.4.3) function identified at the Tier 2 level in Fig. 3. The same numbering convention described for the higher tiers is again used at this level, with the fourth digit being assigned to each

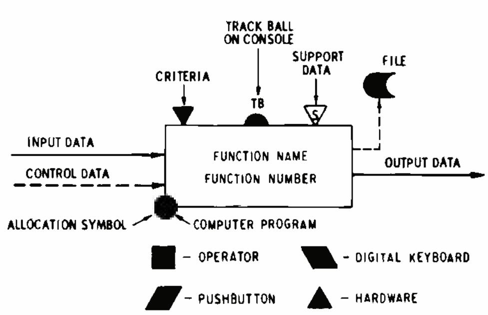

Fig. 4—Functional flow symbols.

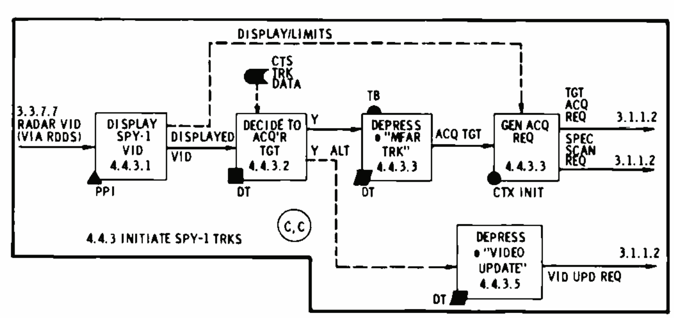

Fig. 5—Tier 3 functional flow diagram (example).

subfunction of the three-digit functions that flow down from Tier 2.

At the present state of development, a Tier 4 level has not been required except for certain complex areas of the Radar System Signal Processor group.

Functional descriptions

For each function depicted on the flow diagrams, there is a corresponding narrative description that further defines the function by supplying information that cannot be shown schematically (Fig. 6). All description are prepared in a standard format and provide the following data:

Abstract—Briefly describes why the function is in the system and provides a clear, concise description of the function's purpose.

Input and output data—Lists the input and output signals and/or other data in greater detail than can be depicted on a flow diagram.

Support data—lists the supporting data that is required by the function.

Criteria—the major portion of the functional description. This section describes how the function operates at the particular tier level involved. Formulas and limits are included when required for a complete understanding of the function.

Allocation—This extremely important section identifies the specification(s) and/or design document(s), and the particular paragraph(s) within such documentation, that specifies the function. This enables a complete system audit by making all functions traceable to approved documentation and all documentation traceable to allocated functions.

To further the usefulness of F^2D^2 documentation, the functional descriptions are periodically updated and issued as a series of AEGIS memorandums.

F^2D^2 facilities

The diagrams and descriptions are displayed on swinging panels and along the walls of a room permanently assigned for the use of this management tool. This room is used by the management and other members of all program disciplines as an up-to-date source of information on the overall system and its interrelationships. It also serves as a conference room for the discussion and resolution of functional changes and as a briefing room for both resident and visiting Navy personnel.

Function Name: INITIATE SPY-1 TRACKS Function Number: 4.4.3

Abstract

This function manually acquires targets which are not in the CTS.

Incoming Data	Outgoing Data
. Radar Video	. SPY-1 Target Acq Request (includes request number; 2D or 3D desig; x, y, z for 3D or x, y for 2D; $\dot{x}$, $\dot{y}$; elevation range for 2D; time; console range setting; active/passive mode; exclusive track ind.)
. System Track Data	. SPY-1 Special Scan Request - (includes request number; 2D or 3D desig; x, y, z for 3D or x, y for 2D; $\dot{x}$, $\dot{y}$; elevation range for 2D; time.)
	. Target Acq. Requests - includes the same data as forwarded to the sensors.

Criteria

An operator views Radar Video and may request Special Scan around a particular point in space. If elevation is known, the function will identify x, y and z. If elevation is not known, it will identify x and y Parameter z will be the minimum and maximum of the elevation sectors selected for the particular display. The operator may then Request Target Acq. from the SPY-1. The range switch setting of the console is forwarded as part of this request. This range switch setting is used by the SPY-1 to set the acq. range gate extent to compensate for the possible inaccurate setting of the ball-tab on the display.

Allocation

This function is allocated to the C&C Computer (Track Management Program Function, Display Console Control Program Function) and to operators (Sensor Supervisor, MSS and D/T). Paragraph 3.3.4.5, 3.3.3.5, of WS-9908/1A.

Fig. 6—Sample functional description.

Conclusion

AEGIS F^2D^2 is a systems engineering management tool that provides a complete functional definition of the weapon system. It translates the missions, goals, and requirements of the AEGIS Weapon System specification into functional block diagrams and functional descriptions for every level of system operation. The diagrams include descriptive message names for function inputs and outputs, and describe how each function produces its outputs by operating on its inputs. As a tool for system definition, F^2D^2 provides the baseline from which all functions are quantified and allocated. As an auditing tool, it provides the visibility required to ensure that all functions have been incorporated in the design and that the design is in accordance with the system specification. Design control is supported through the combined use of definition, audit, and the associated functional descriptions.

Usually, flow diagrams trace only a single line of action (single thread) through a single system reacting against only one type of threat under a specified set of conditions (scenario), and are, therefore, essentially one-dimensional. F^2D^2 as developed and used by the AEGIS program represents a significant expansion of this flow diagram technique. It not only depicts multiple thread, multiple scenario flows, and shows the interrelationships of each, it also enables all system functions to be analyzed from top to bottom and from initial input to final output. F^2D^2 is, therefore, a multi-dimensional, multi-level representation of AEGIS, and provides the visibility needed for the efficient management of this weapon system. This detailed visibility has resulted in the early identification and resolution of system problems and functional discontinuities, thus avoiding later interruptions during the integration and test phases.

Because of its proven value in the development of the first AEGIS engineering development model, F^2D^2 is also being used in the design and development of the engineering development models scheduled for later in the program. The utility of F^2D^2 is not limited just to AEGIS. It is applicable to any large weapon system or design program.

Acknowledgments

The writer desires to thank E. M. Yanis and D. Miller for their assistance in the editing of this article.

Active nutation damping in dual-spin spacecraft

K. Phillips

Active nutation damping generally requires a unique element to provide the necessary damping torques, plus a nutation-sensing system to properly monitor and control the active element by closed-loop action. This paper describes and analyzes, by computer-assisted mathematical techniques, a nutation damper for a dual-spin spacecraft in which the active "element" is derived from the inherent cross-axis torques generated by the spacecraft products of inertia, and the existing motor controlling the relative spin rates of the two dynamic components comprising the spacecraft.

NUTATION, in a spin-stabilized spacecraft, is an undesirable cyclic angular motion about the spacecraft transverse axes, manifesting itself as a coning motion of the spin axis around the total angular momentum vector. Passive nutation-damping systems of the type presently used in RCA spacecraft designs furnish relatively low damping rates — the best possible under the weight allotment for this system. So-called "active" damping systems, although more complex, are capable of much higher rates for a given weight. The conventional "active" system requires a unique element to produce the necessary damping torque (such as jets or a reaction wheel) plus a nutation-sensing system to afford proper control of the active element.

Kevin Phillips, Advanced Stabilization Group, RCA Astro-Electronics Division, received the MSc in in Electrical Engineering at Bedford, England in 1960. In 1965 he joined RCA and has been engaged in servo-loop and system design, analog computing, and brushless DC torque motor development for space applications. Most recently he has been working a variety of aspects concerned with the three axis performance and stability of dual-spin spacecraft. When in England, Mr. Phillips was employed by the British Aircraft Corporation, working initially on hydraulically controlled fin servos of a ballistic missile, and then as Design Authority on the system aspects of a hot-gas-actuated anti-tank guided missile. Mr. Phillips subsequently joined the Sperry Gyroscope Company where he was employed as a Senior Engineer, controlling various aspects of the design and development of missile autopilot systems. Mr. Phillips is a member of the IEE in England and is a chartered engineer of Great Britain (C. ENG.).

This paper presents the analysis of a type of active damping system for which a specific active element is not needed. Instead, the necessary damping torques are derived by means of products of inertia between the spin (pitch) axis of the spacecraft and the yaw or roll axes. This technique is called "inertial damping".

The equations of motion of the spacecraft are analyzed to show that a torque from a motor controlling the pitch-axis motion in a dual-spin craft can induce torques on the other control axes in the presence of such products of inertia. Heretofore, such coupling has been regarded as a disadvantage to three-axis control because of the "undersired" motions transferred to the other axes, and the products have deliberately been designed to a minimum.

The mathematical analysis was developed by first linearizing the complex three-axis equations of motion. Then, with the aid of the Laplace transform and basic servo-control system theory, a relatively simple computer program was written. This shows that the previously unwanted torques can be utilized to advantage to damp out nutation.

By means of the computer program, it was shown that damping time constants at least an order of magnitude better than those practical from the passive damper can be obtained.

The dual-spin spacecraft considered in this analysis comprises two coupled bodies, each of which can be spun independently around a common axis. One body is a de-spun platform and the other is a momentum storage wheel. The wheel is used to control motion of the platform about the wheel-spin (or pitch) axis by sensing the pitch angular error at the platform and applying a corresponding torque to a motor driving the wheel. This torque on the wheel sets up an opposing reaction torque on the platform, which tends to reduce the sensed error. Analysis of the spacecraft equations of motion show that if the spin axis is not a principal axis of inertia of the platform, such that products of inertia exist between that axis and any transverse (non-spin) axis, the reaction torque can also produce (or counteract) angular motion (or nutation) in the transverse plane.

Fig. 1 is a diagram of a typical spacecraft illustrating the reference axes used. All the axes in this figure pass through the spacecraft center of mass. The pitch axis (3), is the spin or momentum axis since the bias momentum wheel is aligned with this axis. The yaw axis (1), and the roll axis (2), are termed transverse axes, and the plane formed by axes 1 and 2 is termed the transverse plane. An infinite number of other axes could be drawn through the center of mass, that emanate radially in the transverse plane. Any such axis is also called a transverse axis.

System description and analysis

The inertial damper depends on products of inertia existing between the wheel spin or pitch axis and the transverse (mutually perpendicular) axes of the spacecraft. Thus, a torque from the motor driving the spacecraft wheel will not only act to change the relative speed between the platform and wheel, but will also induce torques about the transverse axes. If the nutational motion is sensed about one of the transverse axes (say the roll axis) and the sensed signal is fed into the pitch-control loop along with the true pitch-error signal (as shown in Fig. 2), these torques can enhance or retard the growth of nutation, depending upon the relative phasing of the sensed signals to the resulting induced torques. This phasing is, in turn, dependent upon the magnitude and signs of the aforementioned products of inertia.

Should the spacecraft be nutating, any transverse axis will experience an angular

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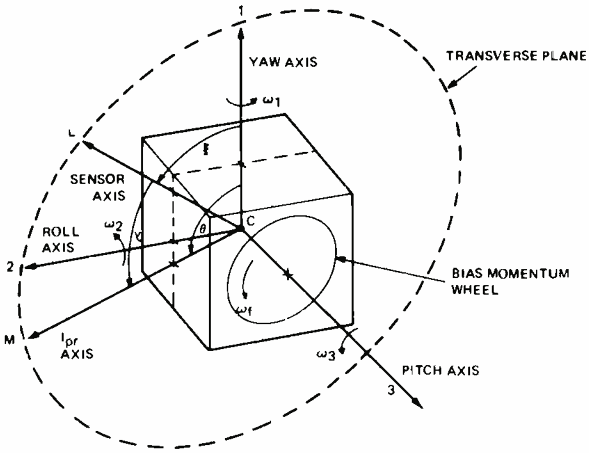
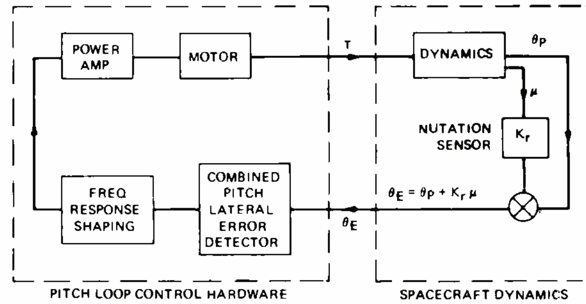


Fig. 1 — Dual-spin spacecraft with reference axes.



Notes: Transfer function of T/θ_E through pitch loop hardware = $P(s)$.
Transfer function of θ_E/T through dynamics = $D(s)$.
Overall open-loop transfer function = $T(s)$ [illegible].
μ is any quantity that measures lateral nutation motion: for a rate gyro on the (2) axis $\mu = \omega_2$

Fig. 2 — Block diagram of pitch loop employing inertial damping.

cyclic motion about it at nutation frequency. Also there will be a phase difference of $x°$ between the cyclic motions of any two transverse axes, inclined at $x°$ to each other in the transverse plane.

The method of nutation damping is based upon utilizing a sensor that detects angular motion about some axis L in the transverse plane, which is inclined at an angle ξ from the positive (1) axis in the direction of the positive (2) axis, and cross products of inertia between the yaw/pitch and roll/pitch axes (defined as I_{13} and I_{23} respectively). I_{13} and I_{23} can be expressed as a composite product of inertia I_{pr} where:

$$I_{pr} = \sqrt{I_{13}^2 + I_{23}^2} \qquad (1)$$

I_{pr} exists in the plane defined by the (3) axis and an axis M in the transverse plane. M is inclined at an angle θ from the positive (1) axis in the direction of the positive (2) axis, and has a value:

$$\theta = \tan^{-1}(I_{23}/I_{13}) \qquad (2)$$

Axes L and M are represented in Fig. 1.

The sensor feeds a signal proportional to the detected cyclic motion into the bias-wheel control loop, thus modulating the momentum-wheel motor torque at nutation frequency. Depending upon the angular difference λ, between θ and ξ, where:

$$\lambda = \theta - \xi \qquad (3)$$

this torque can force the nutation angle to grow or decay. If λ is varied from 0° to 360°, there is one value λ_0, which gives maximum nutation damping.

To determine the optimum phasing, λ_0, and the degree of the damping for any given spacecraft, a computer program has been written. Through this program, the roots of the characteristic equation of the closed-loop, cross-coupled pitch loop are worked out. This is achieved by multiplying the cross-coupled dynamics transfer function $D(s)$ in Fig. 2 by the transfer function of the pitch-loop electronics and motor drive, $P(s)$. The resulting open-loop transfer function defined as $T(s)$, gives the system characteristic equation from the following relationship.

$$1 + T(s) = 0 \qquad (4)$$

The program factorizes this equation in the Laplacian (s) domain, isolates the complex roots, and from them calculates the nutation damping time constant. The cross-coupled dynamics transfer function $D(s)$ depends upon the type of nutation sensor used, and the angle ξ.

Typical results

A typical spacecraft configuration was analyzed by means of the computer

List of symbols

$D(s)$	cross-coupled dynamics transfer function θ_E/T
H	spacecraft total angular momentum
H_1, H_2, H_3	momentum about yaw, roll, and pitch axes
I_f	pitch-wheel moment of inertia about the spin (pitch) axis
I_p	pitch moment of inertia of the platform without the wheel; $I_{33} - I_f$
I_{pr}	maximum product of inertia between the spin axis and the transverse plane = $(I_{13}^2 + I_{23}^2)^{1/2}$
I_{11}, I_{22}, I_{33}	moments of inertia about the spacecraft yaw, roll and pitch axes, including the wheel
I_{12}, I_{13}, I_{23}	products of inertia associated with the yaw roll and pitch axes
K_r	coupling factor of the lateral motion with the sensed pitch error θ_E
$P(s)$	transfer function of pitch-loop control hardware in terms of pitch motor torque per unit pitch angle
T	motor accelerating torque (positive for wheel acceleration)
$T(s)$	Overall cross-coupled pitch open-loop transfer function = $P(s)$ $D(s)$
θ	angle between yaw axis and the line in the transverse plane which, in conjunction with the pitch axis yields the maximum product of inertia I_{pr}.
θ_E	sum of pitch angular error and the sensed nutation motion = $\theta_p + K_r\mu$
θ_N	half-cone angle of nutation cycle.
θ_P	spacecraft pitch error; defined as the angle between the yaw axis and the plane formed by the pitch axis and the local vertical
μ	nutational motion, measurable in the form of any cyclic angular acceleration, rate, or positional motions about any axis in the transverse plane.
ϕ	spacecraft roll angle; defined as the angle between the pitch axis and the plane formed by the orbit normal and velocity vector
ω_f	absolute angular velocity of pitch wheel
ω_{fr}	angular velocity of pitch wheel relative to body
$\omega_1, \omega_2, \omega_3$	angular velocities about the yaw, roll, and pitch axes
ω_0	orbital rate
ξ	angle between yaw axis and the axis in the transverse plane about which nutational motion is being sensed

$$\frac{\theta_E}{T} = \frac{-[1+(S/H_3)T_p(CI_{23}+NI_{13})+(S^2/H_3^2)\left\{I_{11}I_{22}-I_{12}^2-T_p[C(I_{12}I_{23}+I_{13}I_{22})+(I_{11}I_{23}+I_{12}I_{13})N]+I_{13}H_3K_R\right\}+(S^3/H_3^3)(I_{11}I_{23}+I_{12}I_{13})K_RH_3]}{s^2I_p\{1+(s^2/H_3^2)(I_{11}I_{22}-I_{12}^2-[I_{22}I_{13}^2+I_{11}I_{23}^2+2I_{12}I_{13}I_{23}]/I_p)\}} \quad (5)$$

program developed. The basic spacecraft parameters used throughout the analysis are given in Table 1. Eq. 3 shows that the phasing angle, λ, can be varied by varying either θ or ξ in Fig. 1. For each value of ξ chosen for any given nutation sensor, however, a new transfer function, $D(s)$, relating the summed outputs of the pitch and nutation sensors, would be required. Thus, for ease of analysis, computer runs for different values of ξ were obtained by selecting an arbitrary but fixed sensor and sensor axis angle, ξ; generating the appropriate transfer function, $D(s)$, for use in the computer program; and then varying the I_{pr} axis angle, θ, by modifying the values of I_{13} and I_{23} incorporated in $D(s)$. The required values for I_{13} and I_{23} for a given I_{pr} and θ value were calculated from Eq. 1 and 2.

Thus, a rate gyro was assumed to be the nutation sensor, measuring nutational rate along the roll axis such that the angle ξ was 90°. The required transfer function, $D(s)$, for this sensor was then derived in a similar manner to that shown in Ref. 2, after first noting that:

$$\theta_E = \theta_p + K_R\,\omega_2 = D(s)T$$

This relationship led to the following expression for $D(s)$ given. In Eq. 5, C=cos θ_p; $N = \sin\theta_p$; and $T_p = \tan\phi$.

This result was incorporated into the computer program in the manner previously described. K_R in this transfer is the gyro gain and was put into the program as a variable to allow assessment of its effect. A nominal value of 3.14 rads/rad/s was chosen for its value.

The product of inertia, I_{pr}, was assumed to be 5 lb-in-s^2, a fairly modest unbalance when compared to the moments of inertia shown in Table 1. To help give an intuitive feel for what an I_{pr} of 5 lb-in-s^2 means, such a value could be generated by a 2-lb mass situated at a radius of 19.3 in. from the pitch axis and 50 in. along the positive pitch axis. Also, the I_{pr} axis can be better visualized by knowing that, as a result of the 2-lb mass, the I_{pr} axis would be aligned with a projection on the transverse plane of the line joining the spacecraft origin and the 2-lb mass. Thus, a rotation of the 2-lb mass around its 19.3-in. radius from the pitch axis would cause an equal angular change in the angle θ, with no change in the magnitude of I_{pr}.

For various sets of spacecraft conditions, then, results of nutation-damping time-constant were derived by means of the computer. These are shown graphically in Figs. 3 through 7. The vertical axes on these figures show the reciprocal of the nutation-damping time-constant, $(1/\tau)$.

Table I — Spacecraft parameters assumed for all damper analyses.

Parameter	*Value*
I_{11}	421 lb-in.-s^2
I_{22}	460 lb-in.-s^2
I_{33}	366 lb-in-s^2
I_{12}	7 lb-in.-s^2
I_t	4.46 lb-in.-s^2
H	140 lb-in.-s
ω_S	0.318 rads/s

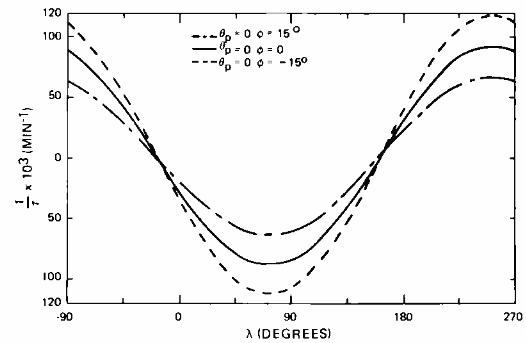


Fig. 3 — Inertial damping: gyro sensor nutation inverse time constant versus phasing angle.

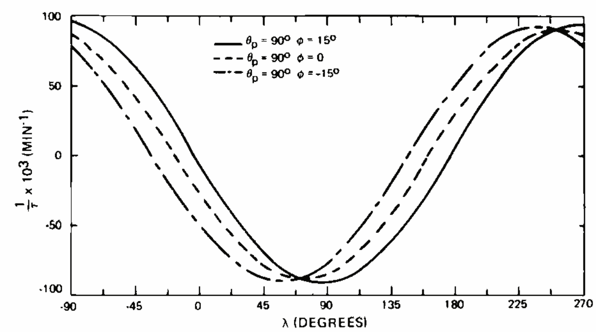


Fig. 4 — Inertial damping: gyro sensor nutation inverse time constant versus phasing angle.

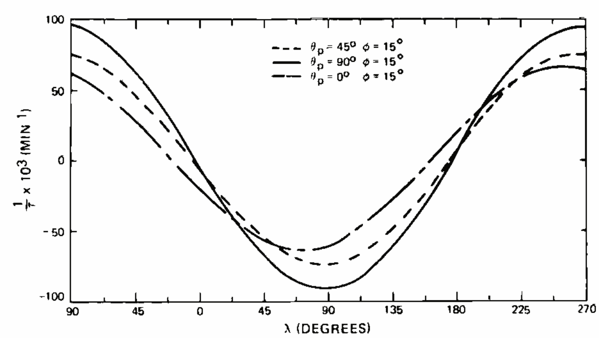


Fig. 5 — Inertial damping: gyro sensor nutation inverse time constant versus phasing angle.

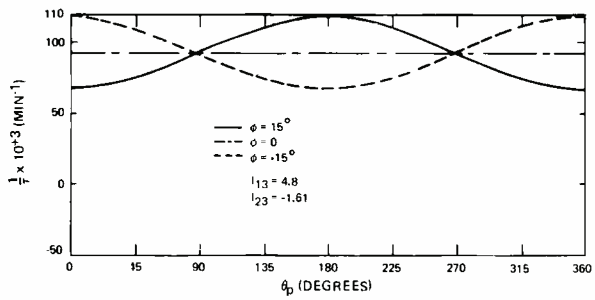


Fig. 6 — Inertial damping: gyro sensor nutation inverse time constant versus pitch error.

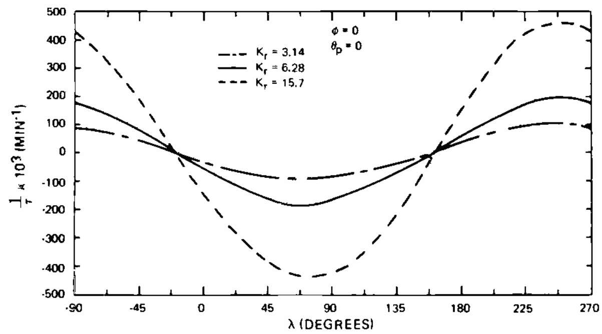


Fig. 7 — Inertial damping: gyro sensor nutation inverse time constant versus phasing.

Thus, zero on this axis represents the limit of stable nutation damping; any system having a negative $(1/\tau)$ would be unstable, with an exponentially *increasing* nutation rate, defined by the value of $(1/\tau)$. The goal, then, is to establish the largest positive $(1/\tau)$, since this would represent the fastest rate of exponential nutation decay. Figs. 3, 4, and 5 show the inverse time constant as the phasing angle, λ, is varied through 360° while I_{pr} is held constant.

The various plots shown represent different combinations of steady-state pitch offset, θ_p, and roll, ϕ. From the curves, it can be seen that there is an optimum value of the angle λ, and hence the cross-products for a given configuration, that will give the best nutation damping. In this case, a value of 250° for λ, which corresponds to an I_{13} of +4.8 in.-lb-s and I_{23} of −1.61 in.-lb-s, is seen to be close to the optimum for all combinations of roll and pitch error. Fig. 6 shows the variation of time constant plotted against pitch error, with I_{13} and I_{23} fixed at the optimum point found above. Here, the curves show that over the examined range of ± 15° of roll angle, a positive damping time constant is obtained for any pitch error, with an average value of less than 11 min. Thus, such a system would give satisfactory damping if the vehicle were continuously rotating in pitch.

An investigation into the relationship between the roll rate-gyro gain constant, K_r, (shown in Fig. 2) and the time constant is illustrated in Fig. 7, in which K_r is increased from 3.14 rads/rad/s to 6.28 and 15.7, and plots were made of inverse time constant *vs.* λ. As can be seen, the inverse time constant increases directly with K_r, indicating that for best damping K_r should be made as large as system constraints (such as motor-power-amplifier saturation) will allow.

Another result observed was that the inverse time constant varies directly with the vector sum of I_{13} and I_{23}; that is, I_{pr}. This was checked by doubling I_{pr} and noting that the time constant was cut by one-half.

Conclusions

Nutation damping by means of products of inertia (the inertial damper) was shown, by a computer-aided technique, to be feasible and effective. The linearized model has since been checked out by means of a fully non-linear three-axis time simulation of the spacecraft with the optimized inertial damping, wherein excellent correlation of results for the two different methods was found to exist.

A time constant of approximately 10 to 15 min. can be achieved by merely adding a 2-lb mass in an appropriate place to an otherwise balanced spacecraft; better still, the time constant can be achieved without additional weights, but by a suitable orientation of spacecraft components (in the design stage) to give the necessary unbalance. These parameters are considerably more favorable than those of existing passive (liquid-filled) dampers; one presently used in a similar RCA spacecraft, has a weight of 15 lbs and a time constant of about 40 min.

It was also shown that the time constant is inversely proportional to the magnitude of the product of inertia and the gain of the nutation sensor. The values selected for examination of these quantities in this analysis were far from representing any practical limit. Time constants at least ten times faster than those demonstrated should present no serious problem.

This type of damping system requires no additional power, since it derives its effect from the existing spacecraft pitch momentum wheel.

It was stated previously that the phasing angle, λ, was varied to obtain optimum damping by adjusting the I_{pr} angle, θ. To determine if the same value of λ would produce optimum damping if the sensor-axis angle ξ were varied instead, a different sensor configuration was assumed, and a new transfer function $D(s)$ was generated for this configuration. Using this in a modified computer program, it was found that for the same spacecraft, the optimum λ was the same, regardless of which of the two values of ξ was used. This means that if a spacecraft configuration exists with fixed and unmodifiable products of inertia, the nutation sensor axis can instead be rotated in the transverse plane to achieve the optimum λ.

One other scheme was found to be feasible. If nutational motion is being sensed by some transverse axis sensor whose sensing axis cannot be shifted, and if the spacecraft products of inertia are fixed and cannot be changed, such that $\lambda = \lambda_r$, the required optimum damping can be achieved by electrical phase lag of the sensor signal. The required amount of phase lag is determined by the angular difference $\lambda_r - \lambda_o$. The value of $\lambda_r - \lambda_o$ could be anywhere from zero to 360 degrees. The electrical circuit would be required to generate $\lambda_r - \lambda_o$ degrees of phase lag at nutation frequencies, but at all other frequencies, the phase shift would be immaterial, since the circuit would be subjected to that one frequency.

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A picture source sync generator

R. D. Post

In a television plant with multiple picture sources, the problem of combining output video signals to produce acceptable picture continuity involves frequency and phase synchronization of these signals at their combination point. This point, usually a studio switcher, must receive synchronized signals from its picture sources if output continuity is to remain synchronous during switching or mixing. Lack of synchronization between the signals will not only destroy picture continuity for the viewer but will disrupt a video tape recording that is in process.

THE TECHNIQUE most commonly used in the television industry to produce synchronization of multiple picture sources has been the distribution from a master sync generator of a common set of timing pulses to all picture sources that are to contribute to a particular continuity. All the live cameras, film cameras, and video tape recorders used on a particular show will then have the same time-base reference. However, this only solves the frequency half of the problem. Since different picture sources have different internal delays, and since the paths for pulses into, and video signals out of, the various picture sources to the combining point are of varying lengths—depending on the location and type of the picture source—the video signals at the combining point would be the same frequency but have varying phase relationships.

To compensate for this unacceptable error, delays have to be included in the pulse paths for each picture source, so that the electrical lengths of all paths from the master sync generator to the combining point are equal. Since one path will be longest, the other paths are each complemented with the appropriate delay value to make their length equal to the worst case.

Pulse tree distribution

A traditional six-cable pulse tree distribution system is shown in Fig. 1. One of two master sync generators feeds six cables and six amplifiers, which in turn feed six delay lines per picture source, other than the longest picture source. The delays for each picture source are adjusted to complement the longest delay, so that the video outputs all arrive at the common switching point at the same timing, *t* zero.

This system has several inherent disadvantages:

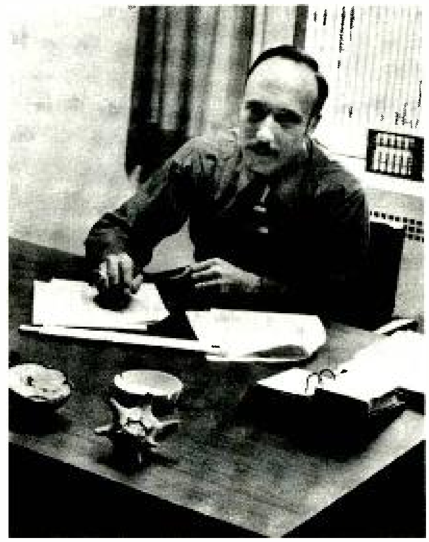
- Failure of the master generator in use causes all of the picture sources to fail.
- Failure of one amplifier causes two picture sources to fail.
- Genlocking requires the use of a devoted master generator, which cannot then be used as a spare.
- All picture sources in the system are of necessity tied to the same set of pulses at any time.

Addition of a picture source with a longer delay than exists in the system is highly penalizing, since all the other picture sources must then have delay added to them to readjust them to *t* zero. What is needed to avoid this is a "negative" delay to pull back the new source to match the old ones, but this is, of course, not possible with physical delay lines.

This system therefore is operationally inflexible, prone to gross failure, difficult to modify, needlessly complicated, and wasteful of space and power.

Encoded timing signal

In recent years, the trend has been toward the encoding of these six timing signals into a single signal, which is then distributed over one cable to minimum-cost decoders associated with each picture source throughout the plant. This technique is obviously more efficient than the older brute-force six-cable system, but questions as to coding format, distribution structure, and encoder/decoder character-



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received the BSEE in 1949 from New York University and did graduate work in digital design and computer programming at Columbia University. Following graduation, Mr. Post joined the National Broadcasting Company as a TV Studio Engineer. In February, 1951, he was appointed to the NBC Color TV Task Group as a color video engineer, where he contributed to the setup of the original NBC Color Studio 3K, and participated in the first Mobile Unit field tests of the RCA all-electronic Compatible Color Television System for the FCC. In December, 1951, Mr. Post joined the NBC design engineering group as an audio-video engineer, assuming responsibility for design, installation, and final acceptance tests on systems such as the original Dave Garroway "Today" studio and many other NBC studios. In 1956, he was promoted to Project Engineer with responsibility for the NBC Democratic Convention Plant built in the Chicago Stockyards, including the first Huntley-Brinkley color studio and the first on-air use of a five-way split. In November, 1956, Mr. Post was appointed Project Planning Engineer, assuming responsibility for analysis, evaluation, and writing of advance specifications for new NBC technical facilities. In 1957, work was begun on a relay-realized computer and interface, for use as a real-time control device for the first fully automated TV station, NBC's WBUF in Buffalo. In 1958, a multiple-studio control TV automation system, again using relay-realized computers, was installed in NBC's WRC-TV plant in Washington. In 1959, Mr. Post became Staff Engineer—Advanced Planning, where he planned, specified, and designed a new NBC Burbank facility, called Burbank Switching Central. In 1961, he became Project Engineer for Burbank Switching Central, the first real-time multiple-channel TV automation system with all-core-computer control, which became operational in 1966. He is now a Senior Engineer with NBC in New York where he has been concerned with the NBC-New York plant modernization, similar to Burbank and called Television Central.

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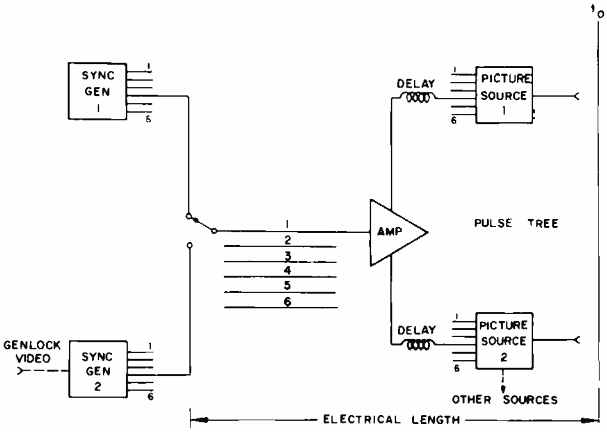


Fig. 1—Six-cable pulse distribution using a shared tree.

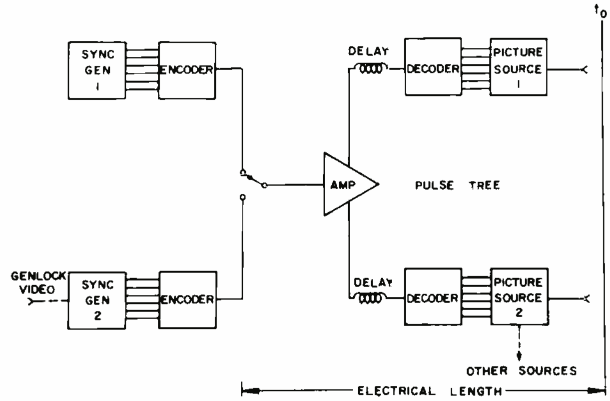


Fig. 2—Single-cable encoded pulse distribution system using a shared tree.

istics must be resolved to fully realize its potential advantages.

Such a coded single-cable pulse distribution system is shown in Fig. 2. This system uses the same traditional tree structure that was shown in Fig. 1 and assumes the typical minimum decoder that reconstructs the six pulses and no more. The system is now much simpler and less wasteful of space. However, independent of the coding format used, the system is still operationally inflexible, prone to gross failure, and difficult to modify.

Pulse distribution switcher

It is evident that a simple decoder in a pulse tree structure does not permit full realization of the single-cable pulse system's potential. But consider the pulse tree. The basic reason why the pulse tree came to be used was to provide an economic means of distributing six pulses. With only one pulse signal to handle, it becomes plausible to use an isolated pulse switching system and dedicated paths to each picture source. Fig. 3 shows such a system.

Each picture source may now be independently switched to any master sync generator. This provides a tremendous increase in operational flexibility over the previous tree structure, where all the picture sources in a tree had to share the same time base. The system, however, still requires a dedicated master sync generator for every genlock function, and still is prone to gross failure and difficult to modify.

NTSC sync timing signal

The distribution structure shown in Fig. 3 would seem to be ideal. But to further optimize the system, let us consider the coding format, and the related encoder and decoder. The use of special coding formats has been predicated on compatibility with a minimum decoder. That minimum decoder, however, is the cause of the gross failure mechanism in this system and its penalizing delays.

Modern digital techniques now allow plausible realization of a sophisticated fail-safe decoder, with back-timing capability that eliminates the need for system delays. Such a decoder does not require an optimized coding format, but can be made compatible at low cost with any format that contains all the timing information in readily available form.

A coding format that is compatible with present plant equipment and techniques, and is available as an output from current master sync generators and picture sources already exists, however, and the advantages of using it are evident. That format is the NTSC video synchronizing structure itself, which obviously contains all the timing information that a picture source requires.

The decision to use a composite video time base reference as the signal in a time base distribution system means that the decoders functionally become genlocked sync generators, each dedicated to a particular picture source, i.e., picture source generators. However, the system demands are such that these picture source sync generators must have unique characteristics not shared by any previous sync generators.

Picture source sync generator system

Fig. 4 shows such a video time base distribution system. All the disadvan-

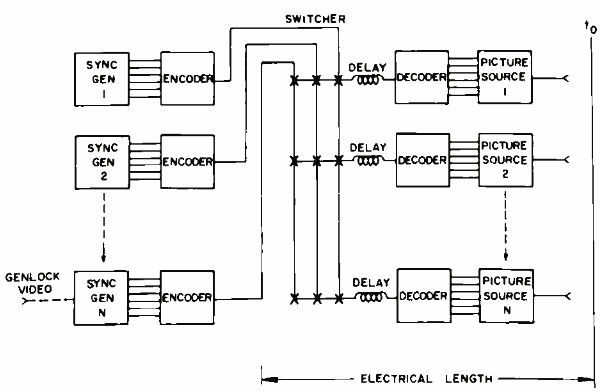


Fig. 3—Single-cable encoded pulse distribution system using a switcher and dedicated paths.

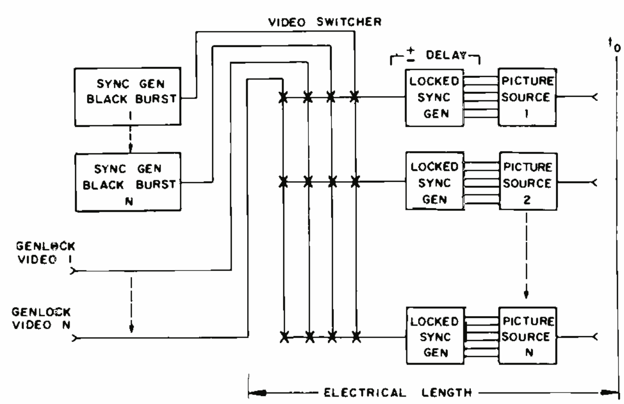


Fig. 4—Single-cable encoded pulse distribution system using a video signal and genlocked sync generator.

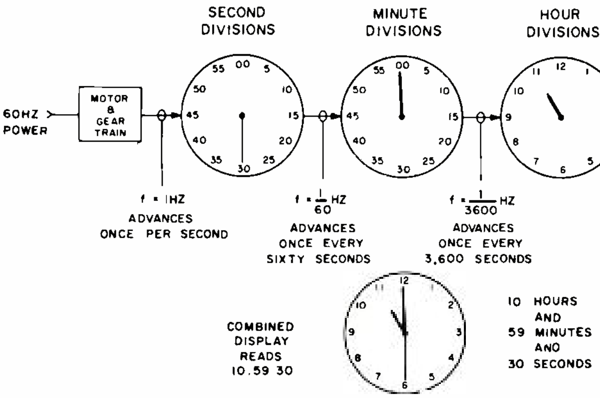


Fig. 5—Seconds, minutes, and hours clock.

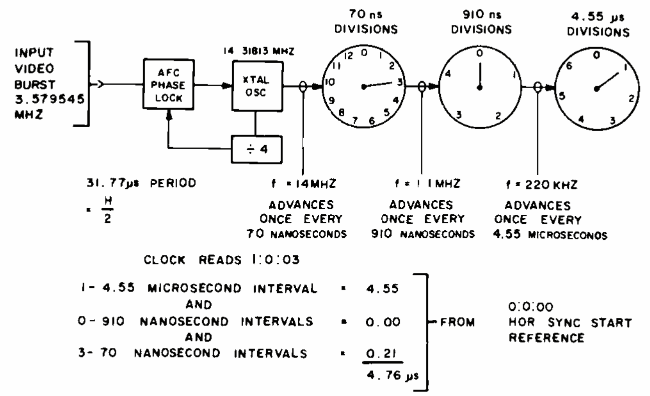


Fig. 6—Digital sync generator clock.

tages of the previous systems have now been eliminated in this final system, and new capabilities have been added that did not exist before.

The system is extremely flexible operationally. Not only can any picture source be locked to any master sync generator time base, but it can also be locked to any video source without the use of a master sync generator. In addition, each picture source generator has a black burst output, which makes it a potential source of time base information for any other picture source generator.

The system cannot fail in a gross sense. Each picture source generator is a free-standing, fail-safe device which will continue to sustain its picture source even if its input video time reference disappears. Only one picture source can fail at a time due to one equipment failure. If a master generator fails, all the picture sources switched to its bus will lose genlock until they are transferred to another time base, but none of them will lose their pulses.

The system no longer requires any pulse delays to compensate for differences in path length to the combining point, since each picture source generator can be delayed or advanced from its input video time base reference, digitally. Addition of a new picture source will therefore never require modification of the other sources. This will be true even if the new picture source or its associated path is electrically longer than any other in the plant, since the picture source generator has the equivalent of negative delay capability, and can pull the picture source back in time.

All the above advantages of using the picture source sync generator as a pulse distribution decoder do not come without some penalty, however. The most important price paid in a plant for the use of an independent sync generator, in place of a regenerator of pulses at each picture source, is the need for that sync generator to be free of routine operational adjustments.

In earlier regenerative systems, the presence of one or two master sync generators that required routine setting of pulse widths and amplitudes due to drift was an undesirable but acceptable situation, since there were only one or two. In the picture source sync generator system, however, where each live camera, film camera, and video tape recorder in the plant has its own sync generator, the need for routine operational adjustment would be very penalizing, since every picture source would demand adjustment individually. This would be unacceptable from both an operational and manpower viewpoint.

The picture source sync generator has no routine operational adjustments or maintenance. It is almost completely digital in design and uses devices and techniques that do not drift with time or temperature. It is in essence a specialized programmable digital computer, with internal high-precision clocking to establish all pulse widths and timings.

To gain insight into this clocking process, consider a normal time-of-day clock. Fig. 5 shows the familiar hours, minutes, and seconds display for an electric clock, divided into its three parts. The 60-Hz signal drives a motor and gear train, rotating the seconds hand over its 60-division scale. Every 60 seconds advances the minute hand by one division over its 60-division scale, and every 60 minutes advances the hour hand by one division over its 12-division scale.

The combined display in Fig. 5 is the familiar 12-hour clock face. It reads 10:59:30, that is, 10 hours, 59 minutes, and 30 seconds from the 12:00:00 reference. It is obviously a plausible and economical way to convey time of day, but it does require the mental "anding" of three related quantities—hours, minutes, and seconds—to be read. This process of dividing a time period into three related measuring scales in order to efficiently identify a particular instant in that time period is identical to the technique used in the picture source generator clock to identify the instant in time that a pulse will begin or end.

Digital sync generator

Fig. 6 shows the digital sync generator clock as a visual display. This clock is the heart of the digital sync generator. It is identical structurally to the previous time of day clock, but uses a different input clocking frequency and has different time values and numbers of divisions in its three displays. It obviously cannot be read literally or even constructed in this physical form, but an insight into the way it works may be gained by comparison with the familiar time-of-day clock.

Instead of 60 Hz, the input signal to this clock is 14 MHz, derived from the output of a high-stability crystal oscillator which is phase locked to the incoming video burst. The three displays have time values of 70 ns, 910 ns, and 4.55 μs as shown, instead of seconds, minutes, and hours. In addi-

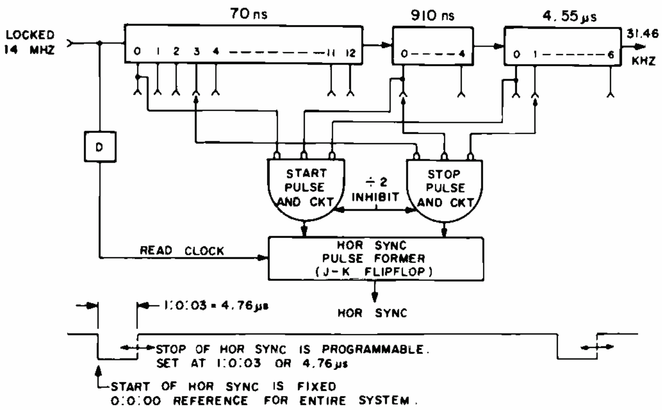


Fig. 7—Shift register pulse timing clock.

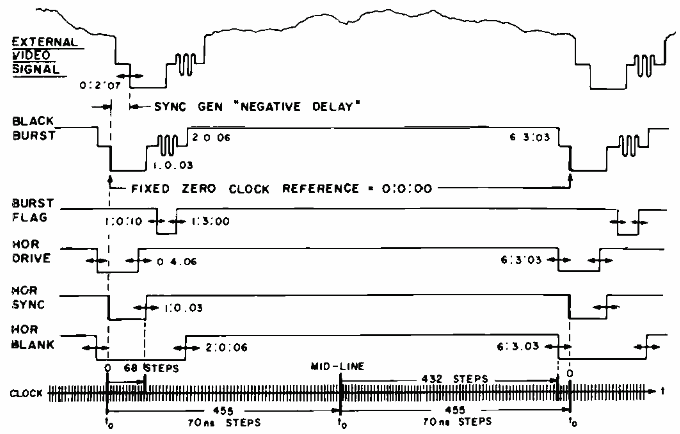


Fig. 8—Horizontal pulse clock timings.

tion, there are 13, 5, and 7 steps respectively per display, compared to the 60, 60, and 12 found in the time-of-day clock.

The total number of counts in this clock per complete cycle is 455, and since each count is 70-ns long, the total time of each cycle is 31.77 µs, or exactly half the time between horizontal sync edges.

The clock as shown reads 1:0:03, that is one 4.55-µs interval and three 70-ns intervals from the reference leading edge of horizontal sync. This value of 4.76-µs is the NBC standard for horizontal sync width, and as such will define the trailing edge of horizontal sync.

Fig. 7 shows how this definition is accomplished in the actual picture source sync generator. The pulse timing clock consists of three digital shift-register counters or dividers, each defining a particular time unit, and interconnected so that the reset to zero of the 70-ns register at each thirteenth step advances the 910-ns register one step, and the reset of the 910-ns register at each fifth step advances the 4.55-µs register one step. At each 70-ns interval in time, one and only one position in each of the shift registers will be in a low state, corresponding to the "hands" of the clock. Each shift register has its terminals brought out to pin jacks on a programming board. By choosing one terminal from the 70-ns register, one from the 910-ns register, and one from the 4.55-µs register as the three inputs to an "and" gate, we can define any particular 70-ns period out of the 455 in a complete clock cycle.

A separate "and" gate is provided for every variable pulse edge. The terminals from these gates are all brought out to the same programming boards that the shift-register pin jacks are on, and each gate input terminal is provided with a pin plug at the end of a short piece of wire. Each of these gates can be programmed independently, therefore, for its own pulse edge timing.

Horizontal sync start, which is the zero reference for the entire pulse timing structure, has a gate which is wired solidly to the 0:0:00 shift-register outputs. Horizontal sync stop is plugged into 1:0:03, which delays it 4.76 µs from the fixed 0:0:00 horizontal sync start pulse, and thus establishes the desired horizontal sync width of 4.76 µs.

This shift-register clock produces pulse outputs at twice the horizontal line frequency, which is necessary to time the 31.5-kHz equalizing and vertical serration pulses. Outside the verticle interval, alternate pulses are inhibited at the "and" gates by a divide-by-two signal which is synchronous with the pulse structure, resulting in the normal 15.7-kHz pulse rate.

As seen in Fig. 7, not only are the shift registers that measure time clocked by 14 MHz, but the output pulse edge former is also clocked by a "read clock" pulse. This pulse is delayed sufficiently from the main clock pulse to insure that the new time has "settled" before it is read. This insures that the instant in time that a pulse edge is generated is always timed by the jitter-free 14-MHz signal, independent of propagation delay in the counters.

Horizontal lock in this generator is achieved by the familiar technique of altering the count in the 13-step shift register to 12 or 14, as a function of horizontal phase error.

Fast vertical genlock is achieved by clamping a set of vertical binary counters to the count corresponding to the beginning of vertical sync and releasing them when input vertical sync appears.

When locked to an NTSC video color signal, this generator is under the control of incoming burst, the most accurate and stable component of that video. The entire output pulse structure is rigidly locked to that incoming burst and *only* to that incoming burst. All programmed pulse timings and widths are derived from that burst and are completely independent of short-term jitter in incoming pulse edges, or longer-term input pulse variations due to APL shifts or master generator instability, as long as these input variations do not exceed the limits of a "window" of about 140 µs. If the input varies so that this window is exceeded, the unit will automatically correct the horizontal phase error by one or more increments of 70 ns each, and then revert to burst-only lock. With a normal master sync generator black burst as a reference, this process will never occur.

The clock of Fig. 7 is the heart of the picture source generator's flexibility. The use of its shift registers as a programmable scale to establish both the internal pulse timings and the overall external reference delay is essential.

Fig. 8 shows a typical set of horizontal pulse timings. Two cycles of 455 steps each exist between succeeding horizontal sync start references. Only half of these, the half-line preceding the end of blanking, are available for timing, due to the divide-by-two in-

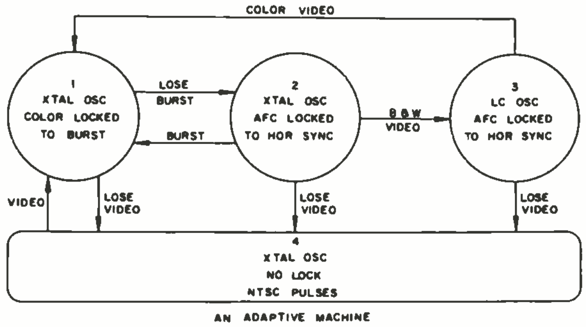


Fig. 9—State diagram as a function of input video (full genlock mode).

hibit. All clock readings are taken to the right of the reference. There are no negative clock values. Pulses that lag the horizontal reference, such as the start of blanking, are timed for their next occurance in the forward direction, ignoring the intervening 455-step cycle.

The generator is shown with a 0:2:07 negative delay setting, about 2.3 μs. A separate "and" gate is provided to establish this relationship between the external video's horizontal sync leading edge and the generator's horizontal sync reference. The output of this gate is used in the horizontal sync phase detector, and the timing value called for appears as an overall positive or negative delay between input and output, rather than as an output pulse.

While the pulse timing flexibility previously described is an essential feature of a picture source generator, it does not represent the only demands that the system places on it. In particular, the ability to automatically adapt to varying conditions in the input video reference signal and still sustain a locked set of output pulses is important.

Automatic genlock modes

Fig. 9 is the complete state diagram for the generator. Each circle in this drawing represents a particular machine state of the same physical generator. Fig. 9 shows the eight different decisions automatically made by this generator in response to gross changes in the input video reference signal. These decisions are designed to sustain the genlock where possible, and in all cases, to insure continued output pulse continuity.

State 1 is the generator in a full color genlock mode, locking its crystal oscillator to a complete NTSC color signal. If burst is lost in that input color signal, machine will automatically shift to an AFC lock of its crystal to the incoming horizontal sync edge, and continue to sustain all its output pulses, including burst. This is its State 2. If burst is restored to the input signal when in State 2, generator will automatically return to State 1.

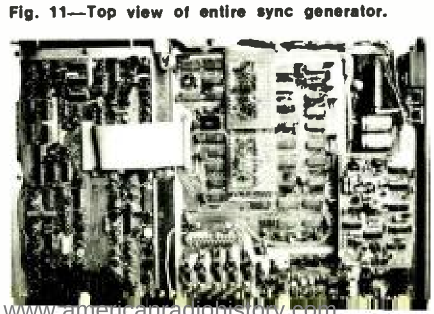
If the input video signal goes outside normal limits to black-and-white standards, when in State 2, the generator automatically shifts to an AFC lock of an LC oscillator which can be pulled over a much greater frequency range. This is State 3, and as shown, generator will not return from State 3 to State 2 if input video drifts back into color standards without burst being restored. In State 3, generator automatically drops the burst from its black burst output, to sustain ability of another generator to lock to it.

The generator will automatically return to State 1 from State 3 if a full NTSC video signal, with burst, is restored to it.

Finally, the generator fails-safe if input video disappears, by automatically shifting to an unlocked free-running crystal oscillator mode that still sustains NTSC output pulses, State 4. If video is restored, generator returns to State 1.

Fig. 10 shows the front panel of the picture source generator. Tallies are provided for incoming video and sync lock, and for incoming burst and color lock. These tallies enable operator to correlate locking condition and incoming reference status at a glance. Pushbuttons below these tallies enable

Fig. 11—Top view of entire sync generator.



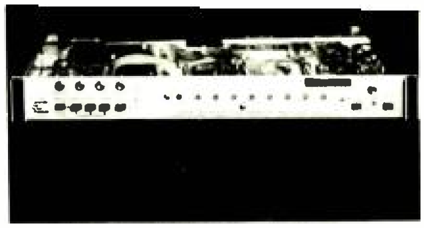


Fig. 10—Front panel of picture source sync generator.

other optional modes of operation. Test jacks for the input and all output pulses, phase and frequency adjustments for subcarrier, and a bar or dot switch complete the panel.

Fig. 11 shows a top view of the entire generator. The board to the left is the genlock system, while the large board to the right is the sync generator itself. To the extreme right is a plug-in bar and dot generator subassembly, while the two boards toward the top are the plug-in programmable pulse timing patchboards. The 14-MHz crystal is mounted in a proportional oven, below the bar and dot generator.

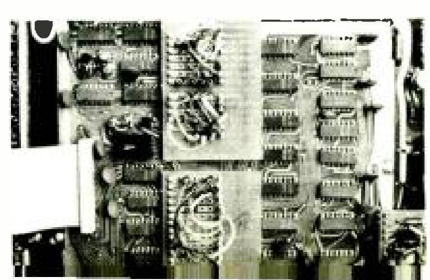
Fig. 12 shows a closeup of the two pulse-timing patchboards. The 4.55-μs shift-register patch bay is at the top, with the 910-ns and 70-ns units just below it. Five jack positions are provided at each timing point to allow multiple assignment of "and" gate inputs to the same shift register terminal, if necessary.

In an emergency, the entire generator assembly can be unplugged, removed from its case without disconnecting any external cables, and replaced with a spare. In order to allow the spare to be speedily programmed with the same pulse timings that the old generator had, the patchboards can be unplugged and transferred to the new unit, providing it with an identical set of timings.

Conclusion

Over the past year numerous picture-source generators have been installed at NBC-New York. The results have verified the basic merit of this approach. Furthermore, it would seem logical, in the future, to make the picture-source generator an integral part of new television picture sources, rather than an adjunct to them.

Fig. 12—Closeup view of two pulse-timing patchboards.



Discrete 4-channel records, 1973

Warren Rex Isom

The discrete-4 channel record with its 30 kHz carrier imposed upon each of the walls of the stereo groove is described. A review of progress in each of the several aspects of recording, lacquer cutting, metal parts, electroforming, and manufacturing is given. This paper was first presented by the author at the 44th convention of the Audio Engineering Society at Rotterdam, The Netherlands, February 22, 1973.

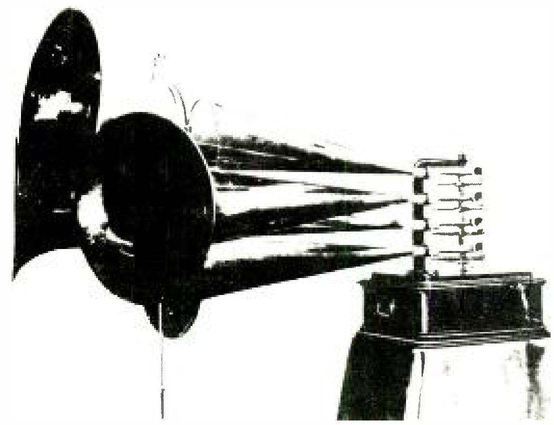


Fig. 1 — An experimental "four channels" setup used in twenties to add loudness.

FOUR-channel sound, discrete or otherwise, is not new. In the early twenties, it seems, that the emphasis was on volume or level, and not on recovering the acoustical environment of the recording; hence 4-channel "mono" was used to enhance playback level by a factor of four (Fig. 1).

Historical

The first public demonstration of four-channel sound by RCA from magnetic tape was during the celebration of the 25th anniversary of the David Sarnoff Research Center in Princeton, New Jersey, in September, 1967. The demonstration was impressive and foretold the future with greater accuracy and immediacy than was then suspected.

Three years later in August, 1970, RCA introduced as a commercial product discrete 4-channel magnetic tape under the trade name of Q-8 and in the format of the familiar eight-track continuous loop cartridge. Previous to this, there had been several releases of discrete 4-channel sound on open reel tape. The response to the discrete 4-channel cartridge tape established discrete 4-channel sound as a commercial product.

In October of the same year, the Victor Company of Japan introduced at the Convention of the Audio Engineering Society in New York discrete 4-channel sound from a phonograph record employing a 30-kHz fm carrier superimposed upon each of the two groove walls. A record with a playtime of 18 minutes was demonstrated with a 50-dB signal-to-noise ratio at a relative level of -5dB, with channel separation of 23 dB left to right, and with 20 dB front to back[1].

A commercial product

In September, 1971, RCA committed to discrete 4-channel sound from records

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quadraDisc

Fig. 2 — The QuadraDisc trademark.

and made initial releases in May, 1972, under the tradename of QuadraDisc (Fig. 2). In February, 1973, the performance capabilities of the disc can be given as a playtime of 25 to 30 minutes, a level 3 dB above the standard reference, 55 dB signal-to-noise ratio, and with essentially the same freedom from distortion as a standard stereo record. In fact, its level or loudness is equal to the average of those stereo LP records listed on the charts as best sellers, and its technical performance as a stereo record is better.

Technical progress has continued since the original introduction but the system constants have remained fixed. For stereo play, the discrete 4-channel disc looks like and plays as if it were a regular stereo record.

Four channels in one groove

When examined visually without the aid of optical instruments, the discrete 4-channel record groove appears to be the same as a stereo groove but under the scanning electron beam microscope, great differences are seen (Fig. 3). Each of the two walls carry two channels of information; namely, the sum or combination of the front and rear signals from each side on the corresponding wall of the groove in regular stereo fashion.

In addition to this, a frequency modulated carrier at 30 kHz is superimposed upon each of the two stereo channels. These fm carriers provide for the recording of the difference of the front and rear signals from each side on the corresponding wall of the groove. Each wall of the groove now carries two sets of

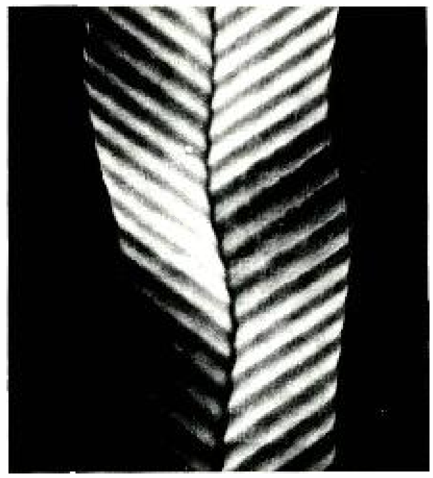

Fig. 3 — Discrete 4-channel record groove magnified 1500 times. (The ratio of magnification is approximately 500 per inch of groove width as reproduced in print. If, for example, the picture is reduced so that the groove width in print is one-half inch, the magnification is 250).

signals: the sum of the front and rear signals on the stereo base band and the difference of the front and rear signals on the carrier band. Basically speaking, this is an interference-free arrangement because the carrier signals are super-audible to the carrier signals and the stereo signals are sub-audible to the carrier signals. This is possible because of the advances of modern technology in record manufacture, pickup cartridge development, and in electronic signal processing.

The average length of the carrier wave is 0.0003 inch or 0.85 micron. The length of a stereo band wave marked on the figure is that of ten carrier waves. Hence, the stereo wave is that of a 3000 Hertz signal.

The fm system

The 30 kHz fm carrier on each groove wall is modulated by the difference between the front and back stereo signals. When there is no signal, the carrier remains at 30 kHz. When there is a full amplitude signal present, the carrier is modulated to the limit of its deviation. The frequency of the difference signal is the frequency at which the carrier is modulated.

The use of the frequency modulation carrier approach to the discrete 4-channel record raises the question of the bandwidth and deviation limitations required for optimum performance. If the deviations are too low, the noise is high; if too high, the fm spectrum is too wide and the outer side frequencies are attenuated by the pickup on the upper side and troublesome in the stereo-band on the lower side.

Analytical studies were made to establish guide lines for the deviation of the carrier. Fig. 4 shows the spectrum for two sine waves of 7 kHz and 8 kHz with a peak deviation of 1 kHz for each. The amplitude of the side frequencies are 0.5% at 29 and 31 kHz and only up to 6 to 7% at 22 and 38 kHz. None of the energy extends into the stereo band below 15 kHz.

When 5 kHz peak deviation is used as shown in Fig. 5, the energy at 29 and 31 kHz is more than 10%; that at 22 and 23, and at 37 and 38 kHz is well over 30%. However, in the stereo band at 14 kHz, there is 4% and 10% at 15 kHz[2]. This relationship between deviation, noise and distortion is the basis for specifying deviation at standard reference level as 2.2 kHz[3].

Noise reduction

An automatic noise reduction system is used in the f-m channels to give maximum signal-to-noise ratio. During recording, the dynamic range is compressed up to 15 dB independently in each of two bands. These bands are from 200 to 2000 Hz and above 2000 Hz. These bands are accordingly expanded during reproduction[4]. With this signal processing technique, 55 dB overall signal-to-noise ratio is achievable.

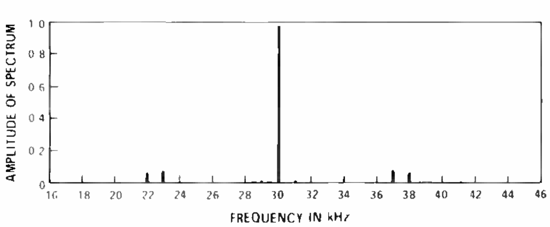

Fig. 4 — Spectrum of fm wave with 1-kHz peak deviation.

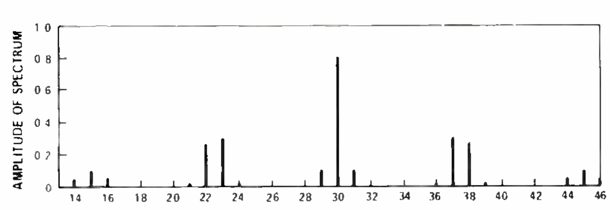

Fig. 5 — Spectrum of fm wave with 5-kHz peak deviation.

Compatibility with stereo

The discrete 4-channel record is recorded to give full compatibility with existing stereo players. To accomplish this compatibility, all of the stereo signal is recorded in the stereo groove of the record. This means that the left front and the left rear signals added together, are recorded as the left signal on the inner groove wall. The same is true of the right signals on the outer wall. When a discrete 4-channel record is played in stereo, the complete recorded signal is reproduced. This provides complete stereo signal compatibility.

A simple matrix

The left difference signal (LF - LR) is used to modulate the fm carrier recorded on the inner groove wall of the record. On reproduction, this difference signal (LF - LR) is added to the sum signal (LF + LR) to give an algebraic sum of 2LF (Fig. 6.) This is the signal that is reproduced, suitably attenuated, by the left front speaker. When the difference signal (LF - LR) is subtracted from the sum signal (LF + LR), the algebraic result, 2LR, suitably attenuated, is reproduced by the left rear speaker. The two right channels on the outer groove wall are similarly reproduced.

$$\begin{array}{r} (LF+LR) \\ +\,(LF-LR) \\ \hline 2LF \end{array} \qquad \begin{array}{r} (LF+LR) \\ -\,(LF-LR) \\ \hline 2LR \end{array}$$

Fig. 6 — The algebra of the simple matrix used in discrete 4-channel sound.

The basic reproduction of each of the four signals is exactly the same, with the exception that the left channel tends to be, as it is in stereo, the favorite.

Playback

The discrete 4-channel record adds more than one new dimension on playback. Stereophonic sound added a new dimension to monophonic sound. A wall of sound replaced the single speaker. Discrete 4-channel adds three more walls and all of the included space. The objective is to be able to reproduce the entire acoustical environment of the recording as it was at the time recording was made or as it is wanted at the time that the recording is "produced"; that is, at the time that the original recordings are mixed down from the multi-channel original recordings to the 4-channel release master tape.

The listener in his home finds that there is a wide area in which he can enjoy the reproduction. In fact, he soon realizes that he can hear it as advantageously from any place in the room as he could have heard it from the corresponding spot in the studio if he had been there at the time the recording was made.

The preferred listening area is relatively large. (Fig. 7); particularly when compared to that for 2-channel stereo (Fig. 8). When stereophonic records are reproduced on a discrete 4-channel system, the two left and the two right speakers are paralleled and four speaker stereo sound is enjoyed. Fig. 9 illustrates the enlargement of the listening area that results.

Recording and microphones

What is heard is very dependent upon the recording and the manner in which it was recorded. Basically, the technique of microphone placement for a large orchestra in a large hall will vary greatly from that for an intimate group in a small room. And this differs from that used to exercise the opportunities and the freedoms of discrete 4-channel sound to the fullest. Discrete 4-channel sound has little restraint for artistic creativity.

In recording the full presence effect of the symphony orchestra, two tracks on the tape are used for two microphones in the rear of the auditorium, one on each side of the balcony if there should be one-otherwise placed most appropriately to capture house presence. The microphones for the remaining tracks are placed very much as they are for stereo recording. During mix-down, it has been found helpful to reproduce the two back channels on speakers immediately to the right and left of the two front speakers. In this way, the level of the back channels is determined so that the balance of the stereo reproduction from the front is not disturbed.

In "center of the action" type of recording, the microphones are placed so that the full surround is adequately covered. During mix-down, there is usually a speaker in each corner of the room so that the feeling of being in the center of a performing group is reproduced. In this type of recording, the primary sound is equally likely to come from any direction.

The third type of discrete 4-channel recording can best be called creative. The limitation of imagination is extended by the mechanical implementation of the ability to change the direction and placement of the sounds of voices, and

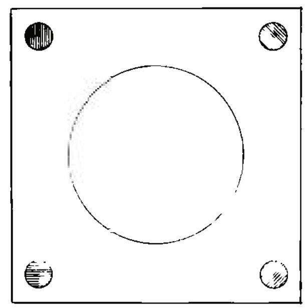

Fig. 7 — Discrete 4-channel sound has a relatively large prime listening area.

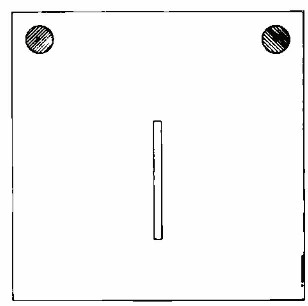

Fig. 8 — Two-channel stereo has its preferred listening area very much restricted.

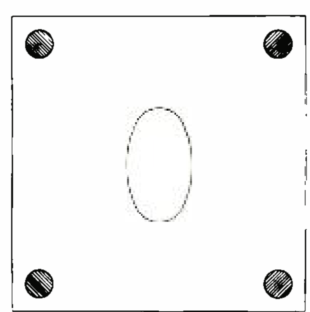

Fig. 9 — Two-channel stereo sound with four speakers wired with two in parallel on each side enlarges the preferred listening area much as shown.

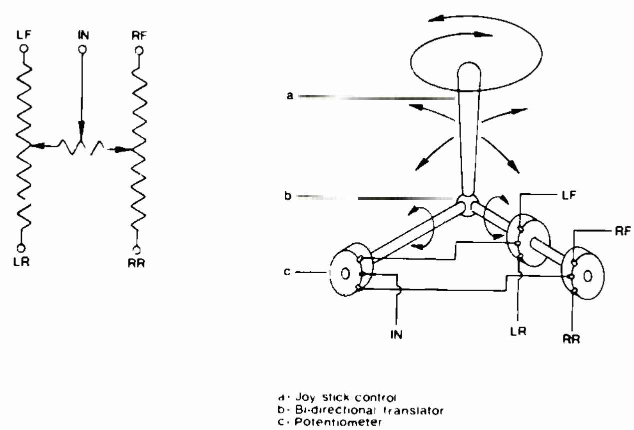

Fig. 10 — A 4-channel "joy-stick" pan-pot used "mixing down" from 8-, 16-, or 24-track original recordings to discrete 4-channel master tapes.

instruments at any time. Fig. 10 shows schematically both electrically and mechanically the "joy-stick" pan-pot. With 16 tracks and 16 "joy-stick" pan-pots, there are innumerable combinations that can be manipulated. The trick is to produce meaningful sound and greatness, as well as novelty, from this new freedom.

The "joy-stick" pan-pot and other equipment innovations have given new tools by which some 8-, 16-, or 24-track original recording can be mixed down to discrete 4-channel. There have been some very satisfactory results obtained by this method but the greatest successes have been scored when the acoustical presence has been recorded purposefully on separate tracks, no matter which of the three basic approaches was used.

Sixty-six of the first numbers released on discrete 4-channel records were classified as a matter of interest. Twenty-six employed full acoustical presence, twenty-six relied upon the "center of action" approach, and fourteen were of the creative type.

The great milestones of progress: the fm system

Progress with discrete 4-channel records has been great since its introduction by the Victor Company of Japan in October, 1970. Probably the greatest element in this progress has been the nature of the frequency modulated carrier system used for the two additional channels superimposed upon the stereo groove. The great key of performance of this system is that the signal is contained in the frequency content of the recording and not in its wave-form. This means that the playback stylus is not required to trace out the waveform of the fm carrier in the record groove; the stylus needs only to respond only to the peaks of the wave so that the "zero crossings" of the carrier can be counted, timed, or measured depending upon the type of the demodulator used for the recovery of the signal. No matter if an ideal, a delay-line, or pulse-rate demodulator is used, there is no dependence upon the wave-form[5]. This accounts for the fact that the record continues to play well even after there is but a faint trace of the carrier left in the groove.

The freedom from carrier wave-form tracing has given a groove that is manufacturable by the conventional record making processes. The lacquer is electroplated with the same techniques as a normal stereo LP lacquer. The other metal parts are also electroformed without change in method. Likewise, the discrete 4-channel record is molded in the pressing plant the same as any other high quality record.

The compound

A compound that produces a record with good surface quality, lubricated, and with anti-static properties is required for best results. All of these requirements relate to minimizing extraneous motions of the pickup stylus that might be similar to that imparted by the carriers. Good surface quality reduces the presence of very small particles in the groove that produce the very faint grinding sound heard when the silent grooves of a record are played. The by-product of record playing is debris worn from the groove that tends to fall into and remain in the groove. To reduce this to near the vanishing point, selected lubricants are used in the compound. To reduce wear is to reduce dust-like debris.

Ordinary phonograph records invariably accumulate large static charges that at-

Fig. 11 — Reproducing stylii shapes: (left) Shibata; (center) conical; (right) elliptical.

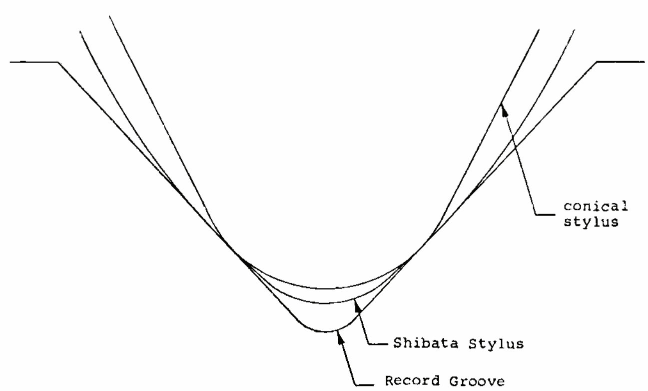

Fig. 12 — Stylii-groove interface reveals that both the elliptical and conical stylii have a point contact; the Shibata a line contact; hence, extended wear-lift.

tract atmospheric dust that clings to particles produced by wear from usage. To eliminate this tendency and to prevent the collection of dust in the groove, an antistatic agent is necessary in the compound from which the record is molded. The compound, then, has been designed to reduce wear and to repel dust. Such a record not only stays clean but is easy to clean.

The Shibata stylus[5]

The development of the Shibata stylus is a most important milestone in the art of reproduction of sound from phonographic records. The wear life has been extended by at least a factor of five over conical styli and probably by a factor of ten over elliptical styli. The significance of this for the discrete 4-channel record is very great.

Fig. 11 shows the Shibata stylus modeled on the left. A conical shaped stylus is in the center and the elliptical stylus is on the right. Fig. 12A shows outline drawings of the same. The direction of the record groove motion to be imagined is almost directly into the paper. With this relative motion in mind, it is apparent that the prow shaped by the two facets cut on the "front" of the Shibata stylus tends to shed any debris or dust found in the groove. This stylus exhibits a self-cleaning characteristic inasmuch as dust and debris in the groove is pushed aside rather than ahead or packed in the groove by riding over it. These facets also effectively reduce the radii contacting the groove walls and permit the stereo groove to be traced with high fidelity equal to or greater than that of the elliptical stylus. The conical stylus tends to ride over anything found in the groove. Records played with conical stylus must be frequently cleaned for best results. The tendency of this stylus to pack dust in the groove makes cleaning difficult.

The elliptical stylus was designed to faithfully trace out the wave form of the signal recorded in the groove and this it does well, much better than the conical but no better than the Shibata. There is a definite tendency for the elliptical stylus to push ahead whatever debris it finds in the groove. The accumulation ahead of the stylus progressively adheres and hardens until fidelity of reproduction is lost and groove wear increased. it is

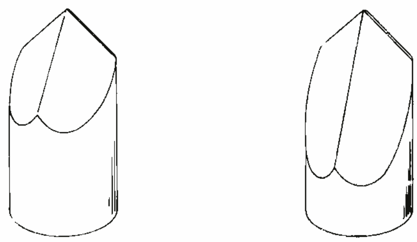

Fig. 13 — Lacquer cutting stylii shapes: (left) 35° back-angle: (right) 45° back-angle.

extremely important that elliptical styli be kept clean.

Fig. 12 shows the interface surface between the record groove and the Shibata and the conical and the elliptical styli. The conical stylus has a point of contact on each side with the groove such as has the elliptical. The Shibata has more nearly a line of contact on each side. The extended wear life factor of records played with Shibata is the result of this design feature. The self-cleaning feature described above contributes continued high fidelity reproduction.

The Dorren phase locked loop

The demodulator for playback of the fm signals was dependent upon a continuous flow of carrier information. Any loss of carrier for whatever cause produced a transient in the reproduction that was objectionable. Some sophistication was added to the carrier detection circuit in the form of a phase locked loop that gives immunity to the temporary loss of carrier.

35-degree back-angle lacquer cutting stylus

Fig. 13 shows a model of the standard 45° back-angle lacquer cutting sapphire stylus. Fig. 13 shows the standard 45° beside the new 35°. The 35° stylus is much sharper. Fig. 14 shows the difference in the carrier wave in records produced from lacquers cut by these styli. Note the presence of carrier on the 8kHz wave in the stero channel for the 35° cutter and its near absence in the 8kHz wave cut by the 45° stylus. Also, the radiused ridge top produced by the 35° stylus is seen as much more suitable for extended life and good reproduction. In addition, the 35° cutter adds new clarity and presence to the high end of stero recordings.

Summary

The discrete 4-channel record has reached technical maturity in a very short time by the constant and consistent determination to mix modern technology with the old art of recording, making for new dimensions in the enjoyment of recorded music on discs.

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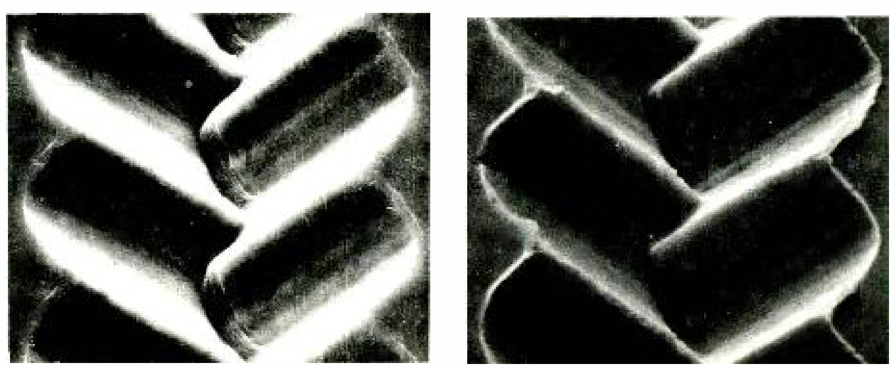

Fig. 14 — Record groove showing a 8-kHz signal in the stero band (the large wave form) showing the super imposed 30 kHz rather well-formed by the 35° back-angle lacquer cutting stylus on the left, but practically lost when the 45° back-angle stylus is used.

RCA Global Communications, Inc: An engineering profile

E. J. Williamson

RCA Global Communications started in 1919 as an international communications carrier operating a few "wireless" circuits. Today, Globcom operates thousands of globe-spanning circuits via radio, submarine cables, communications satellites, and terrestrial networks. The engineering department is organized to support this wide range of activity and to provide new developments for more efficient operations.

E. J. Williamson, Mgr. Leased Facilities & Engineering Administration RCA Global Communications, Inc New York, N.Y. received his formal education at Rutgers University. He joined RCA Global Communications, Inc. in 1937. Over the years, he has been engaged in the operation, installation and design of VLF, HF, UHF and microwave facilities and systems; power generation and distribution systems; and structural, architectural and mechanical aspects of physical facilities. Since 1959, he has been engaged in the design and development of equipment and systems used in control centres and in the transmission of signals over voice-grade channels in the microwave, HF, submarine cable and satellite media. He is registered as a Professional Engineer in the state of New Jersey and is a member of the National Society of Professional Engineers and of IEEE.

GLOBAL COMMUNICATIONS, INC. was organized in 1919 at the behest of the United States Government to provide a U. S. owned and operated international wireless communications system. The new organization originally was called Radio Corporation of America.

When the Victor Talking Machine Company of Camden was acquired in the late 1920's, the Corporation was reorganized into its essential structure of today. But during the years between its inception and reorganization, the new corporation branched out into other radio-related fields such as marine communications, broadcasting, sound systems and equipment manufacturing. The international communications effort, after the reorganization, was the province of RCA Communications, Inc., a wholly-owned subsidiary of RCA Corporation. With the updating of the corporate image a few years ago, the name was changed to what it is today RCA Global Communications, Inc., or, in abbreviated form, RCA Globcom.

Early in the operations of international radio communications, an agreement was reached with AT&T, whereby they would be concerned primarily with voice communications and RCA Globcom would provide record communications services (i.e., communications in printed or graphic form). Hence, today, RCA Globcom is designated as an international record carrier.

Developments in the communications art

Internationally, radio communications were conducted using frequencies in the VLF region — in the order of 20kHz-generated first by spark and arc transmitters and then by Alexanderson alternators. In the early 1920's, high frequency transmission was demonstrated to be highly efficient and reliable if used correctly. A period of intensive development ensued which lasted until about the mid-1960's, and HF transmission evolved into systems of extremely high efficiency and reliability. This came about with innovations in the use of frequency and space diversity receiving systems and the selection of optimum frequencies of transmission for different seasons of the year and hours of the day. Development of highly directive antennas and multitone, single-sideband (SSB) transmission permitted the operation of circuits with a minimum of transmitter power consistent with reliable signal reception.

Operations began with manual Morse transmission, and in 1947 had progressed to printing telegraph or "teletype" to a great extent. With the development of the 7-unit Moore code, received-error detection became feasible, which ultimately resulted in the automatic-error detection and correction systems known as ARQ. This, in practice was combined with the recently-developed time-division-multiplex (TDM) systems. The combination, designated MUX-ARQ, was a cooperative development between the Netherlands PT&T and RCA Globcom; it permitted an error-free copy to be produced by machine methods for the first time. Due mainly to this development, telex service was inaugurated by RCA Globcom.

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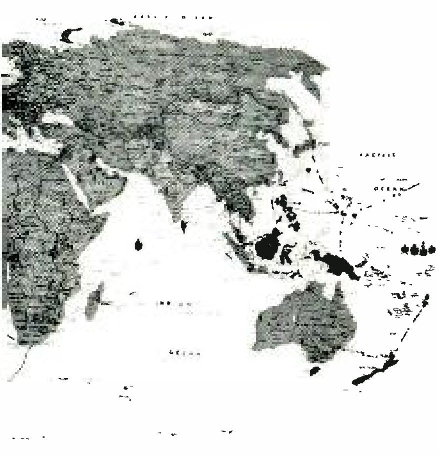

As RCA Globcom's overseas telegram and telex services expanded, it soon became apparent that manual methods of handling message telegrams and manual operation of telex switching were not the best from either service or economic viewpoints, and computer-controlled methods were introduced. This has resulted in a dramatic reduction of cross-office routing (previously about 20 minutes, now a few seconds) for transient international message telegrams, and a remarkable reduction in the time required for a telex subscriber to reach his called party.

Initially, the radio operators performed their functions at the radio receiving stations and controlled the transmitters at the transmitting stations by means of telegraph wire lines, using direct-current methods. Shortly thereafter, it was found more suitable to have the operators at a central office in the city, and have them connected to the receiving and transmitting stations by the same sort of wirelines. With the growth in the number of circuits being operated by RCA Globcom, it became more economical to utilize each such line for more than one signal, i.e., multiplexing. Various systems of relays, well-known in the telegraph industry, were used for this purpose, but the desired degree of multiplexing was still not possible. However, by adaptation of tone- or frequency-division multiplexing (FDM) means, the number of signals on one line was increased to as many as fifteen. These improvements were initiated in the early 1930's, and were followed in the mid-1930's by an ultra-high-frequency system between RCA Globcom's New York and Philadelphia offices, with a drop-off for transmitter control at the New Brunswick transmitting station. Effectively, this system replaced a wire line in each direction. In 1953/1954, a microwave system, having a capacity of 24 voice-grade channels, was designed and installed, serving RCA Globcom's New York central office, the Rocky Point transmitting station, and the Riverhead receiving station. In the late 1950's, frequency-shift modulation techniques were introduced on these channels. This improvement permitted up to 24 telegraph signals on each of the voice-grade channels.

In late 1959, equipments and systems were devised to take advantage of the recently installed TAT-1 submarine telephone cable across the Atlantic Ocean, and commercial operations started over this transmission medium in early 1960. The techniques and experience gained from the multiplexing of wirelines and microwave channels were used for this development.

With the launching of Telstar and Early Bird satellites during the early 1960's, experiments and evaluations demonstrated the feasibility of this new transmission medium for communications usage. Again prior techniques were applied and extended, and in the mid-1960's communications satellites became another means of transmission used by RCA Globcom.

Globcom operations today

From what had started out years ago as a

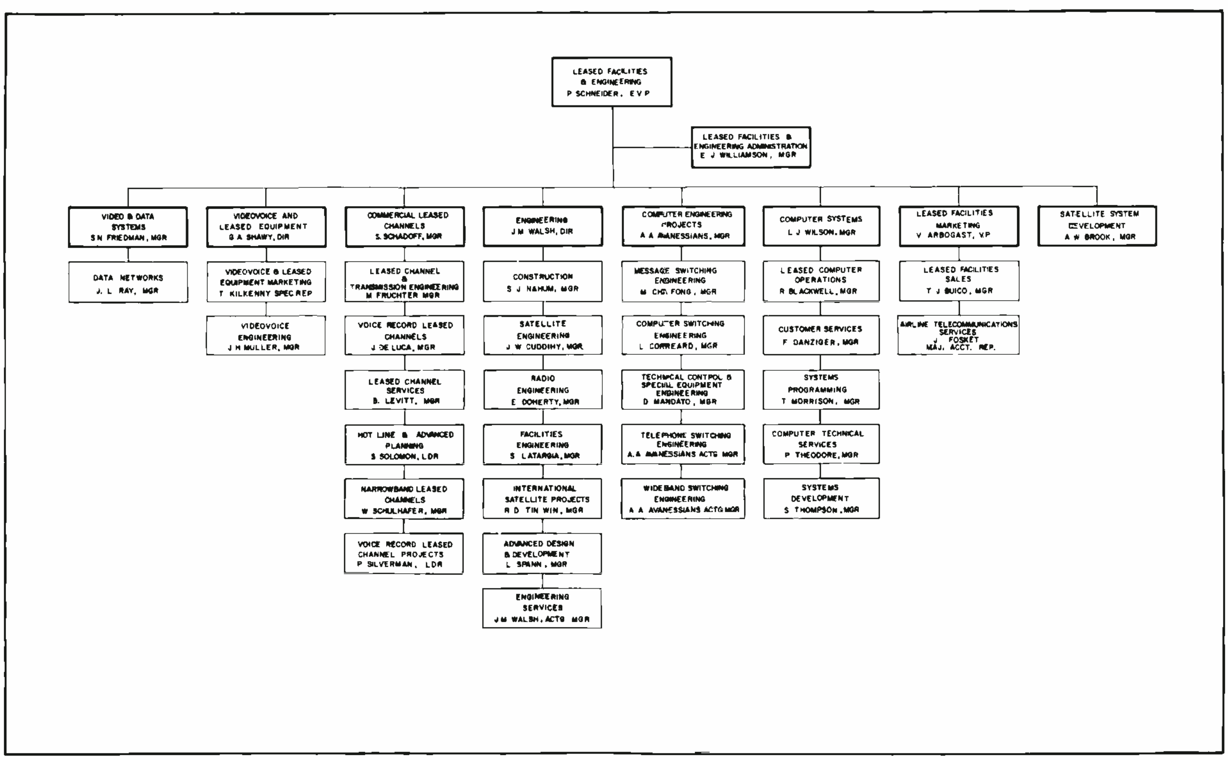

Fig. 1 — RCA Global Communication's leased facilities and engineering organization (3/31/73).

Fig. 2 — Testing six-channel level variations to drop-out recorder prototype.

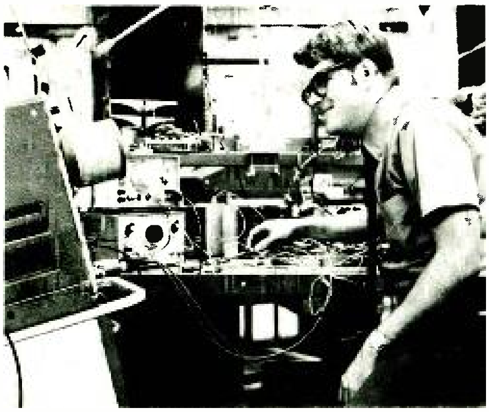

Fig. 3 — Proving a circuit paper design.

Fig 4 — Adjusting VideoVoice terminal prototype.

Fig. 5 — Investigating analytic router performance.

small "wireless" company with a few very low-frequency circuits, RCA Globcom today operates thousands of circuits over the entire globe using radio, submarine cables, communications satellites and terrestrial networks. In addition to its overseas telegram and telex services, it also operates full-time leased channels to subscribers having sufficient volume of traffic to warrant such service. These leased channels run the gamut from a 16-word/minute teletype channel to a 9600 bit/s data channel; from a single type of transmission to a multiple-use transmission. These three services account for the greater portion of RCA Globcom's revenue. Services contributing their share to the remaining revenue are:

Datel — a voice coordinated data transmission service on a call-up basis;

TV transmission — a service to provide the TV networks with transmission facilities for rebroadcast of overseas TV programs and events;

PIX — a facsimile service for news media and industry;

PTS — a facility to supply the broadcast networks with programs originating from overseas points;

Executive hot line — a leased, call-up service with data and voice capability effectively providing private-line facilities to subscribers and their overseas offices; the system concentrates many subscribers into a few overseas trunks and requires no dialing or ringing on the part of the subscriber;

Marine — a ship-to-shore service for ocean-going vessels;

Aircon — an information utility service used for airlines reservation services, industrial inventory services, highway transport despatching, and other organizations requiring switching or data storage and retrieval; and

Videovoice — a new picture transmission service that provides simultaneous voice record service

The foregoing developments, and others too numerous to mention, have all been products of RCA Globcom's Engineering Department.

Engineering department

In early June 1972, the organization structure of RCA Globcom was reorganized from the existing classical organization to the more modern one of profit centres. One of the three profit centres is the Leased Facilities & Engineering Department. Carrying out the profit centre theme, this new Department is organized in a similar manner with five profit centres, each completely responsible for its own P&L. In the new organization, there are three support Divisions, viz. Leased Facilities Marketing, Engineering and Computer Engineering Projects (see Fig. 1). These latter two comprise the bulk of the engineering effort in the Department. It can be seen from Fig. 1 that there is also a certain amount of engineering activity in each of the profit centre Divisions.

While each division operates in a particular field of effort, there is a considerable amount of lateral coordination. This results in a significant degree of cross-fertilization, with ensuing technical benefits across the entire Department.

A significant amount of engineering activities are also conducted by several groups in the Operations Department. Such efforts are those day-to-day requirements needed by the actual operating areas, plus that engineering required for the installation work needed to keep the operating plant abreast of our ever-increasing traffic demands. Normally, such engineering implements normal or standard arrangements. However, for newer types of services, equipments, and systems, support is provided by the Engineering Department. Engineering also supports Operations in the solutions and remedies of extraordinary operating difficulties and problems. Again, cross-fertilization results from the close rapport maintained between Operations and Engineering.

Inputs to Engineering come from many external sources, as well as from within. Such inputs may be requests from Operations for newer types of facilities or systems; from Marketing for newer services to be offered to, or requested by, the subscribers; from RCA Globcom management for proposals for such things as RCA Alaska Communications, Inc., and the Domestic Communications Satellite System; from other international record carriers, U.S. and foreign, for collaboration on topics of mutual interest.

The activities of Engineering, of course, require laboratories facilities, instrumen-

Fig. 6 — Solid-state customer control unit development.

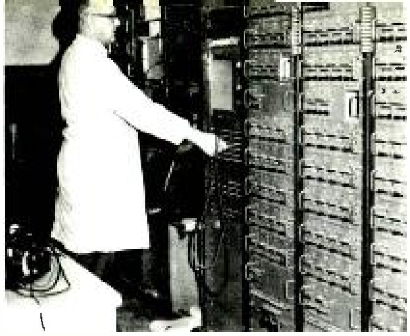

Fig. 7 — Monitoring performance of frequency division cable multiplexer.

tation, prototype fabrication provisions, etc., to determine technical parameters, assist Operations, and prove out new designs. Figs. 2 through 5 show some of the facilities provided for the engineers in performing these tasks.

Research and development

In addition to the investigation of techniques and hardware to augment and improve RCA Globcom's operations in the international message, telex, and leased channel services, Engineering is currently engaged in efforts in other major fields.

Automation

Processor-controlled automation is one such field. Prime existing examples of this field, already in operation, are the Computer Telex Exchange, The Computer Telegraph System and the Automatic Information and Retrieval Computer Operated Network (AIRCON). These are all primarily switching systems with data storage and retrieval capabilities.

In the same field, but in another category, efforts are being expended in the direction of automating, by computer means, as much of the technical operations as possible. In this category, plans, studies, and proposals are being formulated-under the general heading of Automated Technical Control to implement systems to monitor automatically and continuously all circuits and facilities to detect degradation, alarm failures, diagnose and analyze faults and impairments, issue reports of such impairments and analysis, maintain operating information, indicate corrective action to be taken and digest all such derived information to provide statistical analysis of the operations to indicate reliability, outages, usage of facilities, system weaknesses, and similar information.

Satellite Communications

In the field of communications satellites, Engineering has planned, designed and proposed a Domestic Communications Satellite System to be procured, installed and operated jointly by RCA Globcom and RCA Alaska Communications, Inc. encompassing all of the United States including Alaska, Hawaii and Puerto Rico. The proposal has been submitted to the Federal Communications Commission and its approval is being awaited. Internationally, RCA Globcom has planned, proposed and constructed satellite earth stations including the existing station in Guam which is operated by RCA Globcom.

Alascom

Engineering is currently and actively engaged in assisting in the expansion of facilities of RCA Alascom. This encompasses complete direct-distance dialing, the extension of communications facilities to bush communities, the provision of additional trunks by microwave, the institution of trunks by microwave, the institution of TV educational services via satellite, and the provision of microwave communications service for the proposed oil pipeline from the North Slope.

Videovoice

Although the pangs of birth for our Videovoice terminals are still vivid in our memories, a concerted effort is under way to improve and enhance the terminals to increase their potential uses and, hence, their marketability.

The future

Much of the work of Engineering in the future is already being influenced by current efforts and accomplishments. A great deal of these efforts will be directed toward automation, especially that which can be processor-controlled. This, of course, is dictated by the growing need to reduce operating expenses and increase the productivity of the operating personnel to better the margin of profit. Although medium-scale-integration techniques are being used currently, large-scale integration will be utilized in the future to reduce the costs and size, and to increase reliability. At the same time, such efforts will also be directed toward increasing the reliability of existing services and thus improve Globcom's competitive position with respect to the other international record carriers.

Fig. 8 — Transcribing telegrams to printing perforated tape for use in computer telegraph system.

Fig. 9 — Checking out VideoVoice prototypes.

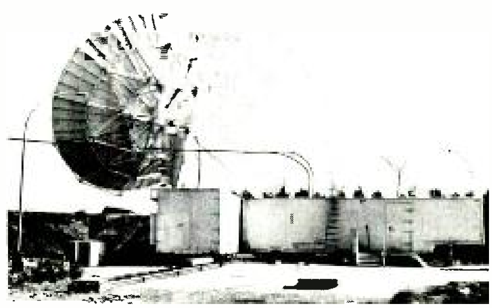

Fig. 10 — Transportable satellite earth station Shanghai, China.

Fig. 11 — AIRCON San Francisco, the third RCA Global Communications, Inc. computerized messages switching center, was inaugurated on April 18, 1972 at the company's facilities in the West Coast city. The AIRCONS are common-access computerized clearing houses that direct information flow for private communications networks. The heart of the newest center consists of three computers, each capable of accepting teleprinter transmission speeds of 66, 75 and 100 words a minute and speeds as high as 2400 baud to carry data.

Electroless plating in the electronics industry

Dr. N. Feldstein

During the last decade, electroless plating processes in the electronics industry have gained increased acceptance, due to the unique properties and capabilities attainable by such metallization techniques. In several applications electroless plating has provided a combination of improved processes, reliability, and cost savings.

ELECTROLYTIC PLATING is an old technology, but electroless plating is relatively new and its commercial significance and impact were realized only during the last decade. By contrast to electrolytic plating, no external power supplies are required with this metallization technique. Electroless plating may best be defined as an autocatalytic chemical reduction of metals or alloys taking place at heterogeneous interfaces. Plating thickness is generally proportional to immersion time. Although the process is also known as chemical plating, it should be distinguished from chemical plating processes in which a direct displacement of an active metal takes place by noble metal ions present in solution.

Although electroless plating is more expensive than electrolytic plating, the increased interest in this technique is warranted by some known advantages over electrolytic plating (electrodeposition):

1) Excellent uniformity of plating, independent of the size and shape of the object.
2) Plating may take place upon dielectric substrates (*e.g.*, plastic, glass, ceramic, photoresist etc) semiconductors, and metals.
3) The deposits are generally more dense and hence they provide improved corrosion-resistance properties at a reduced thickness.
4) Power supplies and electrical contacts are not needed. This is especially significant whenever complex parts are to be plated or with parts in which isolated elements are to be metallized.
5) Some of the deposits have unique chemical, mechanical and magnetic properties.
6) Selective plating[1] may be carried out. In so doing, etch-back procedures are eliminated.

Electroless plating formulations

It should be noted that all electroless plating formulations are thermodynamically metastable and thus greater care in technique and chemical specification is required. Examination of typical bath formulations would reveal the basic compoenents listed in Table I, along with several additives which are generally proprietary.

To date, there are only a limited number of metals that can be successfully deposited from electroless plating baths (Table II lists the basic metals). In general, such solutions are prepared in aqueous media. It should be noted that depending on the choice of the reducing agent used, different alloys may be deposited. However, there are a far greater number of alloys (containing iron, tungsten, zinc, molybdenum, vanadium, ruthenium,etc.) that can be deposited from suitably prepared baths.

In the deposition of nickel and cobalt, the ability of direct initiation depends upon the substrates as well as the reducing

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agent used. In general, using the amineborane derivatives, direct initiation may be carried out onto nickel, cobalt, iron, palladium, rhodium, copper, silver, gold, chromium, titanium, tungsten, molybdenum and aluminum. By contrast, using hypophosphite as the reducing agent provides a direct initiation onto a more limited group of metals, *i.e.*, nickel, cobalt, iron, palladium and rhodium. In the case of aluminum, a zincating process is required prior to the electroless nickel (*Ni-P*) metallization. In the electroless deposition of the more noble metals (copper, palladium, gold, and silver), direct plating can be carried out on a wide variety of metals and their alloys. The initiation may be due to either the autocatalytic process or to an initial replacement reaction of the noble-metal ions with the base metal substrate.

Table III provides several plating compositions of some of the above metals along with plating conditions and reported deposition rates. The choice of these specific examples was made arbitrarily with no thought to any specific application.

Electroless nickel plating

Of the various metals and alloys that can be deposited electrolessly, the use of commercial electroless *Ni-P* is the greatest in volume. The use of electroless copper is gaining acceptance because newer baths with improved stability are being developed, and because of the greater penetration of additive printed circuitry processing. The reasons for the wide acceptance of electroless nickel plating may be understood through reviewing some of its physical characteristics.[6-8]

Porosity and corrosion resistance

Electroless nickel deposits tend to have unusually low porosity compared to electrodeposits. A half-mil deposit of electroless nickel on smooth semi-bright steel provides considerably better corrosion protection than one mil of electrodeposited nickel. There is a considerable variation in corrosion resistance for electroless deposits depending upon the percent of phosphorus and the porosity. There appears to be a greater tendency for pitting of deposits obtained from alkaline solutions than from acid solutions, the latter having a lower percent phosphorus. Wetting agents are beneficial in preventing pitted deposits. The equivalent corrosion resistance at recessed areas with electrodeposited nickel would have been virtually impossible without excessive build-up at exposed areas.

The resistance of electroless nickel (*Ni-P*) to chemical attack is usually superior to that of electrodeposited nickel and is even further improved by an inert-atmosphere heat treatment at 750°C. Electroless nickel has found wide application for coating steel where low corrosion rates are normally encountered but iron contamination and commodity discoloration results without the protective deposit.

Hardness and wear resistance

As deposited, (*Ni—P*) electroless nickel has a hardness of over 500 Vickers Hardness Number (VHN) (kg/mm^2) which is considerably harder than conventional electrodeposited nickel. In addition, by heat treatment at 400°C, the hardness is increased to over 900 VHN which approximates the hardness of chromium deposits. The hardness of as-plated and heat-treated electroless nickel is dependent upon the phosphorus content of deposits. While heat treatment at 400°C requires a protective atmosphere, high hardness may be achieved in an ordinary furnace, without protective atmosphere, at about 280°C for 15 to 20 hrs. The wear resistance of electroless nickel reaches a maximum level by heat treatment at about 400°C and is improved with increasing phosphorus content. The ductility of as-plated electroless nickel increases with phos-

Table I — Typical make-up of electroless plating baths.

Component	*Function*	*Example*
Metallic salt	To provide metallic ions for deposition	Nickel sulfate
Complexing agent	To complex metallic ions and thus prevent precipitation	sodium citrate
Reducing agent	To provide the reducing power for the bath	sodium hypophosphite
pH adjuster	Adjust solution for best performance	sodium hydroxide
Stabilizer	To minimize the homogeneous precipitation of electroless formulations	thiourea

Table II — Types of baths reported.

Deposit	*Reducing agent*	*Remarks*
Ni-P	Sodium hypophosphite	2 to 17% by wt. of phosphorus reported; baths are acidic or alkaline
Ni	Hydrazine or borohydrides	Alkaline bath free of codeposits
Ni-B	Dimethylamine borane and similar compounds	0.5 to 5% by wt. of boron; bath operates over a wide pH range-acidic to basic
Cu	Formaldehyde	All baths are alkaline
Co-P	Sodium hypophosphite	Alkaline media only
Co-B	Dimethylamine borane	Both acidic and alkaline
Pd	Sodium hypophosphite	Alkaline
Au	Borohydride salts and dimethylamine borane	Alkaline
Ag	Formaldehyde, hydrazine	Alkaline

Table III — Plating compositions, electroless Ni-P deposition.

Bath constituents	*Concentrations (g/l)*
Bath #1[2]	
Nickel chloride (6H$_2$0)	26
Sodium hypophosphite (H$_2$0)	24
Lactic acid	27
Propionic acid	2.2
Succinic acid	7
Lead ion	0.002
pH	4.6
Temperature (°C)	90 to 100
Approx. desposition rate (mil/hr)	0.8
Bath #2[3]	
Nickel chloride (6H$_2$0)	20
Sodium hypophosphite (H$_2$0)	20
Sodium citrate (2H$_2$0)	10
Ammonium chloride	35
pH	9 to 10
Temperature, (°C)	85
Approx. deposition rate (mil/hr)	0.7
Bath #3[4]	
Nickel sulfate (6H$_2$0)	25
Sodium pyrophosphate (10H$_2$0)	50
Ammonium hydroxide (58%)	25 cc/l
Dimethylamineborane	1.5
pH	10.1
Temperature (°C)	25
Approx. rate (mil/hr)	0.1
Bath #4[5]	
Copper sulfate (5H$_2$0)	7.5
Sodium hydroxide	5.0
Formaldehyde (37%)	2.5
Sodium potassium tartrate	12.0
Methyl butynol (ppm)	25 to 150
pH	10 to 14

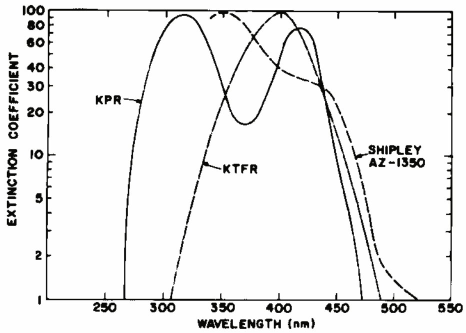


Fig. 1 — Spectral sensitivities of commonly-used resists.

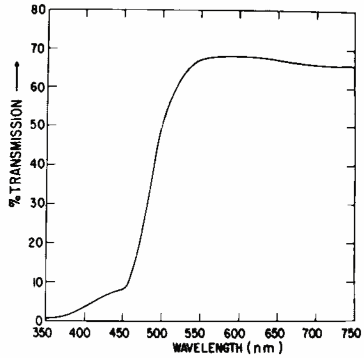


Fig. 2 — Transmission spectra of typical film.

phorus content with greatest increase at about 6.5 to 7.5% phosphorus.

Adhesion

The adhesion of electroless nickel is generally pH-dependent, and is superior when acidic media are used for deposition. Electroless nickel also adheres well to copper alloys, nickel, or cobalt. Electroless nickel has been applied to stainless steels, aluminum and titanium to provide resistance to wear, abrasion, and friction. Adhesion of electroless nickel to these metals, as plated, is relatively inferior, but may be greatly improved by heat treating at 200°C for aluminum or stainless steel, and at 400°C for titanium. Well-adherant deposits have been applied to zincated aluminum from alkaline electroless nickel plating solutions.

Magnetic properties

Electroless nickel deposits from acid solutions are usually non-magnetic owing to the high phosphorus content. Deposits from alkaline solutions (lower phosphorus content) are usually somewhat magnetic but considerably less so than pure nickel. Heat treatment generally increases the magnetic properties of nickel-phosphorus deposits.

Other properties

Properties of electroless nickel containing 8 to 10% phosphorus are:

Property	*Ni-P*	*Pure Ni*
Specific gravity	7.9	8.9
Melting point (°C)	890	1450
Electrical resistance ($\mu\Omega$ cm/cm²)	60 to 75	10
Thermal conductivity (cal/cm s °C)	0.01	0.216
Coeff. of thermal exp. (cm/cm °C)	13×10^{-6}	13×10^{-6}

Fabrication of semitransparent photomasks by electroless plating

In the manufacture of electronic parts, photomasks are widely used to define images on photosensitive materials. In manufacturing semiconductor devices, two main types of opaque photomasks are used:

1) Photographic emulsion on glass (silver in gelatin), and
2) Chromium film on glass.

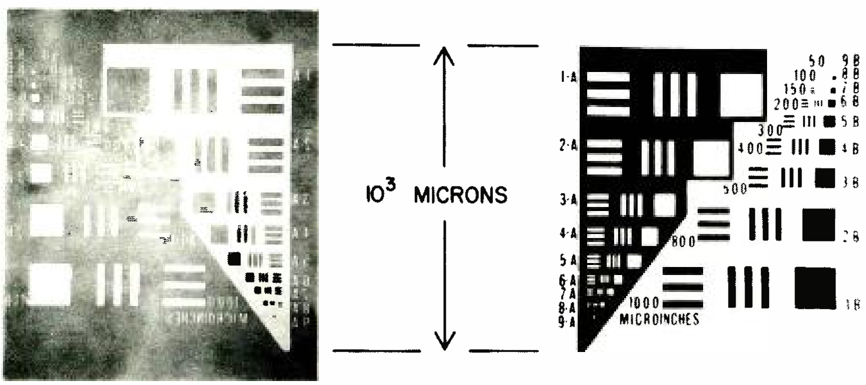
Due to their opaqueness at the sodium-D line (589 nm), registration of opaque masks with existing patterns is difficult. In overcoming this difficulty, semitransparent masks had to be devised to provide the following characteristics:

1) The film should have virtually zero transmission in the region below 450 nm. This region corresponds to the spectral range in which most commercial resists are sensitive (see Fig. 1).
2) For the purpose of alignment, the film should be at least 30% transmitting in the 589-nm region.
3) The deposited film should be readily etchable in solvents that are compatible with commercial photoresists.
4) The deposited film should be abrasion resistant to ensure faithful transfer of the image on a repeated basis.

In recent publications,[9-14] several materials and deposition techniques have been described for fabrication of semitransparent masks. Of the various metallic oxides, the use of iron oxide seemed to have gained acceptance in the industry. Such films are deposited by either chemical vapor deposition or by sputtering techniques. Such films are durable and they meet the optical requirements mentioned above.

Recently it has been demonstrated[15,16] that thin semitransparent films can be deposited from "electroless" copper baths. Prior to the electroless plating step, the glass substrates are cleaned, sensitized, and activated in a procedure similar to the plating onto dielectric substrates.[17]

Fig. 2 shows the spectral response of the current films in the visible and u.v. ranges. Analytical characterization has revealed that the films are predominantly cuprous oxide. It was also found that good edge definition was obtained using dilute hydrochloric acid or ammonium

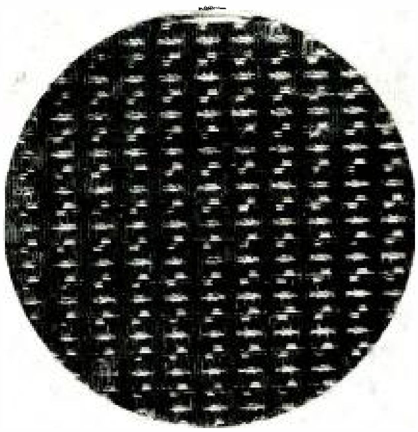


SEMITRANSPARENT MASK

EXPOSED AND DEVELOPED POSITIVE RESIST

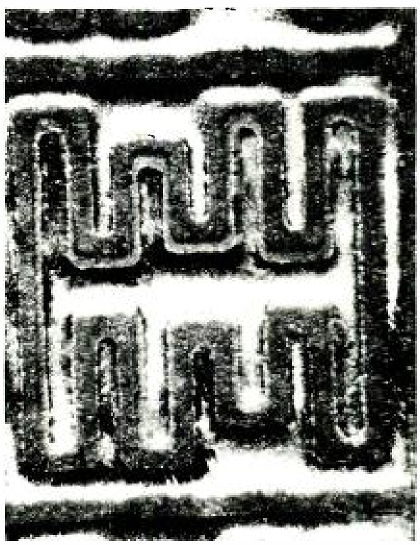
Fig. 3 — Unit pattern of Qualitron test mask.

hydroxide in delineating a desired pattern in the semitransparent film. Fig. 3 shows a delineated test pattern in the semitransparent film and a resist pattern (positive resist) exposed using the current film. As seen, the optical characteristics of the cuprous-oxide films meet the optical requirements of positive commercially available resist. It was also found that by a suitable heat-treatment schedule, the durability of the current masks is greatly improved, providing increased durability compared to emulsion-type masks, but less durable in comparison to iron oxide films. The main advantage of the present chemical plating approach is its potential low cost.



A) View of an entire wafer.

B) View of a single device.



4. — 2N-3055 silicon power devices after solder dip.

Plating of semiconductor devices and packaging

During the last decade, a wide variety of silicon transistors have been introduced commercially in which contact to the clips is made via soft solders. Since direct soldering to silicon has been unsuccessful, intermediate metallization layer(s) must be used. The intermediate layer(s) must meet certain requirements:

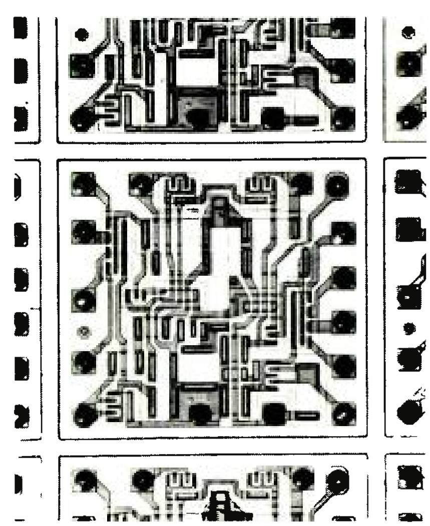
1) The layer must provide good contact to both n- or p- type silicon;
2) The surface must have good adhesion;
3) The metal must be solderable; and
4) The metal-solder interface must be "inert" without the formation of brittle intermetallics during device life.

The use of electroless nickel plating was recognized as a practical approach because the method is of lower cost in comparison to the formation of contacts made by gold-aluminum thermocompression bonding. Sullivan, *et al.*,[18] have investigated the resulting ohmic contact of *Ni-P* deposited onto silicon subtrates. In the reported work,[18] a Brenner type electroless bath[19] was used employing sodium hypophosphite as the reducing agent. It should, however, be noted that at present there are a wide variety of electroless nickel compositions available providing deposits in which the percent phosphorus may be altered deposits having varied boron content, as well as deposits which are virtually pure nickel. Hence, it should be recognized that through the proper choice of an electroless plating bath, improved properties could be obtained, depending upon the specific device used. From the results of Sullivan, *et al.*,[18] it has been demonstrated that, following heat treatment above 600°C, contacts were ohmic and rectifying on n-type and p-type silicon substrates, respectively. Moreover, it was found that for deep (about 1-mil) diffused n- or p-type layers, the resulting contacts were ohmic after heat treatment in the range of 100° to 800°C. It was also demonstrated that for a given surface roughness, an optimum plate thickness should be used for achieving best adhesion. In contrast to the work of Sullivan, *et al.*,[18] Iwasa, *et al.*,[20] studied the deposition of electroless *Ni-P* across p-n junctions, with special emphasis to the nonuniformity in plating across the junction. This undesired effect is due to the photovoltaic effect with light illumination. To overcome this inherent problem, the authors demonstrated that through changes in the nickel complex(es) in solution, conditions may be achieved leading to the uniform plating across the junction. In Fig. 4, 2N3055 power transistor devices are shown after the nickel and solder dipping step.

In the contact formation to III-V compound semiconductors, Peterson[21] described a procedure applicable to gallium-arsenide while Daw, *et al.*,[22] described different pretreatment procedures applicable to the specific III-V compounds. More recently, it was verified[23] that good ohmic contacts could be made to n-*GaAs* using a room temperature electroless *Ni-B* bath without the need for surface activation.

With the continued effort to reduce the costs of packaging and bonding of semiconductor devices, the use of flip-chips for face-down bonding is an accepted method. This approach is especially attractive with advances made in thick-film technology. Fig. 5 shows an array of integrated circuits with solder bumps using tungsten metallization[24,25] Using selective electroless plating, the tungsten pads are metallized with a solderable metal. The deposition of electroless nickel alloys or copper was found to be adequate. Also, discrete flip-chip devices using aluminum metallization, electroless nickel, and solder bumps are used in circuit modules for color tv sets, and have been described previously.[27]

Although the cost of gold has increased appreciably in recent years, because of its superior physical and chemical properties, there are still many applications in the electronics industry in which this metal is specified.



5. — Array of metallized integrated circuits with solder bumps for face-down bonding.

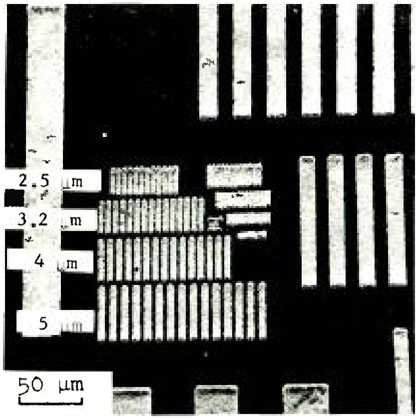


Fig. 6 — Resolution capabilities of 2 micrometers-thick gold plating. (dimensions indicated are before plating.)

Commercially, there are several proprietary electroless gold solutions sold; however, they have several limitations as to the choice of substrate used, and maximum thickness of electroless gold plated. Okinaka and coworkers[27-30] reported a new bath comprised of:

$KAu(CN)_2$	0.003 M
KCN	0.1 M
KOH	0.2 M
KBH_4	0.2 M

The bath is operated at about 70°C, with a plating rate of about 6μm/hr. Deposition from this bath can be made directly on a wide variety of substrates (*e.g., Au, Pd, Cu, Rh, Pt, Cu-Be, Cu-Zn* and *Pd-Ti*) with good line resolution and thickness uniformity. Using this new bath, electroless gold beam leads on silicon integrated circuits have been successfully fabricated. Table IV describes some of the properties of the deposited gold.[30]

Fig. 6 shows the line resolution capabilities for a 2-μm thickness at different initial line width and spacings.

In the packaging of semiconductor devices, many of the TO-5 and TO-3 packages are electrolessly nickel plated to provide solderability, weldability, and corrosion protection. In addition, in many of the ceramic flat-packs in which moly-manganese conductor patterns are employed, electroless nickel deposition provides good brazing quality. Due to the fine geometries and recesses in such packages, electrolytic plating is virtually impossible.

Table IV — Deposit properties.

Adhesion	Excellent on metals
Appearance	Mat yellow
Density	Bulk gold (19.3 g cm³)
Hardness	Soft (Knoop 60-80)
Porosity	~ Zero for deposits >1 μm on uniform substrates
Purity	>99.9%, ~ 0.0001% B
Resistivity	Bulk gold (<0.33 Ω. sq. at 1 μm)
I C bondability	Excellent

In another application,[31,32] electroless nickel (*Ni-P*) films were deposited upon a ceramic base for resistor application. The deposited films had a relatively small temperature coefficient of resistance. Stabilization of the film resistance was achieved by a heat-treatment schedule in the range of 150 to 250°C. It has also been demonstrated[33] that ternary alloys of nickel show a great thermal stability as deposited in comparison to the binary type (*Ni-P*) alloys.

Printed-circuit fabrication

Manufacturing printed-circuit arrays is a well accepted technique by which components are interconnected on solid or flexible type substrates. In most cases, copper conductor patterns are used, regardless of the method by which the patterns are formed. At present, there are two fundamental methods[34-38] by which the conductor patterns are formed:

1) The subtractive (etch-down) method, and
2) The additive process.

Although the former method is still widely used, additive printed circuitry is gaining wide acceptance due to potential cost savings and inherent pollution problems associated with etch-down processing.

In additive printed circuitry there are two distinguishable approaches used:

1) Semiadditive methods (Fig. 7), and
2) True additive method (Fig. 8).

In both approaches, unclad dielectric substrates are the starting point in the processing, and in both cases, surface treatments are provided for the improvement of adhesion between the metal film and the substrate. Moreover, in both cases, surface catalyzation is carried out to provide catalytic sites for the initiation of the electroless copper plating process.

In the formation of the catalytic sites (nucleating sites), two procedures are widely used:

1) Sensitization[17] (via acidic stannous chloride) followed by an activation (via acidic palladium chloride), and
2) "Colloidal" catalytic system[39] (via palladium chloride in excess acidic stannous chloride) followed by an accelerator step.

There are, however, cases in which adhesives or boards impregnated with catalytic fillers[40] are used. In such cases, the standard wet processing used to provide catalytic surface activity is eliminated. In the semiadditive process (Fig. 7), a thin copper layer of approximately 25 microinches is deposited from a suitable electroless copper bath. This deposition is carried out on the en-

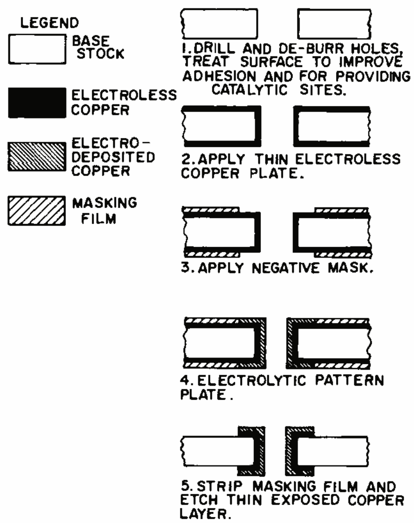


Fig. 7 — Semi-additive plated throuah-hole processing sequence.

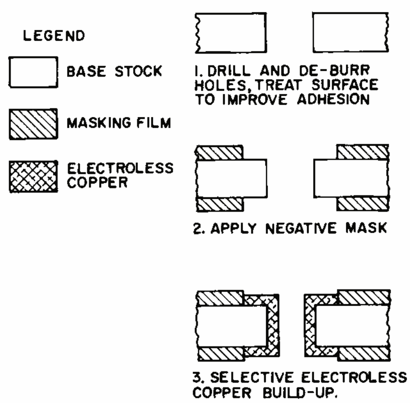


Fig. 8 — True additive plated through-hole process sequence.

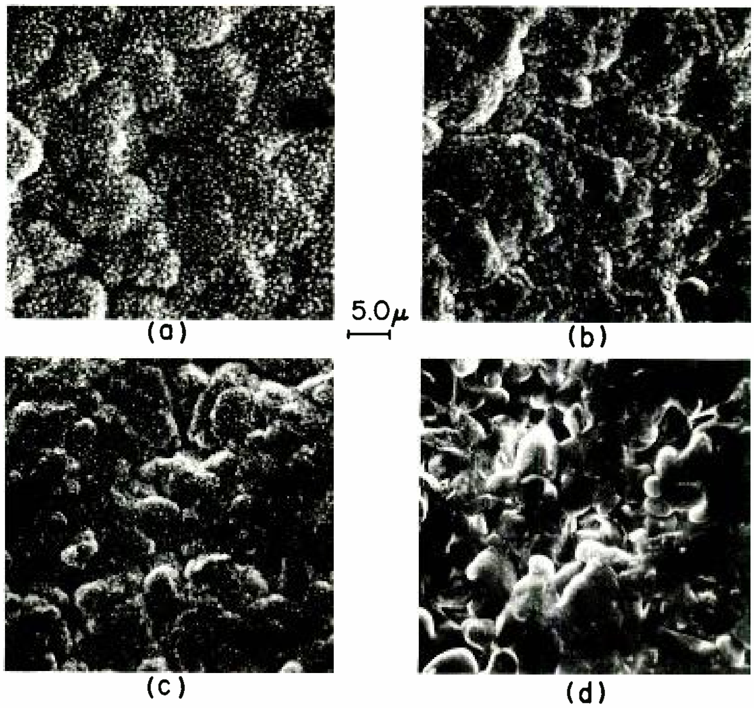


Fig. 9 — Scanning electron photomicrographs of electroless copper deposits. (compositions are according to Table IV).

tire surface. Although there are a great number of electroless copper plating formulations reported, the following requirements are generally imposed on the resulting deposits.

1) The copper deposit must have good adherence to the substrate.
2) The deposit should be dense so as to minimize the trapping of solutions which may cause corrosion or deterioration in adhesion with time and with thermal cycling.
3) The thin film should have a good surface conductivity.
4) The thin film must be durable.

It has been observed[41] that in preparing electroless copper formulations, unique combinations of additives may give rise to copper deposits having unusual physical properties. In Fig. 9, scanning electron micrographs are shown, employing a specific copper bath, however, showing different combinations by which nonionic surfactants and cyanide may be incorporated. Both the surfactants and the cyanide are used in the parts-per-million-concentration range. The general copper-bath solutions are given in Table V.

Table V — Copper bath solutions

Component	*Bath A*	*Bath B*	*Bath C*	*Bath D*
Copper Salt	X	X	X	X
Chelating Agent	X	X	X	X
Sodium Hydroxide	X	X	X	X
Formaldehyde	X	X	X	X
Sodium Cyanide	—	X	-	X
Nonionic Surfactant	—	-	X	X

Visual examination and comparison of the micrographs reveal that the deposits resulting from bath D are generally brighter, less porous, of greater conductivity and are less prone to surface staining than the other formulations. It is also interesting to note that the substitution of the nonionic surfactants in bath D with either cationic or anionic surfactants does not lead to the same improved results.

Fig. 8 shows the basic processing sequence used in the truly additive process. The deposited copper-conductor patterns are generally 1 to 2 mils thick. Although the requirements of the copper deposits are similar to those imposed from the semiadditive process, there are further practical limitations imposed in this case:

- The plating cycle for the copper deposition must be reasonable and of approximately a few hours.
- Electroless bath used for this entire build-up must show good stability.
- The good mechanical and physical properties (ductility, resistivity stress, solderability, thermal cycling, etc.) for the deposits must be obtained.

At the present state of the art, the above practical limitations are not met completely and hence the use of a truly additive process has not yet gained wide acceptance. However, due to the greater simplicity of such a process and the elimination of electrolytic plating, several developments[42,43] are being made toward this objective. Most probably the developments of the next few years will pave the way for practical additive processing.

Processes for color kinescope fabrication

In a continued effort to improve the performance of color picture tubes, color tv manufacturers are engaged in research and development of new methods by which improvements in brightness, contrast, and resolution are achieved. As shown in Fig. 10, the size relation between an aperture in a shadow mask—hence a column of electrons— and a corresponding phosphor dot may be altered. In a new generation of shadow-mask color tubes, the electron-beam diameter is greater than the phosphor diameter, while in previous tubes, the opposite geometrical relationship was maintained. In this configuration, the entire area of phosphor dot is excited by the electron beam, insuring maximum light output for the phosphor area present in the tube. Furthermore, in such a configuration, a slight displacement of the electron beam with respect to the

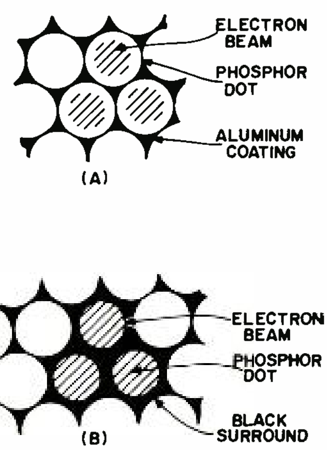


Fig. 10 — Approaches in color kinescope fabrication: A) previous — large phosphor dot, smaller electron beam; B) new — large electron beam, smaller phosphor dot.

stationary phosphor dot will still insure the complete utilization of the phosphor dot. Another favorable aspect of this configuration is its light-absorbing (black "matrix") characteristics. The matrix may cover 50% and more of the faceplate surface area and absorbs much of the incident room light so that loss of contrast is minimized. The opaque black material also absorbs light "splash" or scatter from adjacent phosphor dots, resulting in improved picture detail.

In color-tube fabrication, the shadow mask is employed initially as the "photomask" in the photolithographic definition of the phosphor dots on the faceplate. The phosphor material is deposited from a slurry composition of a water soluble photoresist such as polyvinyl alcohol with ammonium dichromate as the sensitizer.

Due to the dual function served by the shadow mask, *i.e.*, in printing the phosphor groups (red, blue and green) and in final use, it is apparent that the aperture holes in the shadow mask must provide small openings for the electron beam in final use.

Techniques have been developed and two patents have been issued on processes intended to provide a means for 1) temporary partial closure of the shadow mask aperture holes and 2) matrix formation.

Temporary reduction in aperture-mask hole size

Fig. 11 shows the highlights of the steps involved in a process developed[44-45] for producing a shadow mask with temporary partial closure. The shadow mask is shown in a cross-sectional view; relative dimensions in Fig. 11 do not correspond to actual dimensions.

Following a precleaning procedure, one side of the steel is allowed to come in contact with an acidic palladium chloride solution. Because of the relative positions of palladium and iron in the electromotive series, a direct replacement reaction takes place.

$$Fe + Pd^{+2} \rightarrow Fe^{+2} + Pd$$

Following this step, a standard water-soluble photoresist is deposited as shown in step #2. Following the exposure and development of the resist, a mild baking

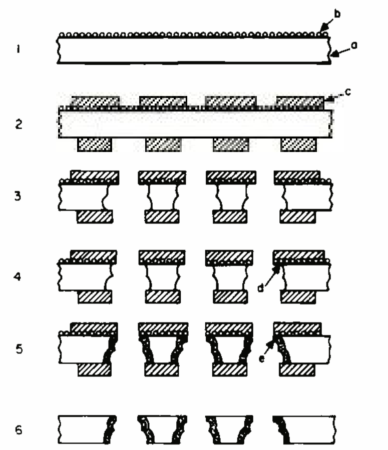


Fig. 11 — Process for the partial temporary closure of aperture mask holes: a) cold rolled steel; b) catalytic layer; c) photoresist; d) electrolessly deposited film; e) composite mettalic structure after build-up.

step is carried out to improve the durability of the resist in the subsequent etching step. By the proper control of etchant composition (*e.g.*, $FeCl_3$, HCl) and pressure, the aperture holes are chemically milled. After the etching step, it was found that sufficient catalytic activity was present below the photoresist overhang to initiate the electroless plating process. In a typical case, the photoresist overhang was about 2.5 mils-long with a thickness of about 0.05 mils. Subsequent steps closely resemble the common steps used in plating of plastic parts. Specifically, electroless plating followed by electrolytic build-up is carried out.

Following the electrolytic build-up, the photoresist film is removed in peroxide solution and the mask is heat treated at about 900°C to reduce its hardness, thereby facilitating the forming operation required. At this stage, the mask is used for the deposition of the arrays of phosphor groups. At the conclusion of the screening operation, the temporarily reduced closure (the metallic overhang) is removed by either electrochemical or chemical etching techniques, thereby enlarging the aperture holes. It is in this final configuration that the mask is inserted and used in the tv kinescopes. The main advantage of the current process is that the initial artwork used in defining the photoresist film also provides the extension for the temporary partial closure.

Black matrix formation

As stated previously, one of the major advantages of the electroless plating technique is its ability for selective deposition. Using this capability followed by a chemical conversion step, a process for the black matrix formation was developed.[46] Fig. 12 shows the highlights of the process.

A cross-sectional view of the faceplate at various stages of this process is shown in Fig. 12. In step 1, following a sensitization and activation of the glass, palladium "nuclei" are present which are capable of electroless plating initiation. Following this step, the phosphor dots are printed in the usual manner (step #2). At this stage, the availability of the catalyst between the phosphor dots provides the means for selective initiation of electroless plating of metals.

The metal to be deposited (step #3) must meet the following requirements:

1) The metal must not affect the efficiency of the phosphors in the completed tube.
2) The metal should be capable of undergoing a chemical conversion reaction to yield a black deposit that does not bleach during later processing steps, such as the air bake of the PVA resist.

Although several metals and alloys can be deposited electrolessly (copper, nickel, cobalt, *etc.*), the deposition of cobalt was chosen. The choice of cobalt was made because cobalt oxides are generally black-brown in color. The black color arises from oxidation of the cobalt according to the following generalized equation:

$$Co + \xrightarrow[\text{heat}]{O_2} Co_xO_y \text{ (black-brown)}$$

This anticipation is fulfilled in practice, and the brown-black color is retained. The oxidation step is compatible with the

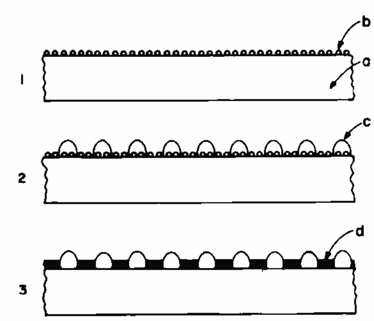


Fig. 12 — Process for black matrix formation: a) glass faceplate; b) catalytic layer; c) phosphor dots; d) metallic deposit.

standard heat-treatment sequence used in color kinescope fabrication. Although preference was given to cobalt deposition, it has been realized that copper deposition and its conversion to black sulfides may also be a suitable candidate providing no interaction with the phosphor material(s) takes place. The present process is especially significant since it does not require additional photolithographic steps[47] (or light exposures) or the possible phosphor dot contamination and thus may offer potential cost savings.

Decorative plastic parts

During the last decade, the plating of plastic parts for decorative application has become a big business. A recent survey[48] has summarized the direction of this industry. Although the greatest percentage of this technology is aimed for automotive industry, in recent years these developments were adopted by the electronics industry. Examination of the wide variety of consumer electronic products (black-and-white, tv, color tv, radios, tape recorders, phonograph players, stereo sets, etc.) shows the presence of plastic parts [acrylonitrile-butadiene-styrene (*ABS*) and polyphenylene-oxide (*PPO*)] which have been metallized primarily for cosmetic appearance. This change from vacuum metallization has taken place primarily due to cost savings.

In many respects, the procedures used in this technology are similar to those described in the fabrication of printed circuitry. Furthermore, some of the requirements stated previously are applicable here as well. In processing plated plastic parts, the following are the basic steps employed:[49-52]

1) Preconditioning to impart improved adhesion of final deposit. In this step, generally, a chemical attack is carried out to provide a microporous surface. It is the presence of such a surface that permits a mechanical interlocking of the metal and the plastics for improved adhesion.
2) Catalyzing of the surface to provide catalytic sites for the initiation of the electroless plating process.
3) Electroless plating to provide conductive surface for subsequent electrolytic buildup. Both electroless nickel and copper are used for this application.
4) Electrolytic build-up to provide durable and bright deposit. In general, a sequence of copper, nickel and chromium is carried out. Although the use of bright chromium predominates, substitution of black chromium deposits has been made.

Although plated plastic parts used in consumer electronics are not exposed to the same severe environmental conditions imposed by the automotive industry, certain requirements are imposed. Typically, the deposits must provide good adhesion with thermal cycling, without blistering or peeling, also, such deposits must be inert (not susceptible to corrosion) with routine manual handling and typical household detergents or cleaning agents.

Replication of audio and video

Although there are several ways by which audio and video recordings can be made, the formation of surface-relief patterns is one approach used. Commercially, reflief patterns may be obtained by several approaches; mechanical cutting, laser recording in photoresist materials, and recording in thermoplastic materials. It has been long recognized that for cost effectiveness, a replication process using metallic stampers should be used. The stamper is electroformed from the initial recording by a sequence of metallization steps. It is the metallic stamper that is used for the pressing of the final recordings.

Most materials used for the initial recordings are organic, and they generally do not wet readily by aqueous solutions. Moreover, these materials are temperature sensitive and thus it is highly desirable to have a replication process operating at room temperature. Fig. 13 shows the basic steps by which replication of a relief pattern was successfully

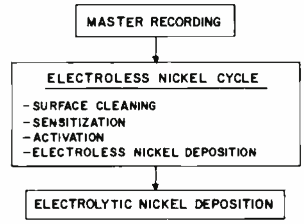


Fig. 13 — Plating sequence in the electroforming of metal masters.

achieved. In meeting the nonwetting characteristics of the smooth organic substrates, an improved sensitizer formulation has been developed,[53-56] insuring good wetting and hence faithful replication of the information. In the case of the HoloTape® replication,[57] the initial information has been recorded in a commercial positive resist. Fig. 14 shows the uniformity of metallic coverage resulting from using the improved sensitizer in comparison to commercially available solution. Following the sensitization and activation steps (Fig. 13), electroless plating was carried out providing a conductive surface for the final electrolytic build-up. A room-temperature electroless nickel bath[4] was found to be useful, insuring low processing temperatures. This surface was also found to be hard so that no deterioration in surface quality has taken place after several thousand pressings. After the electrolytic build-up, mechanical separation provides the metallic stamper. Fig. 15 shows a test pattern recorded as phase holograms at the different stages of replication. This process also is applicable to the replication of audio recording and both silver and nickel are used as the initial metallization layer.

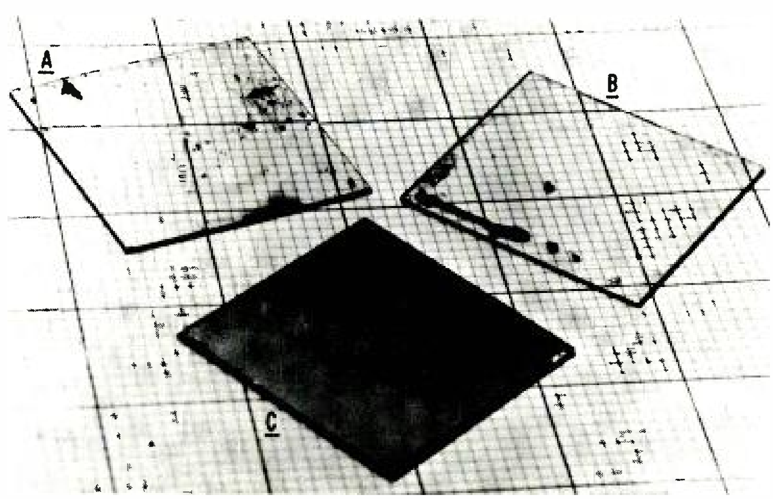


Fig. 14 — Plating uniformity on a commercial positive resist: A) "colloidal"-type catalyst; B) conventional sensitizer; C) improved sensitizer (either A or B).

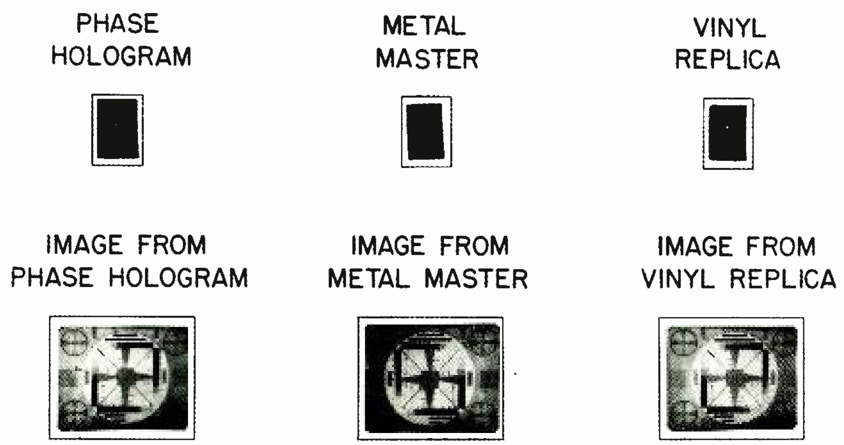


Fig. 15 — Phase hologram replication process.

Conclusions

Electroless plating techniques are widely applicable within the electronics industry. The utilization of the electroless plating techniques may be said to be due to the following attributes:

- Excellent uniformity of plating which is independent of size and shape.
- Plating may be carried out selectively, making etching procedures obsolete.
- Plating may be carried out on a wide variety of substrates ranging from dielectrics and semiconductors to metals.
- The resulting deposits are generally denser than electro-deposited coatings, providing good corrosion resistance. Also various deposits exhibit unique physical properties (*e.g.*, resistivity, magnetic).

Because of continuous activity and interest in electroless metallization techniques, it is believed that the above spectrum of application is minute compared to future developments. Furthermore, with the rapid technical advances and the needs for improved reliability and cost reductions in the electronics industry, newer demands and challenges are imposed on supporting technologies. The growth of the metal-finishing industry has closely paralleled the growth profile of the electronic industry by meeting some of the demands imposed. The application of the electroless plating technique was found to be a natural approach for many processes covering different seqments of the electronics industry. With further increase in the understanding and communication between the design engineer and the plater, a far greater penetration of electroless and electrolytic plating could be realized.

Acknowledgments

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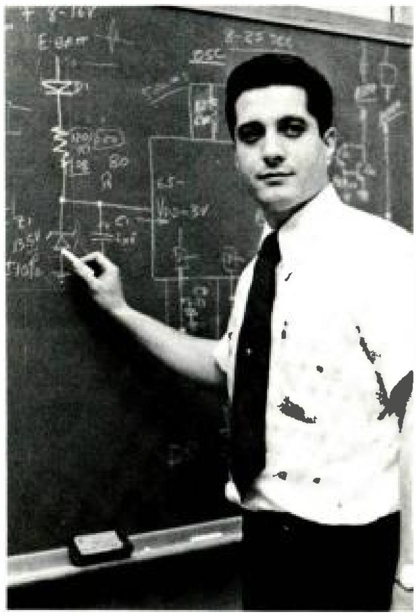
Linear integrated circuits—building-blocks for control applications

G. J. Granieri

Many engineers in the instrumentation and control industries ask semiconductor manufacturers to design and market a single "building-block" IC, an IC that they hope will be universally applicable to the gamut of control circuits. Unfortunately, the cost restraints usually imposed upon control designs make it impossible to devise a universal-IC building block that can be used effectively in a wide variety of applications. Engineers at the Solid-State Division are however, developing and evaluating ten building-block IC's intended specifically for the instrumentation and control industries. The design approach is to provide blocks that contain both basic and auxiliary functions. Each building-block then has the capability of being reduced to its basic elements, thereby providing the user with maximum flexibility in adapting the device to his design requirements.



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SEVERAL of the building blocks are shown in Fig. 1. The blocks can interface with transducers that detect such conditions as temperature, humidity, pressure or light; the output of the blocks is, in turn, capable of driving power devices that control such equipment as motors, solenoids, valves, or relays.

Building block No. 1

Zero voltage switch (CA3058, CA3059, CA3079)

The zero voltage switch (Fig. 2) has been designed into a myriad of diverse applications. It has been used to provide transient-free temperature control in self-cleaning ovens, to control a bun-warmer on a commercial aircraft, to control gun-muzzle temperature aboard a ship stationed in the Arctic, to sequentially switch heating elements in warm-air furnaces, and to switch traffic signals at an intersection.

The schematic diagram for the CA-3059 is shown in Fig. 3. This circuit performs the functions of zero-crossing detection/amplification and provides a buffered signal that can be used to drive thyristors or power transistors. It contains a protection circuit that inhibits output pulses if the transducer interfacing with the IC should inadvert-

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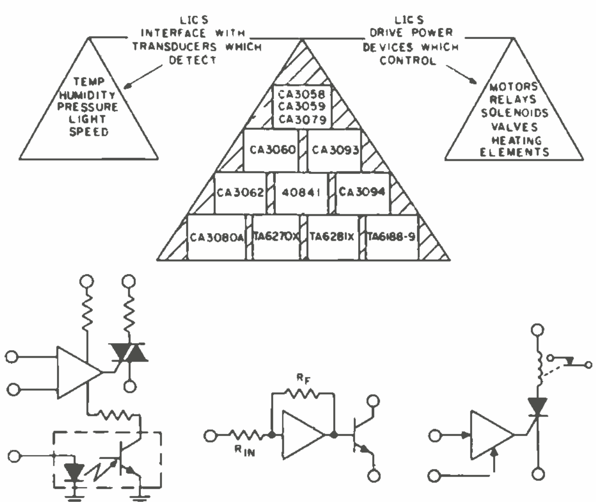


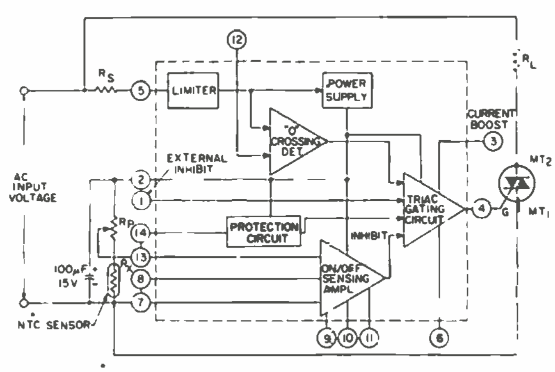


Fig. 1 (left)—LIC building blocks for control applications. Fig 2 (above) Zero-voltage switch.

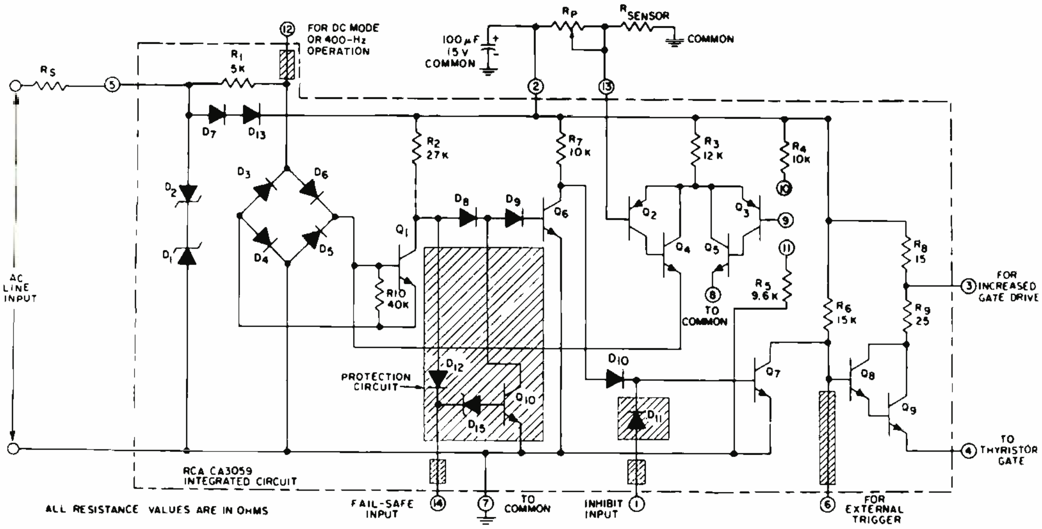


Fig. 3—Schematic diagram of CA3059; circuitry within shaded area not included in CA3079.

ently open or short. It also contains a zener-regulated voltage source that permits operation directly from the AC line.

The circuit for an *on-off* temperature controller is shown in Fig. 4. This basic circuit can control temperatures to within ±1% with or without the addition of hysteresis. The output can trigger thyristors capable of switching 40-A load currents. In Fig. 5, the zero voltage switch, CA3059, is used in conjunction with an operational-transconductance-amplifier CA3080, to switch power to a load. An operational transconductance amplifier, described subsequently (building-block No. 5), is used to provide sufficient gain for control switching with low-impedance sensors. Since the power consumption of the amplifier is very low, its operating power is taken directly from the regulated source in the CA3059.

Fig. 6 illustrates the use of the CA-3059 to trigger a low-current SCR, which, in turn, controls a solenoid, for example, in an electric or gas oven. The high-temperature limit switch shown in this circuit provides an essential safety function; it disconnects the power from the control if either the IC or SCR should malfunction. Since specific Underwriters Laboratory codes regarding the use of solid-state devices in appliances have yet to be delineated, the Laboratory has been favoring the use of a bi-metal limit switch.

Building block No. 2

Hysteresis level-switch (TA6188, TA6189)

Designers have been expressing the need for a building block capable of providing a level-detection function in applications in which zero-voltage switching is not of great importance.

Fig. 7 contains the functional block diagram of the hysteresis level-switch IC, TA6188, currently being developed for commercial service. The IC will be available in a 14-lead dual-in-line plastic package. The block diagram shows its capabilities in the basic functions of level detection (single or dual) and memory (flip-flop). There is sufficient output current (100 mA) to directly drive relays or solid-state power devices. The memory circuit assures a repeatable, predictable threshold level without the addition of positive feedback that sometimes results in objectionable circuit hysteresis.

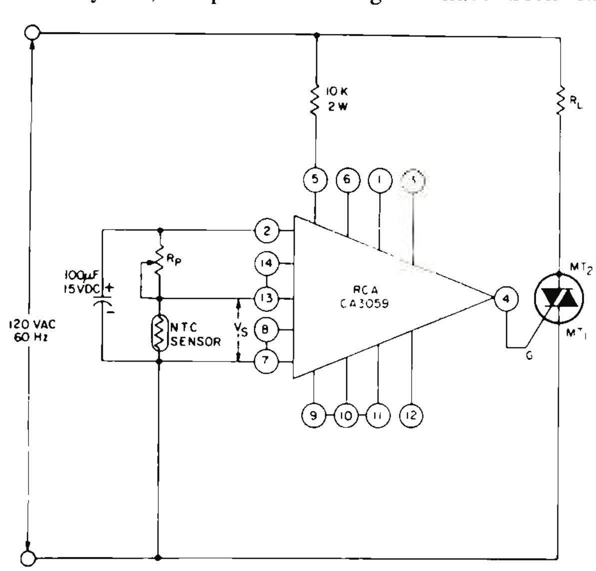


Fig. 4—CA3059 ON/OFF temperature controller.

This IC chip also contains a zener-regulated supply that permits direct operation from AC lines and a self-contained 20-kHz oscillator. The oscillator simplifies the problem of isolating the transducer, connected to input terminal 14, from the AC line. The output transistor can sink or drive current to a load. The hysteresis level-switch is programmable; that is, its electrical characteristics are dependent upon the amplifier-bias-current, I_{ABC}, supplied to control terminal 2. This current establishes bias for all transistors in the amplifier; therefore, the IC can deliver output currents in excess of 100 mA, yet consume only microwatts of standby power.

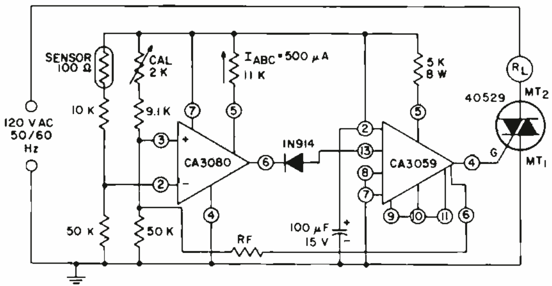


Fig. 5 (left)—High-sensitivity temperature controller with zero-voltage switching and low impedance sensor.

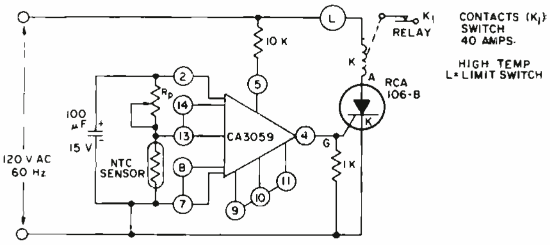
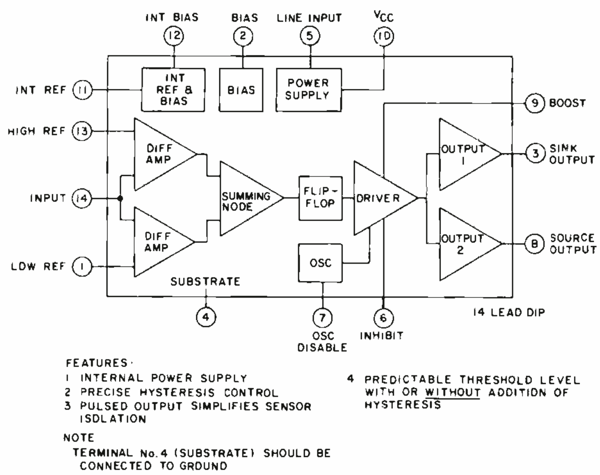


Fig. 6 (above)—Electric/gas oven temp. controller.



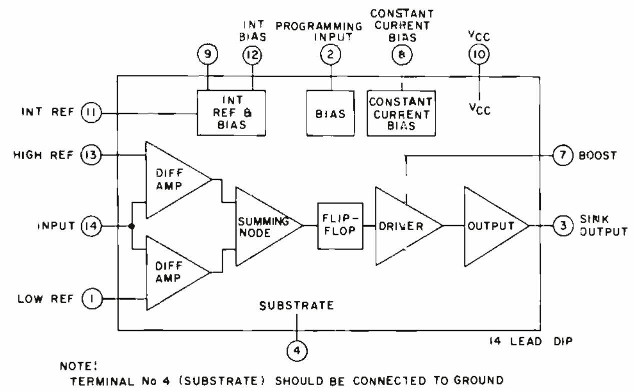
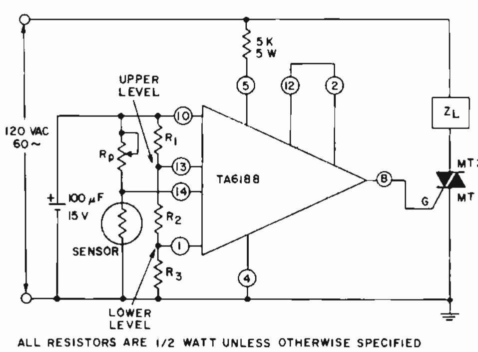
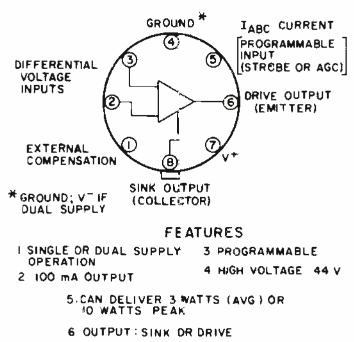
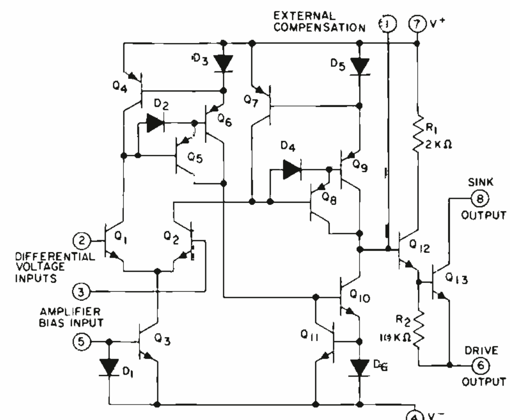


Fig. 7 (left)—TA6188 hysteresis level switch. Fig. 8 (above)—TA6189 programmable high-current comparator.







	OUTPUT TERM	INPUTS INV	NON-INV
DRIVE	6	2	3
SINK	8	3	2

Fig. 9 (left)—Line-operated hysteresis level switch. Fig. 10 (center)—Block diagram of CA3094T (8-lead TO-5 package). Fig. 11 (right)—Schematic diagram of CA3094T.

For those applications in which an on-board regulator and oscillator are not required, a simplified device, the TA-6189, will be available; a block diagram of the TA6189 appears in Fig. 8. Variations of the two circuits can be made available upon request. The hysteresis level-switch is especially suited for use in over-voltage, over-current, and over-temperature applications because the current input to the circuit is extremely low, typically 1 nA; additionally, long-interval *RC* time-delays can be achieved with the TA6188 operated from the AC line. Fig. 9 shows the TA6188 connected as a line-operated dual level-switch with controlled hysteresis.

Building block No. 3

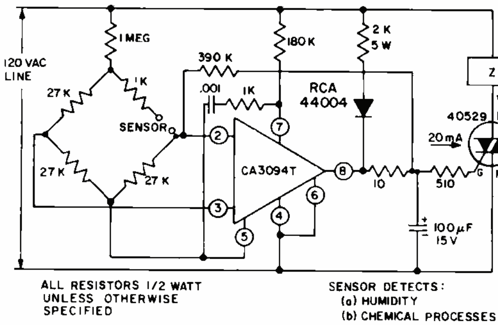
Programmable power switch amplifier (CA3094T, CA3094AT)

One of the building blocks, the programmable power switch/amplifier, CA3094, has been specifically developed for use in power-control applications. Its block and schematic diagrams appear in Figs. 10 and 11, respectively. The CA3094 has the generic characteristics of a CA3080 operational transconductance amplifier directly coupled to an integral power transistor capable of sinking or driving currents in excess of 100 mA. This device offers the designer power capability in a single operational device. For example, although this IC "idles" at the microwatt power level, it is capable of providing peak output power in excess of 10 W and average power in excess of 3 W. Terminals 2 and 3 in Fig. 11 are the usual differential inverting and non-inverting inputs. Control terminal 5 permits the user to tailor the electrical characteristics of the device by choosing the amplifier-bias-current. This terminal can also be used as a strobe or inhibit input.

Many sensors used in controls cannot safely pass DC current without device degradation or danger of device failure. The CA3094 can be directly interfaced with AC sensors as shown in Fig. 12. There is no reference voltage to

Table I—Salient characteristics of a thermocouple Op-Amp vs. CA3741T

Operating characteristics	*Selected CA3080A @ 25°C*	*CA3741T @ 25°C*
Input offset voltage (V_{IO})	2mV (max.)	5mV
Input offset voltage drift ($\Delta V_{IO}/\Delta T$)	(−40 to +85°C) 5μV/°C (max.)	(−40 to +85°C) 25μV/°C (max.)
Input offset current (I_{IO})	120nA (max.)	200nA (max.)
Input bias current (I_I)	1μA (max.)	0.5μA (max.)
Input offset current drift ($\Delta I_{IO}/\Delta T$)	250pA/°C (typ.)	350pA/°C
Open-loop gain (A_{OL})	50,000=94dB (min.) $R_L=\infty$, $I_{ABC}=500\ \mu A$	50,000 (min.)
Input offset drift with life	35μV/1000 hrs. (typ.)	—
Input offset voltage sensitivity ($\Delta V_{IO}/\Delta V$)	150μV/V (max.)	150μV/V



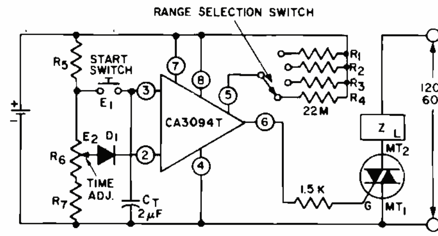


Fig. 12 (left)—Line operated control circuit for ac sensors. Fig. 13 (above)—Pre-settable analog timer.

ground in this circuit; the sensor may "float" within the common-mode restraints of the CA3094. The IC provides DC output current to the triac, which, in turn, can switch AC power to loads.

The CA3094 is particularly suitable for use in providing long time-delays because its very high input impedance satisfies one of the basic requirements for this application. Time-delays in excess of 4 hours have been realized by judiciously using the "programmable" features of the device. The circuit in Fig. 13 produces a long time-delay: 2 hours, with a 22-megohm resistor and a 2-μF capacitor. The provision for adjustable bias current to this IC permits precise control of the *discharge* current on timing capacitor C_T. This capacitor is initially charged to initiate the timing cycle. The end of the timing cycle occurs when voltage E_1 drops below the present level E_2. At this time, input terminal 2 conducts enough current from the bias network to switch the output of the CA3094. Thus, the CA-3094 not only has provision for readily pre-setting the time-delay, but also provides significant output power. Conventional timing circuits using UJT's require additional active devices to switch appreciable power.

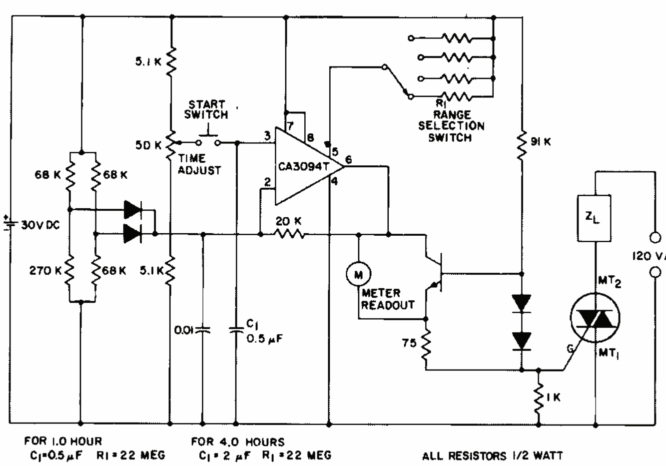
In Fig. 14, the CA3083, n-p-n transistor-array, is used in conjunction with the CA3094 to drive a linear-readout display meter. This configuration provides timing, readout, and load-switching, a combination that can be used in many appliances, such as ovens, washers, and dryers. The CA3094 is also suitable for use in battery-operated traffic flashers because its micropower operation satisfies one of the basic requirements for this application. Fig. 15 shows a 1 flash/sec (25% duty cycle) barricade flasher that "idles" at micropower levels, but that can provide in excess of 100 mA when it is switched on. The flashing rate is independent of battery voltage over the range of 6 to 15 V.

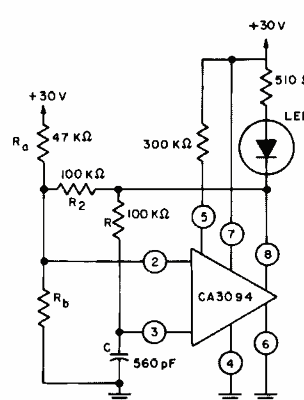
Building block No. 4

Thermocouple operational amplifier (selected CA3080A)

For more than a decade, the instrumentation and control industries have been using thermocouples to measure temperature. With the advent of solid-state devices, the following questions are almost invariably asked: "How do I interface a thermocouple with an op-amp?", "Which op-amp should I use? What op-amp characteristics are important?" Table I lists the salient characteristics of the CA3080A operational amplifier (selected for thermocouple use) versus the commonly available 741 operational amplifier. A key parameter that demonstrates the superiority of the CA3080A is input-offset voltage drift versus temperature. If the ambient temperature changes in the amount of 25°C, the input-offset voltage of the CA3741T shifts 625 μV, whereas the CA3080A varies only 50 μV. In an amplifier circuit with a gain of 100, the output voltage (E_o) variations would be 62.5 and 5 mV, respectively. If the readout device is a 100-mV meter, the circuit using the CA3741T would show a scale error of 60% against an error of only 5% for a circuit using the CA3080A!

Fig. 16 shows a thermocouple meter using the CA3080A in conjunction





$$f_{OUT} = \frac{1}{2RC\ \ln\left(\frac{2R_1}{R_2}+1\right)}$$

$$R_1 = R_a // R_b$$

Fig. 14 (left)—Pre-settable timer with linear readout using IC transistor array. Fig. 15 (above)—Barrier-flasher.

with a MOS/FET device to provide addition current drive. Fig. 17 shows the CA3080A operating as a pre-amplifier for the CA3059A (ZVS) to form a zero-voltage switching circuit for use with thermocouple sensors.

Building block No. 5

Tri-OTA (CA3060)

Fig. 18 shows the block diagram of an IC containing three OTA's (operational transconductance amplifiers). The CA-3060 has the generic characteristics of an OVA (operational voltage amplifier) with the exception that the forward gain is best described in terms of transconductance rather than in voltage-gain characteristics. Table II lists the basic differences between an OTA and an OVA. Tri-level comparator circuits are an ideal application for the CA-3060 since it contains the requisite three amplifiers. A tri-level comparator has three adjustable limits. If either the upper or the lower limit is exceeded, the appropriate output is activated until the input signal returns to a selected intermediate value. Tri-level comparators are well suited to many control applications.

Fig. 19 shows the block diagram of a tri-level comparator using the CA3060. Two of the three amplifiers are used to compare the input signal with the upper-limit and lower-limit reference voltages. The third amplifier is used to compare the input signal with a selected intermediate value of reference voltage. By appropriate selection of resistance ratios, this intermediate value may be set at any voltage between the upper and lower limits. The output of the upper-limit and lower-limit comparator sets the corresponding upper- or lower-limit flip-flop. The activated flip-flop retains its state until the third or intermediate-value comparator in the CA3060 initiates a reset function, thereby indicating that the signal voltage has returned to the selected intermediate value. The flip-flops employ two CA3086 transistor-array IC's with circuitry to provide separate set and positive-output terminals. Fig. 20 shows the circuit diagram of a tri-level detector.

Building block No. 6

Opto-electronic IC (CA3062)

The CA3062 is a monolithic silicon

Table II—Operational transconductance amplifier vs. operational voltage amplifiers.

CA3080
$A_{OL} = g_m R_L = 96\times10^{-3}\times52\times10^{3} = 500$
$R_L = 52$ K $= R_{in}$ (CA3059)
gm of CA3080 $= 9.6\times10^{-3}$
Sensitivity of CA3059 $\simeq 9.6\times10^{-3}$
Sensitivity of CA3059 $\simeq$ 10 mV
Total system sensitivity $= 10\times10^{-3}/500 = 20\mu$V
Change in sensor to obtain 20μ V: 20μ V/60μ A $= 0.333\Omega$
$\therefore$ Sensitivity $\simeq$ 0.3% change in Sensor resistance (100Ω sensor)

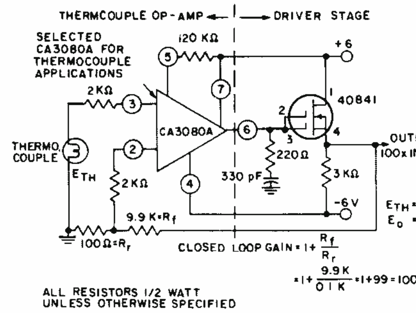


Fig. 16—Thermocouple meter.

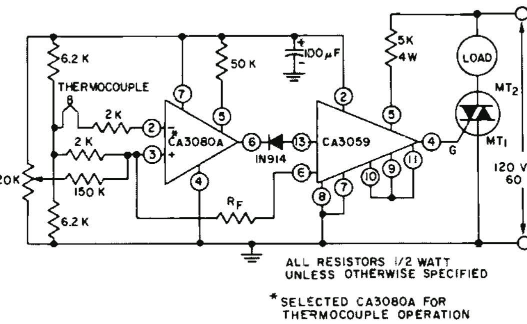
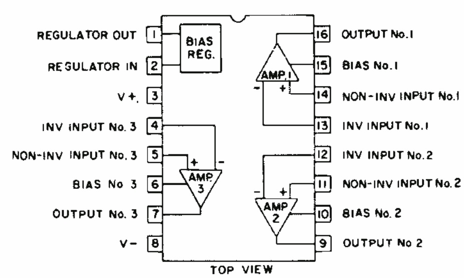


Fig. 17—Thermocouple temperature control with zero-voltage switching.



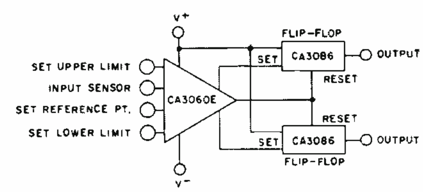


Fig. 18 (left)—Block diagram of CA3060 (TRI-OTA). Fig. 19 (above)—Functional diagram of a tri-level comparator.

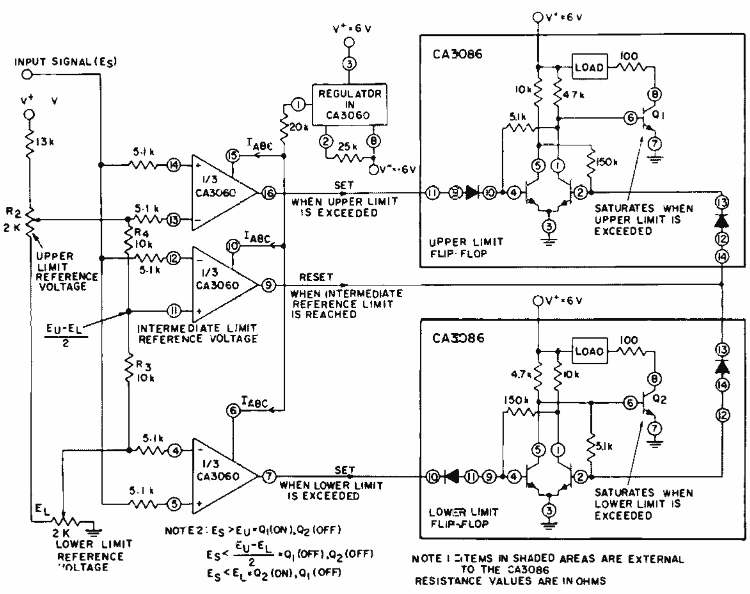


Fig. 20—Tri-level detector.

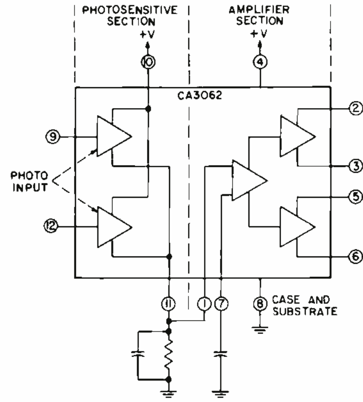


Fig. 21—CA3062 optoelectronic IC block diagram.

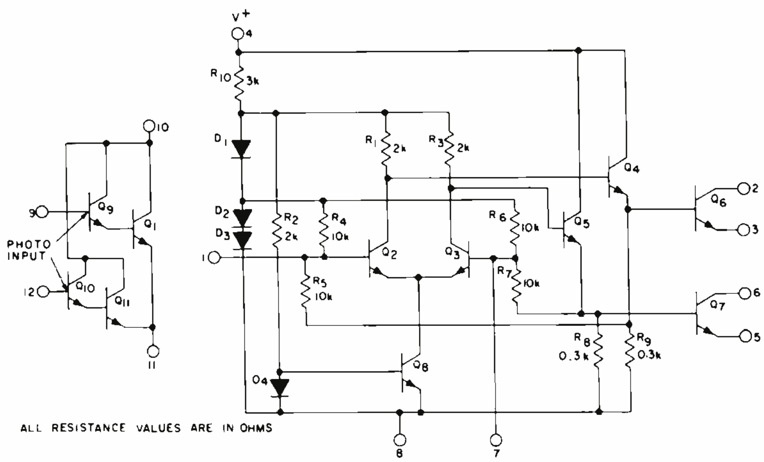


Fig. 22—Schematic diagram of CA3062.

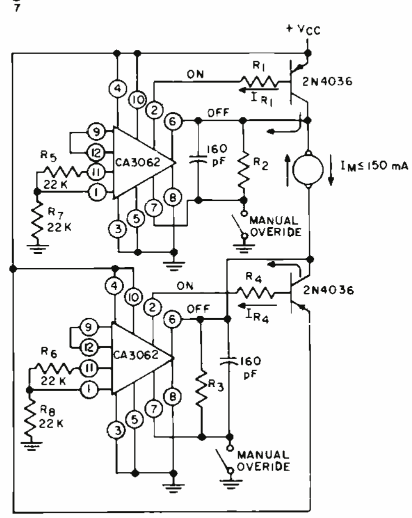
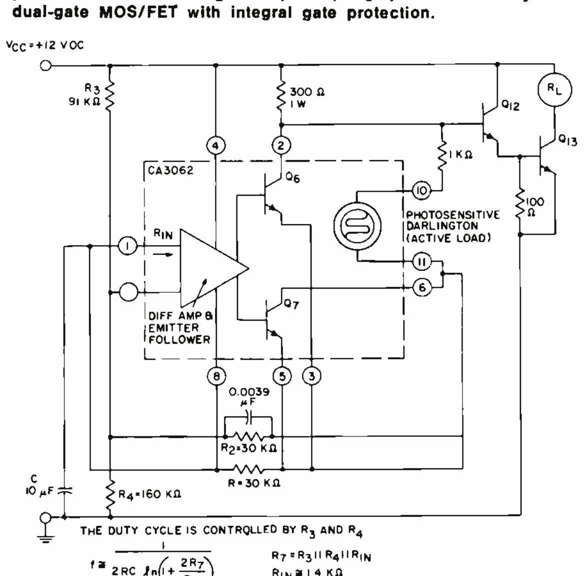
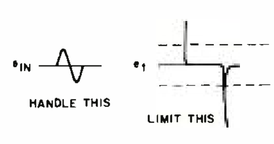
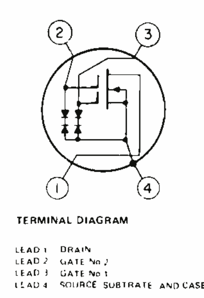


Fig. 23 (above)—Modified 12-lead TO-5 style package, CA3062. Fig. 24 (right)—Light-activated servo system. Fig. 25 (below)—Light-operated power multivibrator. Fig. 26 (below, right)—Schematic symbol of dual-gate MOS/FET with integral gate protection.







integrated circuit containing a photosensitive detector and a switching amplifier that drives a pair of high-current output transistors. The block diagram and circuit schematic for the CA3062 appear in Figs. 21 and 22, respectively. The power amplifier has a differential configuration that provides complementing outputs in response to the light that impinges on the IC through a glass port in the top of the unique TO-5 package shown in Fig. 23.

Fig. 24 shows two CA3062 units operating in a light-activated servo system. The servo motor rotates in either the forward or reverse direction depending upon which IC is illuminated. Equal light input to both devices halts the motor. The CA3062 can also be connected as a power multivibrator as shown in Fig. 25. Light impinging on the photo-sensitive area causes the circuit to operate at a frequency determined by the external passive components in the circuit. The duty-cycle is controlled by resistors R_3 and R_4.

Building block No. 7

Dual gate MOS/FET IC (40841)

Designers have frequently been reluctant to employ MOS/FET devices in their circuits because the gate-oxide is vulnerable to damage by static electricity discharge during handling and/or by electrical transients occuring in circuit applications. Fig. 26(a) shows an ideal gate-protection system which allows a signal to be handled without clipping or distortion, but which limits the amplitude of transients that exceed a safe operating level. The 40841 dual-gate MOS/FET in Fig. 26(b) has "transient trappers" (back-to-back diodes) that protect the gate insulation of this device.

The 40841 is ideal for use in *RC* timing circuits; Fig. 27 shows a five-minute timer. The timer accuracy is ±10% with line variations of ±15% and ambient temperature changes from −25 to +60°C. Repeatability is ±3% at 25°C, and reset time is 150 ms.

Building block No. 8

Transistor/zener diode array (CA3093)

The CA3093E shown in Fig. 28 is a

versatile array of three high-current n-p-n transistors, two zener diodes, and one diode, all on a common monolithic substrate. Fig. 29 shows a line-operated 7-V regulator which should be useful in many appliance applications. since DC power supplies are rarely available in appliances. Fig. 30 shows a temperature-compensated series voltage regulator which is ideal for powering COS/MOS devices used in appliance control applications.

Building block No. 9

n-p-n/p-n-p transistor array (TA6270X)

Designers have been expressing a need for a transistor-array IC containing both n-p-n and p-n-p transistors on the same chip. Fig. 31 shows the schematic diagram and highlights the electrical characteristics of the RCA Dev. No. TA6270X n-p-n/p-n-p transistor array. Fig. 32 shows two applications of the TA6270X; a one-minute timer utilizing the TA6270X in conjunction with the 40841 MOS/FET (Fig. 32a) and a ten-second timer that operates from 1.5 V.

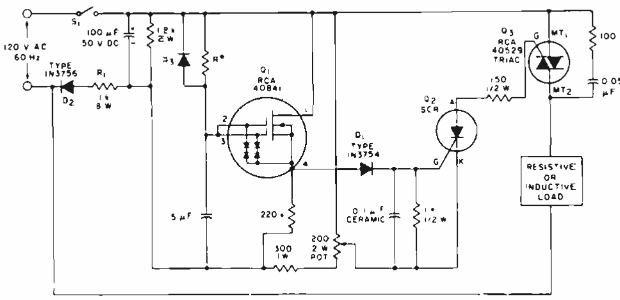
Building block No. 10

Industrial designer's array (IDA) (TA6281X)

Many appliance control circuits use various types of solid-state devices, such as zener diodes, transistors, UJT's, and thyristors connected in various configurations to perform a given system function. The Industrial Designer's Array (IDA), RCA Dev. No. TA6281X, shown in Fig. 33 is currently being developed to enable the circuit designers to further integrate his total system. This array consists of five uncommitted devices in a 16-lead dual-in-line plastic package; the salient electrical characteristics of each of the devices are highlighted in Fig. 33. The array can be connected as shown in Fig. 34 to form a phase-control circuit capable of switching resistive loads. It can also be used to generate time-delays, oscillators, one-shots, and similar functions.

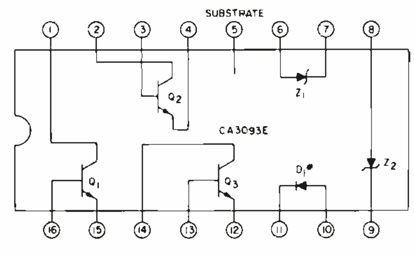
Acknowledgment

The author is indebted to the members of the Industrial LIC Applications Group for their contributions to the design and evaluation of the numerous circuits described in this paper.



* T=5 MINUTES WHEN R=60 MEG   ALL RESISTANCE VALUES ARE IN OHMS

Fig. 27—Five-minute solid-state timer for industrial applications.

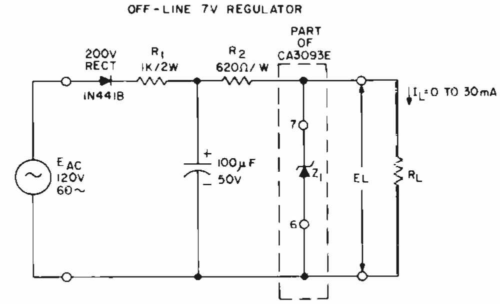


DEVICE CHARACTERISTICS

TRANSISTORS	ZENERS	DIODE
• HIGH IC = 100 mA • VCE (SAT) = 0.7 V @ 50 mA • VCEO = 15 V MIN • Q1 & Q2 MATCHED PAIR VIO = 5 mV MAX, IIO = 2.5 μA	• 1/4 WATT POWER RATING • VZ = 7 V ±10% • RZ = 15Ω TYP • IZ = 35 mA MAX	• VF = 0.7 @ 10 mA • VBR = 6.9 V TYP

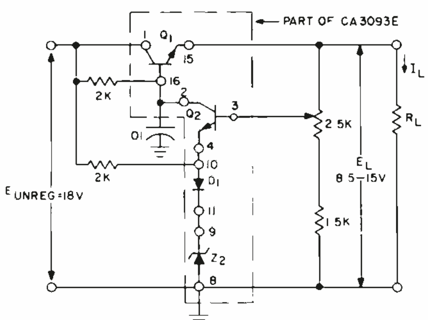
Fig. 28—CA3093E transistor-zener-diode array.

OFF-LINE 7V REGULATOR



CONNECT TERMINAL No 5 (SUBSTRATE) OF CA3093E TO GROUND   92CS-19687

Fig. 29—Line operated seven-volt regulated supply.



CONNECT TERMINAL No 5 (SUBSTRATE) TO GROUND

TYPICAL TEMPERATURE CHARACTERISTIC @ EL = 12V

$\frac{\Delta E_L/E_L}{\Delta T} \times 100 = 0.009\%/°C$

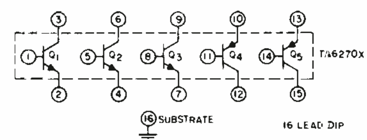
TYPICAL LOAD REGULATION @ EL = 12V, IL = 0 TO 41 mA

$\frac{\Delta E_L}{E_L} \times 100 = 0.4\%$ (NO LOAD TO FULL LOAD)

TYPICAL LINE REGULATION @ EL = 12V

$\frac{(\Delta E_L/E_L) \times 100}{\Delta E_{UNREG}} = 0.45\%/V$

Fig. 30—Temperature-compensated series voltage regulator.



NPN CHARACTERISTICS

hFE (MIN) = 80 @ IC = 5 mA VCE = 5 VOLTS
BVCEO (MIN) = 36 VOLTS @ IC = 1 mA
IC (MAX) = 50 mA

PNP CHARACTERISTICS

hFE (MIN) = 20 @ IC = 100 μA VCE = 5 VOLTS
BVCEO (MIN) = 40 @ IC = 100 μA
IC (MAX) = 10 mA

Fig. 31—npn/pnp transistor array.

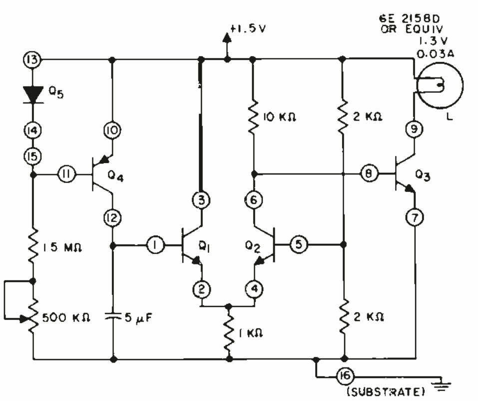
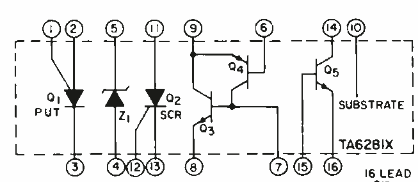


Fig. 32—Ten-second timer using the TA6270X.

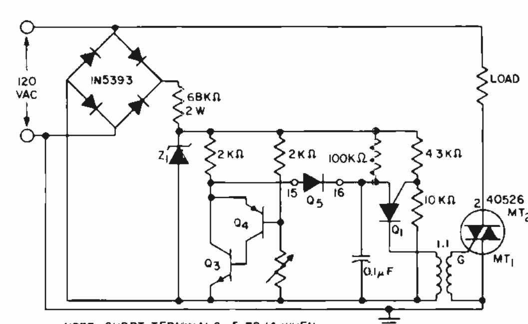


DEVICE CHARACTERISTICS @ 25°C

Q1 – "PUT"	Z1	Q2
Ip 0.15 μA VAK = 40 VOLTS (MIN)	VZ = 7.0 V ±10% IZ = 35 mA (MAX) PZ = 1/4 WATT	VDRM = 40 V MIN IGT = 500 μA MAX IF = 200 mA MAX VF = 1.5 V @ 100 mA

Q3	Q4	Q5
hFE (MIN) = 40 @ 50 mA BVCEO (MIN) = 40 V IC (MAX) = 100 mA	hFE (MIN) = 15 @ 100 μA BVCEO (MIN) = 40 V IC (MAX) = 10 mA	hFE (MIN) = 40 @ 50 mA BVCEO (MIN) = 40 V IC (MAX) = 100 mA

Fig. 33—Industrial designer's array.



NOTE SHORT TERMINALS 5 TO 14 WHEN USING Q5 AS A DIODE

SUBSTRATE TERMINAL 10 SHOULD BE CONNECTED TO AC GROUND

Fig. 34—Phase control using IDA.

Computer security management at Walt Disney world

E. Wyant

Walt Disney World, the Vacation Kingdom, is protected by one of the most advanced systems of our modern era. Overseeing the facilities, utilities, fire protection, security and public health and safety of its guests is an integrated network of computers. These computers, interconnected in a multithreaded manner, form the nucleus of an Automatic Monitoring and Control System (AM&CS), which keeps its fingers on the pulse of the entire Walt Disney World complex. The system described herein is designed in such a manner that failure of critical elements results in a gracefully degraded mode of operation without loss of critical information.

THE SYSTEM (AM&CS) provides instant reporting of status changes by pin pointing the exact location at the appropriate key operating location such as: the communications center, the fire department, the central maintenance dispatching areas, and the hotels. In addition to its basic functions of fault isolation and reporting, it provides the capability to: provide preventive maintenance scheduling, furnish spare parts usage data to an Inventory Control System, provide failure data and analysis for engineering decisions, minimize down time, and to minimize the occurence of catastrophic failures by accumulating fault history and trend data. These accomplishments are only part of the first phase of a system which is designed to grow in a modular pyramid of computers which will eventually encompass new areas of development such as EPCOT, the Experimental City of Tomorrow.

Functions monitored by AM&CS

The AM&CS oversees a multitude of related and unrelated services, scattered throughout the Walt Disney World complex. No single service is concentrated in any one area, therefore the AM&CS brings together widely distributed functions of a service and summarizes the status at the appropriate display location. Services included in the Phase I (Opening Day) system are:

- Fire Alarm and Suppression
- Air Handlers
- Central energy plant
- Fuel loading
- Refrigerator storage
- Security
- Secondary power
- Waste disposal system
- Domestic water supply system
- Elevator Control

These combined services represent some 1300 sensor and control points. Current plans, as part of Phase II, call for expansion to 30,000 points by geographic expansion of existing services and by the addition of new services.

System description

Major factors in the implementation of computer networks are element utilization and system reliability. The system designed for Walt Disney World provides the initial steps toward a total processing utility. System organization is modular to permit both horizontal and vertical growth to achieve the reliability, availability, flexibility and interface requirements of a processing utility.

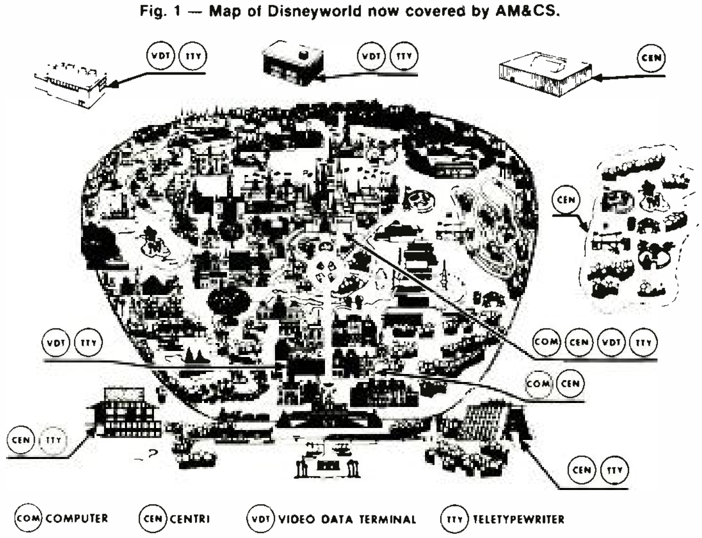
Due to the wide range of the applications (services) the utility system must be "function independent". As new and additions to existing services for the system evolve, they are added as one would add a telephone to that existing utility. Stringent requirements exist in the installed system as it is utilized 24 hours/day. The growth must take place on-line without affecting existing services.

In order to meet these broad requirements, a fail safe computer network is utilized. The system elements are distributed throughout the geographical area of Walt Disney World and is collocated within the user's environment. This permits geographical expansion as the user adds in scope as planned. Fig. 1 is a map (not to scale) of that part of Disneyworld now covered by AM&CS. Geographical distribution prevents local environmental conditions (power failure, lightning, etc.) from causing a total processing blackout. During malfunctioning periods, elements of the system may stand alone, if required, performing critical tasks to avoid catastrophic failures.

The system exhibits a rigid hierarchal structure among various levels of computers. For example, each computer controlling "n" subordinates may also be under the control of two higher level computers. As a result, the system exhibits a pyramid like shape as shown in Fig. 2, level C being controlled by levels B and A.

The system is bounded neither vertically nor horizontally since vertical growth is maintained by adding levels above "A" and horizontal growth is maintained by adding at any level from A to C. This system structure allows the networks resources to be allocated at the point of need when required. For example, if computer A has a task to be performed, it may assign the function to the least loaded subordinate or perform the function itself, if sufficient resources are not

Fig. 1 — Map of Disneyworld now covered by AM&CS.



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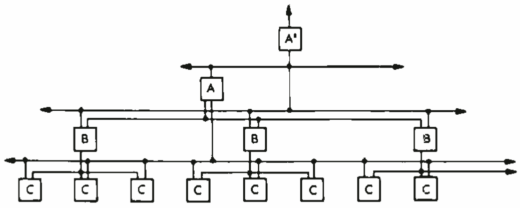

Fig. 2 — AM&CS hierarchy of computers.

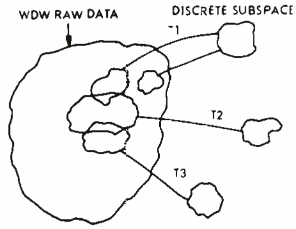

Fig. 3 — Mapping of data.

available. If any subordinate element has failed, the element's immediate supervisor will fill its function until the system has been repaired.

Many advantages may be accrued by this configuration. All elements are utilized all the time, thereby providing a large degree of integrity of the backup system. In reality, there is no backup system since the backup is in terms of resources. This mode of operation provides a smooth failure switchover since this switchover occurs continuously in normal operation.

Monitoring functions fluctuate throughout the day as a function of the state of the items monitored. The processing required to service the users is not deterministic but varies as failures occur. As failures increase, or as users request more processing resources, the processing will increase vertically as shown in Fig. 2. As new tasks are added, subordinate levels will exceed processing thresholds and these tasks will be performed by the supervisory level.

In the latter application the tasks performed in level A' are not critical and may be check-pointed, thereby momentarily increasing the system's resources. Under these conditions, the configuration is only required to carry enough resources necessary to handle a statistical quantity of processing.

It should also be noted here that since regional processing peaks may be smoothed at higher levels, the capability to handle peaks at local levels becomes unnecessary. Thus, the total resources required are, again, significantly reduced.

Although it is known that peaks in all regions simultaneously will overload the system, it is not cost effective to design a system for the probability of this occurring. A system overload results only in a gradual slowdown, not a catastrophic loss of information.

If supervisory level elements fail, the subordinates will then be under the control of the next higher supervisor allowed by the unique dual port arrangement.

Checking of system elements is continuously in progress. Self checking is accomplished by exercise programs resulting in predetermined answers whose values reveal the state of the element. These values are transmitted upward and inspected by the supervisory levels.

A more basic system check is accomplished during the normal monitoring phase of the system. Just as the system will be detecting failures in the monitored functions, it is also monitoring internal points in all system elements. Power supplies of the computers are monitored by other computers as well as other critical points in interface modules. Upon detection of failures, the system undergoes a reconfiguration phase in which the suspect element is taken out of the direct system control.

The WDW complex may be thought of as a large set of physical devices which are observed periodically for changing conditions. In addition, one physical device may be distributed geographically over a wide area.

The seemingly disorganized set of quantities must be arranged in a suitable manner to allow some logical operation to be performed by the AM&C system. A mapping must take place which transforms the raw data space to a set of identifiable subspaces. Uncoupling of related raw data points must be accomplished by changing the bases of the subspaces. This appears pictorially in Fig. 3

Note that common elements of the raw data may map into more than one discrete subspace. These discrete subspaces are, in general, not related to each other after their T_n transformation.

Further requirements of the T_n transformations are to convert this raw data to engineering units and to perform any linearization or similar preprocessing on the data. It may be observed in Figure 3 that n sets of raw data may map into the same subspace. For example, there are about 100 airhandlers, each of which may be processed by the same application program. The T_n transformations then normalize the raw data into a set of data bases containing engineering units formatted to minimize the number of application programs by maintaining data base similarity among such physical devices.

After the application program analysis, the normalized data base may cause an output to the WDW in the form of a control signal or a message to one or more of the display locations. If a control output is required, a reverse transformation is needed to map the output section of the normalized data base into the raw data format required by the physical device.

System operation

The Phase I system (Opening Day) actually implemented is shown in Fig. 4.

The C level (Centri) computers are connected to specified sensors via modularly expandable hardware. They scan the state of the sensors and if a

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change (or changes) in state is detected, this change (alarm, sensor or wiring trouble, or return to normal) is reported to both the B and A level supervisory computers via standard telephone type communications links. In addition, they perform control and self checking functions under the direction of the B or A level supervisory computers.

The B level computer takes the change of state and, through mapping techniques, obtains the appropriate application program. The application program determines the correct action to be taken, such as displaying a message to the proper organization describing the location and event which occurred, requesting status of related points from other C level computers, or directing one of the C level computers to perform a control function. In addition, the B level computer communicates with the A level computer by informing it of the results of its analysis, and it also periodically tests the status of the A level computer.

The A level computer coordinates the message from the B level with that from the C level computer and, if the message is to be displayed, transmits it to the proper organization's collocated display device. In addition, the A level computer periodically performs a complete self check of the entire system and if the B level becomes overloaded, it takes over some of the processing tasks. If it determines that the B level computer has missed a function, it processes it, informs the B level that it is taking over the functions of the B role, and that the B level computer must assume the A role. This is referred to as a role change; the A is now the B and the B becomes the A.

System integrity

The contingency algorithims, the dynamic task allocation capability, and the unique dual port arrangement to each system element provide the facilities to permit failsafe operation.

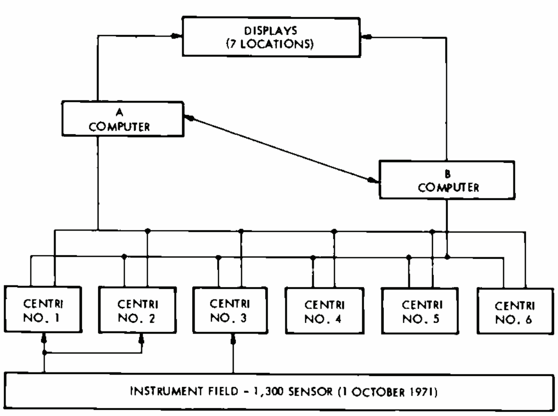

Fig. 4 — Phase I (opening day) AM&CS.

Three phases exist when considering failsafe operation. These are the detection of system malfunction, the check pointing of pertinent status and data, and the removal of the failed element of the system with the insertion of the backup capability.

The detection of system malfunctions is done by monitoring integral points within the system by other system elements. The test points in the Centri's and other system elements are treated as sensors. These points are scanned periodically and the data bases of the higher level computers updated. If changes occur, they will be presented to both the B and A level computers similar to that of a change of state of a WDW sensor. The A computer coordinates the change and the appropriate self check application program is activated. This program will actually perform any required reconfiguration.

Power supplies within the Centri's are monitored for proper output voltage. If they drop below a set limit, the carriers on the communications channels to both the B and A level computers are automatically dropped. The B and A both detect this occurrence and the reconfiguration application program removes the faulty Centri and informs the proper organization.

Critical sensor points throughout WDW are monitored by more than one Centri. Thus the loss of a single Centri does not stop the monitoring of critical WDW sensors.

The integrity of message transmissions between all elements is continuously checked and if found to be faulty, the transmitting computer is requested to retransmit the message. This retransmission may occur as many as five times before the reconfiguration application program removes the faulty transmission link from the system.

Self tests within the C,B and A level computers are performed and their results reported to higher elements. In the case of the Phase IA computer, its results are reported to the B level computer. If errors occur, the reconfiguration application program is invoked to remove the faulty element.

Check pointing of critical functions is constantly being performed by utilizing the backup system elements. That is, the second port to each device is continually utilized in a redundant manner by the higher level computer. For example, the A level computer is executing micro programs in the C level (Centri) computers directly, avoiding the B's capability. The A level will be gathering the raw data points of each Centri, converting them to data bases and storing them on disc just as the corresponding B would do.

The modular monitoring and control cards within the Centri's have software controlled self test capability built in them. These cards are periodically checked and, if one of them fails, the self check application program informs the proper organization of this failure, and exactly which part of the card that failed. This self check is so extensive that the monitoring cards are checked each and every scan cycle of the sensors which occurs once a second.

Each of the four major display locations contains both a hard copy teletype connected to either the A or B level computer and a Video Data Terminal connected to the other computer. Failure of either the A or B, or one of the display devices, does not cause any loss of messages being displayed to the proper organization.

Due to the way the hard copy teletypes are connected, there is always a hard copy message available at one of the display locations.

These techniques provide a number of significant advantages:

- The backup system is continuously being utilized, therefore the integrity of it is known.
- Check point of critical functions is occurring automatically without interfering with the primary path.
- A check on the primary path is made by comparing the data bases.
- The communications paths are checked during every message transmission.

The reconfigured system may require assistance from the higher level which is controlling the failed one to perform the task normally accomplished by the subordinate. This is shown in Fig. 5.

Preventive maintenance and logistics

Although not implemented as part of the Phase I system, the AM&C system has the capability to be expanded in Phase II to provide:

- Maintenance Scheduling
- Reduction of Repair Costs
- Minimization of Failures
- Minimization of Down Time (Part of Phase I)

In most facilities, maintenance is scheduled on the basis of failures as they occur. If there are no failures, then maintenance personnel devote time to preventative maintenance, repairs, and rehabilitation. However, in practice the work does tend to "peak" at irregular intervals. As a result, maintenance personnel tend to be hurried or lose time shifting from one type task to another.

The AM&C system will assist management in smoother scheduling of maintenance personnel. The system outputs will inform management of:

(a) Items that have failed (Part of Phase I)
(b) Items that are potential failures
(c) Items on which preventative maintenance is becoming due.

Armed with this information, maintenance management can effect a more efficient scheduling of personnel.

A major factor in repair of an item is fault isolation; i.e., determining what is wrong. The actual remedial action is sometimes a very small percentage. Actual studies have shown that for complex electronic systems, the fault isolation portion of repair counts for 80 percent of the time. In complex mechanical systems this proportion is somewhat less, but still significant. The AM&C system can reduce this fault isolation time significantly because of its czpability of monitoring a number of points in each system. As an example, for each air conditioner, approximately 50 points may be monitored. If the repairman knows which of the 50 points in out of tolerance or has failed, he knows where to look for the failure and the equipment can be repaired much more quickly.

Similarly, the actual remedial action time is minimized for two reasons. The most significant effect is that, usually, catastrophic failure is a secondary failure. By this it is meant that some small item fails, and as operation continues, this causes a series of failures (as in the so-called domino theory) until eventually catastrophic failure and/or complete ruin occurs. As an example, consider the bearing of a pump. If failure can be detected as the bearing is going dry, then perhaps the only remedial action necessary is to grease the bearing or, at most, replace it. Suppose, however, this failure is undetected. Then the pump motor can burn itself out or the entire pump can freeze. The cost, both in labor and material, to repair a simple bearing problem is considerably less than to conduct major remedial action on the entire pump at an inconvenient time.

As a secondary effect, the AM&C system will feed data into a large scale computer so that failure analysis and inventory control analysis can be undertaken. As a result, quite probably the necessary spare will be in inventory when needed. Many times the reaction time on a failure is less than the lead time to procure a necessary spare. If this factor can be minimized, without an extremely high capital outlay for inventory, then the out-of-service time is reduced.

The actual number of failures can be reduced by a number of factors. The computer will be programmed to schedule preventive maintenance functions. Furthermore, this scheduling can be continually updated based on past performance. As an example, if it is shown that an electrical motor tends to fail every four months and a preventive maintenance schedule is set at six months, then the computer can change the schedule to every three months. This will minimize the number of failures by scheduling the proper preventive maintenance prior to the time when, from a historical stand point, the motor is expected to fail.

Similarly, the historical data on failures will allow the computer to analyze the entire system for weak points. Perhaps a certain component tends to fail at a much faster rate than expected. This in turn causes secondary failures which in turn can cause significant or catastrophic failures. If this component can be pinpointed, then either engineering can redesign the unit to increase component reliability or perhaps a different component can be chosen as a replacement.

In the AM&C system a display in the

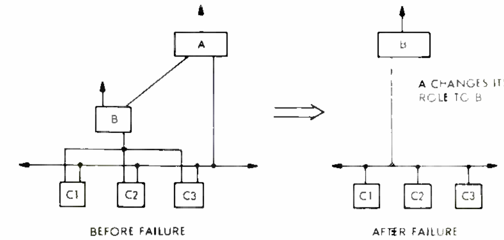

Fig. 5 — Failure reconfiguration.

maintenance center will indicate "alert items". These are defined as parametric values which, although still within an acceptable range, are tending to leave the mean value and go toward the values which are defined as a failure. If, for example, the water temperature is allowed to be 150° ± 10°, and the temperature is usually at the center value, then should a temperature begin creeping upward, warning could be given to maintenance when it is 158 degrees. Notice that the value is within acceptable limits, but the long-term trend is toward the temperature going out of the acceptable values. Should maintenance be alerted to this trend, then remedial action can be taken prior to an actual failure. Many times this trend is long-term; thus repair can be scheduled during down time hours rather than shutting down a show or an attraction when failure occurs.

Conclusion

Finally, the AM&C system contributes to a faster recovery from a failure condition. When a failure does occur, the communication center will at once notify operation personnel of the problem. In some cases, a backup system can be immediately put into effect. Similarly, the information is given to the maintenance center so that maintenance personnel can be immediately dispatched to the problem area. A third factor is that, as trends become evident, the maintenance and operational personnel can be warned that downtime is inevitable. This allows both operational and maintenance personnel time to take emergency measures, such as calling in additional personnel.

In essence, the AM&C system increases overall operating efficiency by insuring a "smoother running show". Thus, the AM&C system reduces the incidence of facilities going down, and then expedites their recovery.

Acknowledgement

The author is indebted to Mr. F.C. Hassett and Mr. H. W. Silverman of RCA for contributions from their work.

TCR-100 recorder — a fundamental innovation for the broadcaster

R. N. Hurst

TV station demands for increasingly automatic and reliable programming of video tapes has resulted in the contemporary design of RCA's TCR-100 recorder. This paper describes the design and operating features that assure the broadcaster a continuous, high-quality program flow.

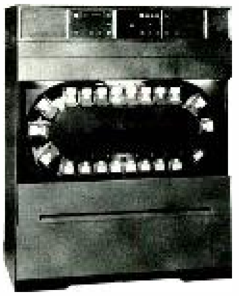

Fig. 1 — The TCR-100 Video Tape Cartridge Recorder. This machine, which will play up to twenty-two 3-minute cartridges in unbroken sequence, is currently in use in over 150 broadcast studios here and abroad.

ENGINEERING developments, according to the textbooks, arise from a happy combination of customer need, marketing research, engineering ingenuity, and technological capability. It is rare, however, that a development is so nearly textbook perfect as was the growth of the TCR-100 video-tape cartridge recorder. In this equipment, the development followed almost to the letter the classical formula for new products, and its outstanding success attests to the soundness of the textbook approach.

A need for automatic tape handling

Customer needs for a better method of handling video tape were becoming evident in 1966. Marketing research showed that, even at the tape-use rate of that era, there was a growing requirement for emulating the audio-cartridge method in the handling of video recordings. Marketing forecasts also showed a burgeoning use of tape, making it even more mandatory that better handling methods be found. Hence, by early 1967, requests came from marketing that engineering consider methods for automatic handling of all video tapes, of all lengths.

The technology of that era, however, was not quite adequate for the task proposed. The need was acknowledged, but the job was deferred.

Early attempts

In early 1968, a proposal was made that a better means be found for handling only short segments. In a slight departure from textbook perfection, this proposal came from engineering, in the form of a 2-minute spool of tape wound on a small hub. The proposal pointed out the advantages that would accrue to the broadcaster by recording, using, and storing commercials in this form. The possibilities of the little spool were recognized immediately and an effort was launched to exploit the idea.

The first enlargement on the concept came with the realization that the broadcaster would need a machine with more than one transport to switch immediately from one short segment to the next. The ability to use common electronics among several transports was also immediately apparent as a cost saving arrangement. One of the early configuration sketches showed five miniature transports in a rack arranged to be manually loaded and threaded with these short segment spools. However, this primitive concept was quickly overridden by the realization that all tape had to be automatically handled and threaded to realize the total potential of the spool configuration.

Robert N. Hurst, Ldr., Broadcast Systems Development, Commercial Communications Systems, Camden, New Jersey, graduated from the University of Louisville in 1951 with the BEE. He did post-graduate work at the University of Pennsylvania from 1952 to 1956. Mr. Hurst joined RCA in 1951, following graduation, and, after one year on the rotational training program, came to the Broadcast engineering activity where he participated in the development of color television broadcast equipment During this period, he also performed tests and studies relating to classified military television applications, and developed equipment for airborne television systems. In 1956, he joined the Advanced Development acitivity, and worked on new color television equipment and on video tape recorder equipment. This latter assignment developed into a full-scale participation in the video tape recorder activity, which extended from 1957 until 1972. During this time, he successively worked on various subsystems for the TRT-1A and 1B vacuum-tube recorders, producing the first transistorized equipment used in these products. He then directed a group of engineers in the design of the servo-mechanisms for the TR-22 series of recorders. He also managed the TCR-100 cartridge video recorder project from its inception to the successful shipping of over 150 units to the field. Since 1972, he has been directing a group of engineers performing broadbased new-product planning and development for the entire broadcast product line. Mr. Hurst has written numerous papers for publications and for presentation at SMPTE conferences, NAB conventions, and other technical gatherings, both in this country and abroad. Since 1967 he has served on the SMPTE Video Tape Recording Committee, and is presently chairman of the Tape Transport Geometry Subcommittee. He was among the original members of the SMPTE Time and Control Code Subcommittee, and was instrumental in the formulation and adoption of the Standard Code. He is presently also a member of the SMPTE Cartridge and Cassette Subcommittee, and is the forefront of the efforts to standardize this medium.

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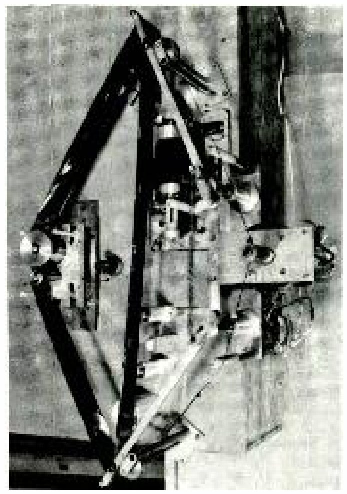
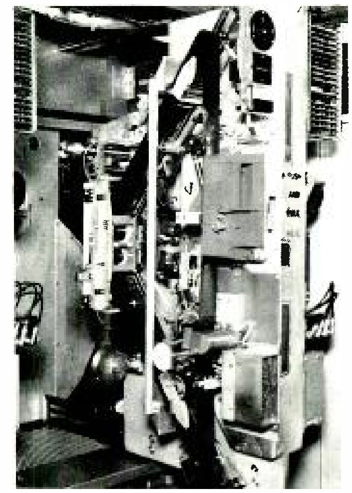
Final manuscript received May 2, 1973.

Fig. 2 — The Signal Processing Unit, which is used in conjunction with the TCR-100 to provide processing of the FM signal.





Figs. 4 and 5 — From string and wire to product. On the left, the hand-cranked original model of an automatic threader. On the right, a present-day automatic threading TCR-100 tape transport.

Automatic handling arrives

At this point, the basic short-spool idea was married to the earlier request (arising from market research) that a way be found to handle and thread video tapes automatically. The two ideas in combination - short segment plus automatic handling-fell into the area of present-day feasibility, and the advantages to be offered to the broadcaster were very enticing. The work was therefore directed toward finding the optimum automatic handling method.

From among several competing methods for automated loading and threading of tape, the concept presently used in the TCR-100 was chosen for a feasibility study. The first automatic threading model was built of plywood and string and operated by hand cranks: it surprised everyone present by functioning perfectly the first time it was tried.

Now with an automatic threading device at our disposal, we next had to develop means of delivering the spools to the threading mechanism automatically. The first step involved encasing the spools in a cartridge, following the precedent set by the audio recording industry. Next, several means of storing the cartridges in a moving magazine were explored, with the final choice being a simple conveyor belt arrangement which could hold a large number of cartridges and deliver them to either of a pair of transports automatically.

Integrated circuits employed

With such an innovative machine being born, we saw that an electronic innovation was also in order. New servo mechanisms, new FM systems, new audio systems and new logic systems employing the latest in integrated circuit technology were placed in design on an urgent basis, with the result that, only fourteen months from that first meeting, a totally new machine - new in mechanisms new in electronics and, most importantly, new in concept - was unveiled at the 1969 convention of the National Association of Broadcasters.

Needless to say, it was the hit of the show. The RCA exhibits were packed with wall-to-wall people. Press coverage was thorough, and the machine was featured on a local television newscast. Broadcasters were quick to realize the potentials of the machine and evinced every interest in obtaining the machines as quickly as possible.

Practical proof needed

However, the RCA engineers were not yet satisfied. Better packaging, better human engineering, better logic - all were possible. Also, for concepts so novel and new, extensive field testing was indicated before we would have the confidence needed to mass produce such a product. Therefore, in the ensuing year, the machine was completely repackaged, drastic improvements were made in the logic, and the human-engineering aspects were improved. This new machine was shown in 1970 at the NAB Convention, and sent out for field testing at Station WDCA in Washington, D.C. This station was chosen for the testing because it was not network affiliated and therefore originated a large number of local commercials every day. It was anticipated correctly as it turned out - that they would thoroughly exercise the machine in a practical, on-line application.

WDCA performance grind

Within weeks the machine had become an essential part of WDCA's operation. Their make-goods decreased, their color

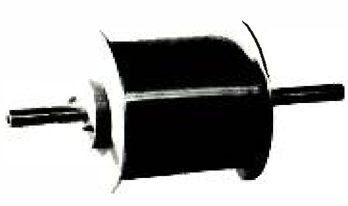
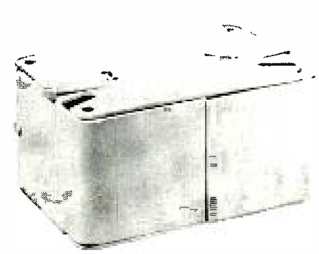
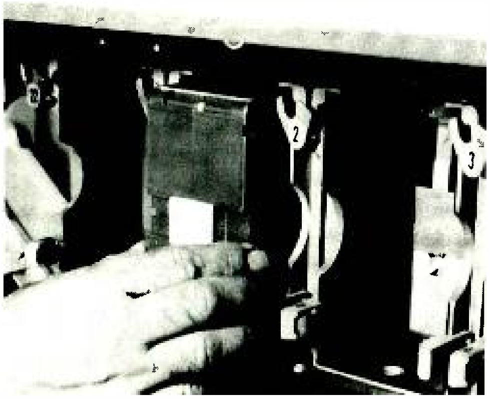


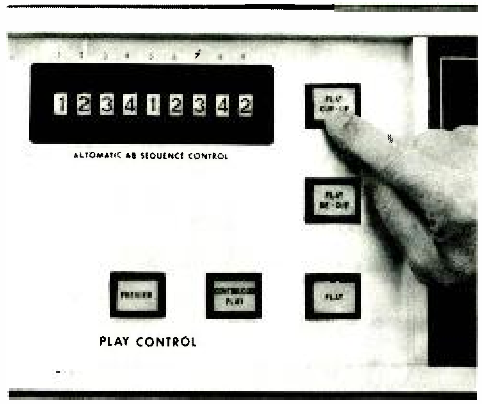
Fig. 3 — The beginning of the cartridge recorder. In early 1968, the author presented this spool of tape to Broadcast Marketing representatives, showing how small a 2-½ 2-minute tape segment could be.



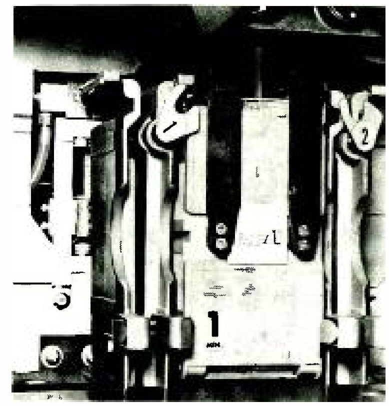
Figs. 6 and 7 — On the left, an early cartridge. On the right, a modern TCR-100 cartridge. Sales of these $20.00 units are approaching the 100,000 mark.



A. The operator places a cartridge in bin number 1 (numbers are on the left)



B. ... and instructs the machine to cue-up the cartridge in the *Play* mode.



C. Two claws seize cartridge and transfer it into the transport area...

Simplified Sequence of Operation — TCR-100: In semi-automatic operation.

quality improved, the number of operating personnel decreased, and their reel-to-reel tape machines were freed for other station applications. The station was visited by envious broadcasters who were entranced with the smoothness of WDCA's operation using the cartridge machine, and were extremely anxious to have cartridge machines of their own.

Although the WDCA operation was in general extremely reliable, the intensive shakedown revealed a few points that needed design attention.

Although the WDCA operation was in general extremely reliable, the intensive shakedown revealed a few points that needed design attention.Using this information, improvements were made, a limited production was begun, resulting in ten machines, eight of which were sent for further field tests and two of which were held in engineering. More field data were gathered, more improvements were made to the machine, and then full scale production commenced.

Over 150 station users

At the present time, there are more than 150 broadcasters enjoying the advantages of TCR-100 operation. Without exception, they find that the machine is an essential part of their operation; that they can no longer exist without its unique capabilities. As a consequence of the intensive field testing; study, and redesign, the machine is extremely reliable.

Equipment transport operation

The TCR-100 is basically two machines in one cabinet. It contains two transports, each with its own independent servo system, its own independent FM system, and its own independent audio system. Each transport is capable of receiving a cartridge, automatically threading and cueing it, playing it, automatically rewinding it, and returning it to the magazine. Each transport also can record a cartridge. As normally received, the machine records on only the right-hand transport; a kit is available to make both transports capable of recording. In the process of recording the entire cartridge is generated, complete with all magnetic cue marks and other format considerations automatically placed on the tape in one pass through the machine. The left-hand transport (known as the A transport) also serves as a source for the copying of a cartridge on the right-hand or B transport. This operation of the machine is called "-to-B".

A unique and important feature of these transports is that they handle tape by the back side only, touching the oxide side of the tape in only two places: at the video and the audio record heads. The result of this arrangement has been a tape life even greater than anticipated by the designers. It had been estimated that backside handling might double tape life; in practice, the very first machine easily quadrupled tape life. Later, customers sent us cartridges still playing with good quality, some having in excess of 800 passes on them. One customer sent us a cartridge finally retired from service after more than 3500 passes.

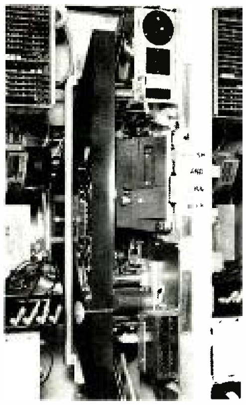
The two transports are parallel to each other and arranged with their motor boards perpendicular to the magazine. The tape path is in a vertical plane with the cartridge near the magazine and the head wheel at the back of the transport.

Capacity for 22 cartridges

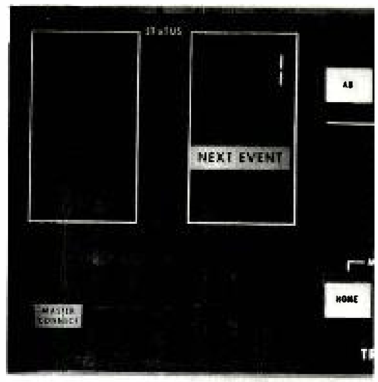
The magazine has spaces for 22 cartridges, which are loaded into the magazine by the operator in the sequence in which they are to be played. In normal operation the first cartridge is played on A deck; the second, on B deck; the third, on A deck; and so on. Although the access openings by which the magazine transfers cartridges to the two decks are separated by the width of five cartridges, it is not necessary for the operator to take this into account when loading the machine. The operator loads cartridges in simple sequence; the machine makes the necessary corrections to place the correct cartridge into the correct deck.

In operation the machine automatically rewinds a cartridge before replacing it in

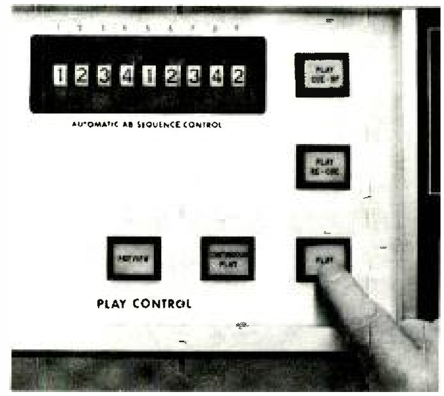
D. ... where the doors are opened and two white threader arms (just to right of cartridge) prepare to extract the tape for threading.



E. In the next instant, the tape is held in a large delta shape over the transport, and will next be quickly lowered into the tape path.



F. The status panel now tells the operator that the *Next Event* is No. 1, so ...



G. ... he pushes the *Play* button, and the program or commercial goes on air. Less than 7 seconds have elapsed since the cartridge was inserted in the bin. *Note*: In *full* automatic operation, the machine will play one cartridge after another, with no human intervention, and with no visible interruption between cartridges.

the magazine. This is essential in avoiding any delay in cueing up that cartridge the next time it is inserted.

Electronic circuitry

In addition to the magazine and transport areas described above, the machine also has four other major areas. Beneath the magazine is found a drawer of electronics which contains the FM, audio, and servo circuitry for the machine. Beneath this drawer is an area reserved for the power supplies, vacuum pumps, and cooling system for the machine.

Above the magazine is the control panel by which the operator may program and control the functions of the machine; this may be done either while standing before the machine or from a remote control position. Behind the control panel is a nest containing the logic circuitry which makes the machine perform its various functions.

All the electronics cards are of the plug-in variety and may be easily placed upon an extender if service is required. In the logic nest the cards are of the nondedicated type; i.e., all connections of the components on the card are brought out to the connector and the necessary interconnections are made by the backplane into which the cards are plugged. Thus, a limited number of types of cards suffice for a very large number of card functions.

Cost effective configurations

The TCR-100 by itself requires that it be fed FM to record. It sends out an FM signal needing demodulation and processing. In brief, it is a FM-in, FM-out machine. The broadcaster may then choose how he obtains the required preprocessed and post-processed signals.

In one very economical configuration the TCR-100 may be connected to a reel-to-reel machine, "borrowing" its record and playback electronics to perform the processing. A TR-70 or TR-60 may be used for this purpose. The configuration is particularly cost effective in that the reel-to-reel machine whose electronics are being borrowed may be used to record at the same time that its playback electronics are being used to receive and process the TCR-100 signal for on-air use.

If the broadcaster prefers a "free standing" machine, he may choose to buy the signal processing unit, which provides the prerecord and the post-playback processing required. The TCR-100 always operates with complete signal processing configurations involving velocity compensation, line-by-line chroma amplitude compensation, and dropout compensation.

How a cartridge is played

To illustrate a very simple use of the TCR-100, let us describe how a single cartridge could be played.

The cartridge to be played is placed in bin No. 1 of the TCR-100, and the operator chooses the A option on the transport control, indicating that he will use only the A deck. He will then press *home* and the magazine will automatically revolve until it places No. 1 bin in front of the A deck. The operator will then press *play cue up*. Two arms will immediately seize the cartridge and transfer it into the receiver of the transport, where two doors will be automatically opened, two fingers will extend the tape into a large triangle, and lower it into the tape path. The machine will then run forward and, finding a magnetic cue mark, will stop and indicate to the operator that the machine is cued and ready to play the next event. The operator will then press *play* and the cartridge will be played for its entire length. Upon finding the magnetic mark at the end of the cartridge indicating that the program is over, the cartridge will be automatically rewound, unthreaded and replaced in the magazine.

It is more normal for the broadcaster to play several cartridges in a sequence. The true automatic nature of the machine is shown in this type of operation described briefly below.

The operator first loads the cartridges into the magazine in the order in which they are to be played. He then selects the

A B mode of the transports and presses the *home* button. The magazine then revolves until bin No. 1 is placed in front of the A deck. The operator then selects the *automatic* mode of the machine.

He then turns his attention to the thumb wheel register called "Automatic Sequence Register" in the control panel. If the first station break calls for three cartridges to be played, he dials a "3" into the left-hand-most window of the ASR. If the next station break calls for five, he places a "5" in the next window, and if the next station break calls for two cartridges, he places a "2" in that window. He can program up to eight cartridges in one station break and may preprogram as many as nine station breaks.

Having performed these operations, the operator now depresses *play cue up*. The machine will automatically transfer cartridge No. 1 into deck A, move the magazine to put bin 2 in front of deck B, automatically transfer that cartridge into deck B, and cue both decks A and B. All this is done without any operator intervention aside from the pushing of the initial button.

When air time arrives, the operator merely presses *play*. Cartridge No. 1 is played, and at the conclusion of its play cartridge No. 2 is rolled and played automatically with a perfect video switch between the two cartridges. Cartridge No. 1 is then rewound and transferred back into its proper bin, the magazine moves again, cartridge No. 3 is transferred into deck A, cued, and made ready to play. At the conclusion of cartridge No. 2 on the B deck an automatic video switch is made to cartridge 3 and it plays in its proper sequence. All these functions are performed without operator intervention.

When the sequence of three has been completed, the machine will automatically cue up and prepare the first two cartridges of the coming sequence of five. Thus, the operator may perform station break after station break merely by pushing the *play* button to initiate the entire break.

The key to the automatic operation of the TCR-100 lies partly in the sophisticated logic behind its main control panel, and partly in the tape format itself. When a customer receives a new cartridge, the tape it contains is unrecorded and devoid of any magnetic marks whatsoever. To record on this tape, the customer inserts it in the machine, and presses *record cue up*. The machine must automatically search out the beginning of the tape, park there, and indicate to the operator that it is ready to record. To carry this out on a tape devoid of any magnetic marks, there must be some form of permanent non-magnetic mark near the beginning of the tape. This is provided by a reflective foil identical in reflectance to that foil used for similar purposes on computer tapes. This foil is sensed by a photocell, and is used to position the tape at the proper record point. No operator effort beyond the pushing of one button is required to prepare the machine for record.

The operator must now inform the machine of the proposed length of recording by means of the message length thumb wheel. If the source to be recorded comes from another tape machine which must be prerolled, he must indicate the amount of preroll desired by setting the preroll thumb wheel.

The operator now presses *record*; the source machine prerolls, and, at the proper time a few seconds later, the TCR-100 rolls automatically. After four seconds, a 100-Hz tone, 0.8 seconds long, is recorded on the cue track, followed by a code burst, 0.2 seconds long, of electronic program identification information (EPIS). This code can provide up to 16 alphanumeric digits to identify the cartridge on playback. Two seconds after the end of the EPIS code, program video and audio commence to be recorded.

This recording continues, and at a point 10 seconds before the end of the message, an 8-kHz tone is recorded. This tone continues for eight seconds, ending just two seconds before the actual end of program. At the end of the program, an additional two seconds buffer is recorded, and the tape is automatically rewound and placed in *play cued* mode for checking by the operator.

If, upon checking the tape, the operator is content with the recorded material, he needs take no further action, for the machine will deliver the cartridge to the proper bin. However, if the operator is not pleased with either the timing of the start of message or the end of message, he may shift the SOM (start of message) magnetic mark, or the EOM (end of message) magnetic mark, by simply dialing into a thumb wheel the number of frames of shift required, and the direction of shift. This shifting is accomplished without altering the audio or video program material.

If, upon reviewing the cartridge, the operator discovers an error in the electronic program identification code, he may revise the code simply by typing the correct code into a register by means of a keyboard located on the TCR-100, and pressing a single button, marked *epis record*. The machine will immediately re-record the code, recue, and replay the just-recorded code, allowing the operator to verify that the code is now correct.

When a cartridge is played, the machine cues to a point just after the EPIS code, thereby allowing the code to be displayed for operator verification during standby and before playback. When the *play* command is given, the machine rolls, and two seconds later produces the program output. Ten seconds before the end of program material, the 8 kHz tone mentioned earlier provides a 10-second pre-roll cue to equipment outside the cartridge machine. However, if the next program segment is from the cartridge machine's other deck, the 10-second pre-roll is ignored. Two seconds before the end of the program, the 8 kHz tone ceases. This cessation produces a signal which causes the adjacent deck to roll. Since the command to roll the adjacent deck occurs two seconds before end of program, and since the subsequent cartridge is cued and waiting two seconds ahead of its program, the result is a continuous, unbroken flow of video as the switch is made between the two cartridges.

In addition to recording and playing, the TCR-100 can automatically dub from one deck to the other, making as many as 21 copies of a single master cartridge, with only the push of a single button required to initiate each recording.

Conclusion

In summary, the TCR-100 is a machine designed to handle automatically the numerous short segments which are such an essential part of a normal broadcast day. It does this in such a competent and reliable manner that the broadcaster who uses the TCR-100 in his station will find he has entered a new era in cost-effective, reliable, and high-quality operation.

COSMIC — a BTSS program for computer optimization of simple microwave integrated circuits

Dr. M. J. Schindler

COSMIC is a BTSS (Basic Time Sharing System) network analysis program with self-optimization capability. Although written for microwave circuits, it accomodates all lumped or distributed circuit elements that can be represented by a complex 2x2 matrix. The network analysis section uses an improved version of ASPIC (Analysis of Simple Passive Integrated Circuits), expanded to accomodate frequency-dependent elements described by S-parameters, or RLC model. Permissible topologies include branches on branches (both parallel and series) and parallel paths; any element can be designated as the interface with a composite "generator" or "load."

BEFORE THE DAYS of computer-aided design (CAD) the electrical engineer frequently had to choose between time-consuming, error-prone calculations of limited accuracy, and the cut-and-try approach. Although frowned upon, the experimental method usually won out, and a good engineer was one whose experience or intuition led him to "cut" rather close to the optimum.

With the evolution of computers, mathematical models have been replacing experimental models of increasing complexity. Eventually we may be able to mathematically describe the forces between all interacting charge carriers of an electrical circuit and, by setting up the proper boundary conditions, solve for the fields and currents of an arbitrary configuration. But today CAD, on this fundamental level, can only tackle very simple geometries.

Dr. Max J. Schindler, Senior Engineer, Microwave Device Operations, Industrial Tube Division, Electronic Components, Harrison, New Jersey, received the MSEE in 1951, and the degree of Doctor of Technical Sciences in Solid State Physics in 1953, both from the Technische Hochschule in Vienna, Austria. He joined the RCA Microwave Tube Operations in 1958 and has since worked on a number of basic technical problems related to the design of traveling-wave tubes, magnetrons, crossed-field devices and solid state devices. Among his major contributions are improvements in periodic-permanent-magnet focusing structures and the formulation of an improved design technique for such structures. His first assignment at RCA was as an engineer in the Microwave Chemistry and Physics Laboratory, where he worked on focusing structures and bulk attenuators for traveling-waves tubes. There followed an assignment as acting group leader of the Magnetron Design Group, where he directed the development of a hydraulically-tuned magnetron. From 1963 to 1967, he has led groups working on the design and development of high-efficiency traveling-wave tubes for communication satellites and recirculating TWT's for ECM systems. Dr. Schindler joined the Microwave Applied Research Laboratory of the David Sarnoff Research Center in 1967, where he worked for two years on crossed-field delay devices and computer techniques for Microwave R&D. After his return to Harrison, he worked in Solid State Engineering on integrated components and on transferred-electron amplifiers. For the last year, he has been instrumental in the development of miniature traveling-wave tubes with the highest power-frequency product in the industry. Dr. Schindler has published many articles, presented a number of papers, and holds three patents. He is a Senior Member of IEEE and is Treasurer in the North Jersey Section. He is listed in *American Men of Science.*

At present, we are therefore restricted to CAD on a much more macroscopic scale. When the behaviour of a real-life circuit can be simulated reasonaby well by lumped components for which acceptable models exist, we can make use of Kirchhoff's Laws and calculate voltages and currents in rather complex circuits with programs like ECAP or CIRCAL. But when the available computer is too small and/or truly distributed elements are involved, CAD is forced to a third level. The circuit is then dissected into manageable pieces, each of which can be described to some extent either by equations or simply by a set of measured parameters such as the well known *S*-parameters. If the engineer who uses such a circuit analysis program is aware at all times of the limits within which the used equations apply, even such a relatively low-level computer simulation is a powerful engineering tool, which can obviate most experimentation.

COSMIC operates at this third level, but the self-optimization feature makes it superior, both technically and economically, to the experimental approach. COSMIC consists of a network analysis section and a minimum-seeking algorithm plus the necessary connective tissue. The network analysis section is an improved form of the BTSS program ASPIC.[1]

In COSMIC, all circuit elements are defined by four "descriptors." When an element is declared variable, the optimization program changes the value of the last two descriptors, one at a time (*e.g.* length and width of a microstrip line, or R and X of a lumped component). After every change, the subroutine ASPIC recalculates an error function which represents the four output functions chosen by the user, all of them weighted and supplied with limits. If the new error is smaller than the previous one, the changed descriptors are retained; otherwise, the previous ones are restored.

Ideally, the global minimum of a network with N variables should be found by varying all the variables in small steps and comparing the resulting "errors." The memory space required to store the N-dimensional array of S steps, and the computer time required to calculate the S^N solutions, quickly becomes prohibitive as the number of variables increases. Various search strategies have therefore been devised and are described in the literature.[2]

For unimodal functions (only one extremum in the desired range) the dichotomous search is very efficient. In this method, pairs of solutions are compared and the best location for a new trial is determined. When more than one variable is involved, they are treated one at a time (sectioning method). This method can, however, lead to a false minimum as indicated by Fig. 1a.

Other methods are therefore preferred. One such method is that of steepest descent (gradient method), again using dichotomous search once the gradient at the base point is determined (see Fig. 1b). As the number of variables increases, the gradient method becomes cumbersome and slow because of the large number of partial derivatives which must be calculated. If the "valley" is of a curved nature, the number of iterations can become excessive.

For COSMIC a pseudo-random search method was adopted which, according to the literature,[3] is more efficient and more reliable than the methods described above. It is basically a sectioning method, but the randomness both increases the speed of the search and avoids the likelihood of "hanging up" on a ridge.

Of course neither of these methods is guaranteed to find a global minimum. Once the search has entered the region of a local minimum, it locks in and becomes utterly oblivious to the rest of the world. Because only a grid search can avoid this predicament, it was decided to equip COSMIC with a limited grid search capability which is also handy for work in the "analysis" mode of COSMIC.

Organization of COSMIC

The logical organization of COSMIC is best understood by following the flow chart of Fig. 2. First, the inputs are read in several groups until the program is interrupted by a PAUSE indicated by the printout "NEXT?" At this point, corrections to the inputs can be made either by typing in individual variables or by repeating part of the input routine. The program returns to this PAUSE whenever the current request is completed, and the user can instruct the computer what to do next. START P, for

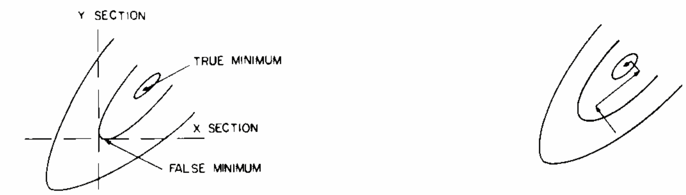


Fig. 1 — Search by sectioning (a) and steepest descent (b).

instance, initiates printout of the descriptors, while START E permits the user to change one specific circuit element. When RETURN is pressed without an entry, the program executes in the mode specified.

After examining for LOOP and CHECK (which will be discussed later) the value of MODE and ITER is checked. If either is zero, no optimization is desired, and the program branches to "ANALYZE". When this branch is completed, control is again transferred to the user by means of the PAUSE.

If MODE > 0, the OPTIMIZE branch is entered and optimization is accomplished by an iterative process to be described later. At the end of each iteration cycle the program checks for completion and, if incomplete, updates the iteration counter JTER. Completion occurs either when the desired number of iterations is completed (JTER = ITER) or when the circuit "error" changes by less than a predetermined amount (normally 2%).

When optimization is complete, the results are printed out, the LOOP flag is set and, after an optional CHECK, control again returns to the user. In the "CHECK" procedure, all variable values are incremented and decremented by *n*% where *n* is given by the user. If any of these changes improves the circuit performance by more than 1%, the relevant information is printed out, regardless of the limits set for any specific variable. The user can thus decide whether he should change any limits, perform additional iterations, or accept the results.

During the PAUSE, the user can also change the outputs (START O), the frequencies (START F) or other input information, or he can write optimization results to a tape (START W.)

To facilitate understanding of the program architecture, the flow chart of Fig. 2 is not only intentionally coarse, but also somewhat fictitious. In the actual program, the section referred to a

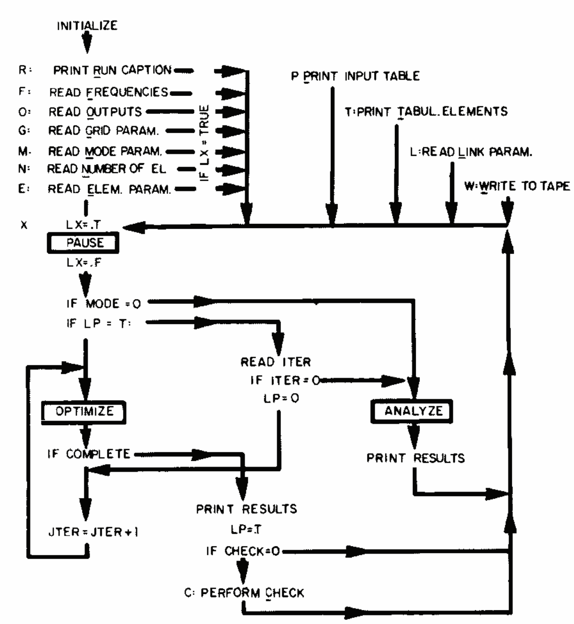


Fig. 2 — Simplified flow chart of COSMIC.

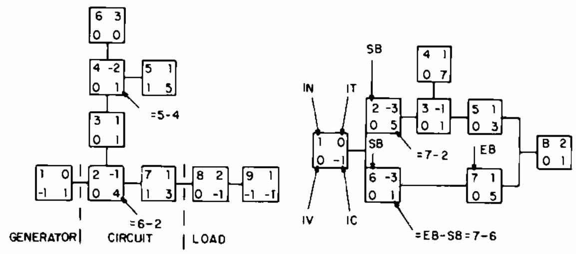
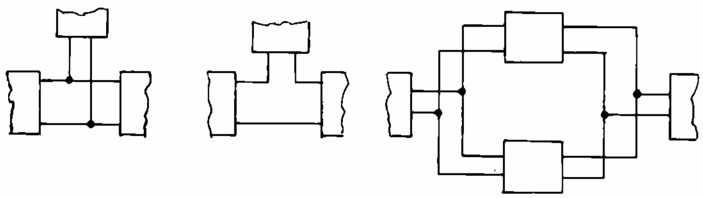


Fig. 3 — Two circuit examples.

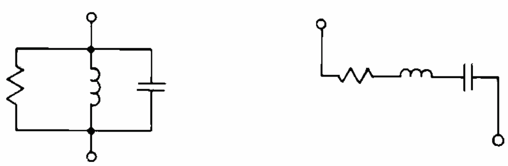
a b

Fig. 4 — Parallel (a) and series (b) cascade connection of circuit element E.



a b c

Fig. 5 — The topological elements: parallel branch(a), series branch (b), parallel path (c).



a b

Fig. 6 — RLC circuits with IC = 1(a) and IC = 2(b).

"CHECK" is embedded within the section labeled "OPTIMIZE" and the section "ANALYZE" is part of the subroutine ASPIC, which is called repeatedly during "OPTIMIZE." The above description should, however, suffice to outline the basic logic used in COSMIC, and the details will easily fall in place when an example is discussed.

Network analysis

The use of COSMIC will best be described by examples after the essential definitions have been made. The circuit to be analyzed is first broken down into elements; one group of elements describes the "generator," another group the "circuit proper," and a third group the "load." If no generator or load are defined, the program assumes a value of 50Ω. The circuit elements can be separated into two kinds: those which represent actual circuit components, and those which represent interconnections (topology elements). The former are described by 4 integers plus 4 real descriptors, or by frequency tabulations, the latter only by 4 integers.

In Fig. 3 the various elements have labels IN, IT, IC, and IV, defining the integers. IN numbers the circuit elements in sequence: 1 must be closest to the power source and each consecutive element number must go away from the input. Labels IT and IC are used to describe the element as to topology and kind of circuit, while IV indicates whether an element is variable, constant, or frequency dependent.

Description of circuit elements

Because this paper is not intended as a user manual for COSMIC, which is available (Ref. 7), only the essential features of element description are reviewed.

Actual circuit elements, when simply strung together in a cascade as in Figs. 4a and 4b, are designated by IT=1, except that the one element which defines the end of the generator (IN=1 in Fig. 3) has IT=0, and the element which indicates the beginning of the load (IN=8 in Fig. 3a) has IT=2. To be uniquely defined, the beginning of the circuit proper or the load cannot be located on a branch, but must always lie on the main sequence of the circuit.

The branching elements have values of IT <0, and include the parallel branch as shown in Fig. 5a, the series branch (Fig. 5b), and the parallel path (Fig. 5c). Branches on branches are permitted to 3 levels. When the computer encounters a branch point, it puts the current transfer matrix (which describes the circuit up to the branch point) into storage, and starts calculation of a new transfer matrix.

When the program encounters the end of a branch, it combines the two matrices according to the topolgy, and then continues to the next higher value IN. Consequently, the numbering sequence is: main line, branch level 1, branch level 2, branch level 1, main line. The integer IC is used in topological elements to define the length of the branch.

The integer IV is used to indicate whether an element is invariant (IV=0), or can be varied for purposes of circuit optimization (IV=1). A third category (IV<0) indicates "tabulated" elements, such as frequency-dependent lumped components which are also accepted as *S*-parameters or in the form of a transfer matrix.

Circuit elements are generally defined by the value of IC(IN) and by the descriptors D(IN, ID) where IN is the sequential number of the element, and ID=1 to 4. Lumped elements, for instance, are labeled IC=1 if the element is parallel-connected (Fig. 6a) and 2 if connected in series (Fig. 6b). Lumped elements can be expressed by *R*,*L*,*C* or in terms of *R* and *X*, *G* and *B*, or the reflection coefficient.

The program accepts three categories of transmission lines: microstrip and parallel-plate ("sandwich") defined by their physical dimensions, and general transmission lines defined by their electrical characteristics. Elements can also be defined by their (ABCD) matrix. The ideal transformer is a special case, which can be used to reduce multiports to two-ports (Ref. 1, p. 11). For specific applications, users may want to input elements not covered in COSMIC (*e.g.*, an acoustic transducer). For this purpose, some space has been left in the appropriate part of the program, and the user can enter his own equations.

Any physical circuit component can be described at up to 10 different frequencies as a "tabulated" element, but the number of such elements is limited by the available storage space. Once an element has been declared "tabulated" by setting IV<0, the read request for the descriptors is repeated NF times, where NF is the specified number of frequencies.

Variable elements

When COSMIC is used in the optimization mode, any element specified by a D(IN,ID) array can be declared variable by setting IV(IN)=1. Only the two last descriptors, D(IN,3) and D(IN,4), are varied in the optimum seeking routine, but the assignment of the descriptors was chosen in such a way that this does not impose a limitation. For microstrip components, the length and width of the conductor are varied; for general transmission lines the impedance and electrical length; and for *RLC* components, *L* and *C* are varied. A variable resistance can be introduced in the form of *R*, *X*. For all variable elements limits must be specified for the 3rd and 4th descriptor; if the limits for one are chosen very narrow, then only the other is in effect variable.

Grid variables

COSMIC permits incrementation of up to 4 descriptors by either a constant increment or by a given percentage. In the ANALYZE mode (MODE=0) the program then provides a complete frequency printout for all combinations of descriptor values, after which the original descriptor settings are restored. In the OPTIMIZE mode the error at all descriptor combinations is calculated, and those descriptor values at which the error is a minimum are substituted for the original descriptors. Thus, a good

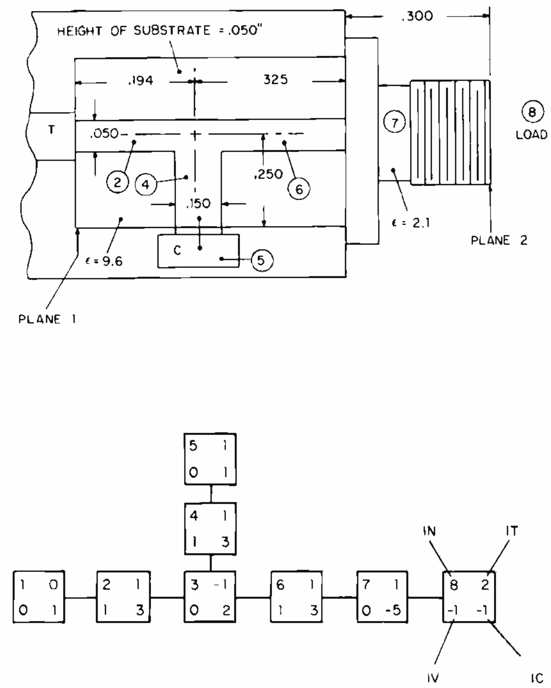


Fig. 7 — Physical (a) and COSMIC representation (b) of the circuit used in the application example.

```
/CODE COSMIC

                                        Ø to 28 literals for identification only
                                        ↓
COSMIC I      10/11/71      13.21      RUN: EXAMPLE, ANALYSIS MODE
IR=0 .......... # of TAPE containing input info (Ø=terminal)
NF=0 .......... # of tabulated frequencies.  If > 0, next READ would be FT(1)=
{FL=1.5........ lowest frequency in GHz
{DF=.2......... frequency increment.  If DF < 0,FR=FR*(1-DF/100)
{FH=2 ......... highest frequency
{OUT(1)=16..... input impedance, real and imaginary
{OUT(2)=-27.... output admittance, magnitude and angle
{OUT(3)=0,0.... outputs 3 and 4 are blanks
{MULT(1)=1 .... multiplier for output #1 is 1.
{MULT(2)=50.... this multiplier will normalize admittance to 50Ω
{MULT(3)=1,1... 1 suggested for unused outputs
{GN(1)=4....... IN for 1st grid variable
{GD(1)=4 .......ID for 1st grid variable
{DL(1)=50 ..... lowest value of 1st grid variable
{DD(1)=50 ..... increment of 1st grid variable.  If DD( ) < 0, D ( ) = D( )*(1-DD( )/100)
{DH(1)=180 .... highest value of 1st grid variable
GN(2)=0,0 .... no second grid variable.  GN(1)=Ø,Ø bypasses grid
MODE=0........ no optimization
NC=8.......... # of circuit elements
{IT(1)=0....... circuit element 1: end of generator
{IC(1)=1                           RLC circuit, parallel-connected
{IV(1)=0                           not variable
{D(1,1)=1.........................  parallel RLC
{D(1,2)=10                          R=10Ω
{D(1,3)=0                           L=σ
{D(1,4)=0                           C=0
IT(2)=1,-3,0..............element 2: stripline with ε=9.6, height=.05", length=.194",
D(2,1)=9.6,50,194,50                 width=.05".  No printout of characteristics
IT(3)=-1,2,0 .............element 3: parallel branch, ending with elem. 5, hence IC=5-3=2
IT(4)=1,-3,0 .............element 4: same as 2, except length=.25"
D(4,1)=9.6,50,250,150
IT(5)=1,1,0 ..............element 5: parallel RLC circuit, parallel connected
D(5,1)=1,0,0,72                        R = α, L = α, C = 72 pF
IT(6)=1,3,0...............element 6: same as 2, except length = .325", but with printout
D(6,1)=9.6,50,325,50                   of line characteristics
IT(7)=1,-5,0..............element 7: 3 mm connector, represented by "general transmission
D(7,1)=.69,0,50,300                    line." From ε=2.1, V/C=.69. No loss, 50Ω, .3" long
IT(8)=2,-1,0 .............element 8: lumped, from slotted-line data, parallel-connected.
D(8,1)=4,50,3.5,-.195                  ZØ=50Ω, VSWR=3.5, Angle= -.195 wavelengths
NEXT?
  6000 START P ◄────── request to print inputs
GRID VAR.1  D(4,4)   DL= 50.000,   DD= 50.000,   DH= .180E+03

   IN    IT    IC    IV     D(IN,1)     D(IN,2)     D(IN,3)     D(IN,4)
    1     0     1     0       1.000      10.000       0.000       0.000
    2     1    -3     0       9.600      50.000     194.000      50.000
    3    -1     2
    4     1    -3     0       9.600      50.000     250.000     150.000
    5     1     1     0       1.000       0.000       0.000      72.000
    6     1     3     0       9.600      50.000     325.000      50.000
    7     1    -5     0       0.690       0.000      50.000     300.000
    8     2    -1     0       4.000      50.000       3.500      -0.195
NEXT?
  6000
```

Fig. 8 — Application example, inputs.

Table 1 — Outputs.

Out	*Caption*	*Description*
0		blank
1 *	I VSWR 0	input and output mismatch
2 *	FGAIN&PH	forward gain ((dB) and phase (deg)
3 *	RGAIN&PH	reverse gain (dB) and phase (deg)
4 *	REFG&PH	reflection gain (dB) and phase (deg)
5	A B C D	term A of circuit chain matrix
6	A B C D	term B of circuit chain matrix
7	A B C D	term C of circuit chain matrix
8	A B C D	term D of circuit chain matrix
9	OPTION 1	user option
10	OPTION 2	user option
11	S11. I:RC	input reflection coefficient
12	S12. R:TC	reverse transmission coefficient
13	S21. F:TC	forward transmission coefficient
14	S22. O:RC	output reflection coefficient
15	Z GENER.	generator impedance
16	Z INPUT	input impedance
17	Z OUTPUT	output impedance
18	Z LOAD	load impedance
19	Z LD CALC	calculated load impedance
20	OPTION 3	user option
21-30	1/....	reciprocal of outputs 11 to 20

starting point is found for the following search. While the *pseudo-random* search routine is restricted to the third and fourth descriptors of the variable elements, the *grid* search can vary *any* descriptor of *any* element. This feature enables COSMIC to choose automatically between a parallel and a series *RLC* circuit.

In addition to the element description, other input information is either required or possible. First of all the frequencies at which the circuit is analyzed are inputted by a low and a high limit, plus either the amount of the increments or their number. Either linear or logarithmic increments can be chosen. If tabulated elements are used, the frequencies can be spaced in arbitrary and irregular intervals. A number of preset inputs can be changed by the user during the PAUSE. They include the reference impedance at the input and output, microstrip conductivity, and logic switches which control various printouts. The inputs governing circuit optimization will be discussed later.

A circuit example and the corresponding inputs are shown in Figs. 7 and 8. This circuit is used to match the output of a transistor (T) to the following complex load. It will be discussed further in connection with the optimization process.

Outputs

In the network analysis mode, COSMIC supplies a wide variety of outputs, all calculated from the chain matrices describing the network shown in Fig. 9.

Mismatches and vswr's are normally calculated with *ZG* and *ZL* as reference impedances, even though these may be complex quantities in order to maintain consistency with the *S*-parameters, and to permit optimization to a complex conjugate match. For a derivation of the 20 basic outputs the reader should consult Refs. 1 and 7. All outputs except 0 to 4 are normally listed by real and imaginary components. The prefix "—" (minus sign) for any of the outputs results

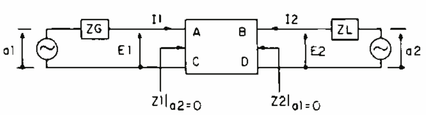


Fig. 9 — Definitions for calculation of outputs.

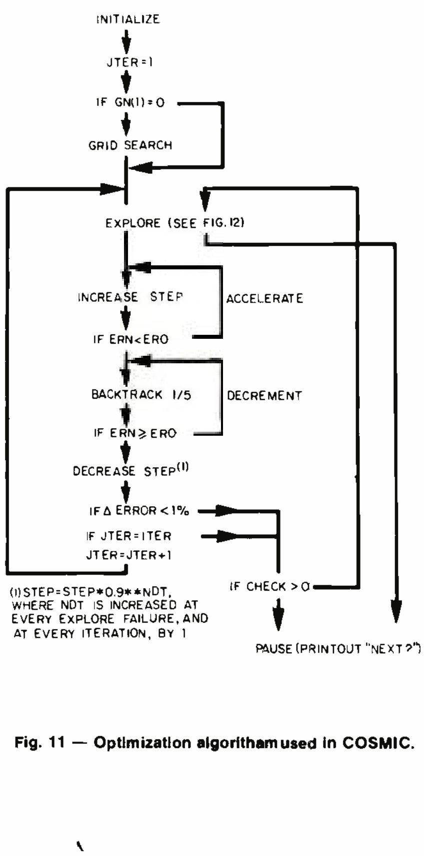


Fig. 11 — Optimization algorithamused in COSMIC.

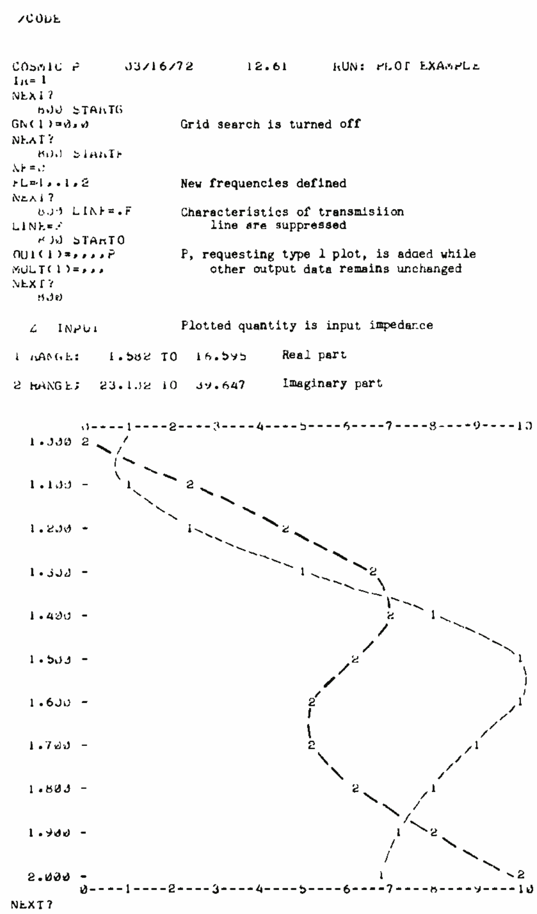


Fig. 10 — Demonstration of plotting routine.

in a printout by magnitude and angle and for identification the symbol "*" is printed after the respective multiplier.

Outputs 21 to 30 are the reciprocals of outputs 11 to 20, respectively. In the printout, reciprocals are indicated by the prefix 1/ before the respective caption, *e.g.*, 1/Z LOAD. Up to four of the above outputs can be used in any arbitrary combinations.

As mentioned before, COSMIC can also plot the real and imaginary part of any of the above outputs. Fig. 10 demonstrates the plotting routine. First, several changes are made as explained in the figure. When "NEXT?" is followed by no entry - return, plotting begins with printout of the plotted variable, and the limits which the program had chosen for the real ("1") and imaginary ("2") part of the input impedance.

The optimization mode

The search strategy of COSMIC is summarized in the program flow chart, Fig. 11. It starts with an optional GRID SEARCH for up to four variables designated by the user. It then enters the EXPLORE segment which will be discussed in more detail later. This segment establishes an N-dimensional vector (N=number of variable elements) which points toward the minimum. In the ACCELERATE section, additional (increasingly larger) steps are taken in the same direction until the error function increases. The DECREMENT section then backtracks until the base point for the lowest value of the error function is established. A new iteration begins with smaller increments but the same or larger acceleration factor. This change is necessary not only to make successive cuts finer, but also to avoid the possibility that the program gets into an endless loop, retracing itself over and over.

The heart of the program is the EXPLORE section, described in Fig. 12. Here the two variables are evaluated sequentially; *e.g.*, line length *L* and characteristic impedance *ZO*, or *R* and *X*. To be physically meaningful, these two variables should preferably be electrically orthogonal, like *L* and *ZO*. From a given base point, the computer can then proceed in four directions (*e.g.*, more or less *L*, and higher or lower *ZO*). The pseudo-random integer KD(IN) determines which step is taken. If successful and permissible, this step terminates the search for element IN, and the next element is examined. Otherwise, the next direction is tried, until an improvement is found, or all choices are exhausted. The size of the increment is DEL times the value of the element. The incremented value is not permissible if it exceeds the boundary value, in which case the next direction is tried. If no direction yields an improvement, the value of the variable is set back to the original amount. For each element an increment is thus established (it can be zero) which decreases the error. When all these increments for the *N* variable elements are calculated, an *N*-dimensional vector has been created that points toward a lower error function. This vector, multiplied by ACC, determines the step size.

The search algorithm was developed with the help of various functions so that the

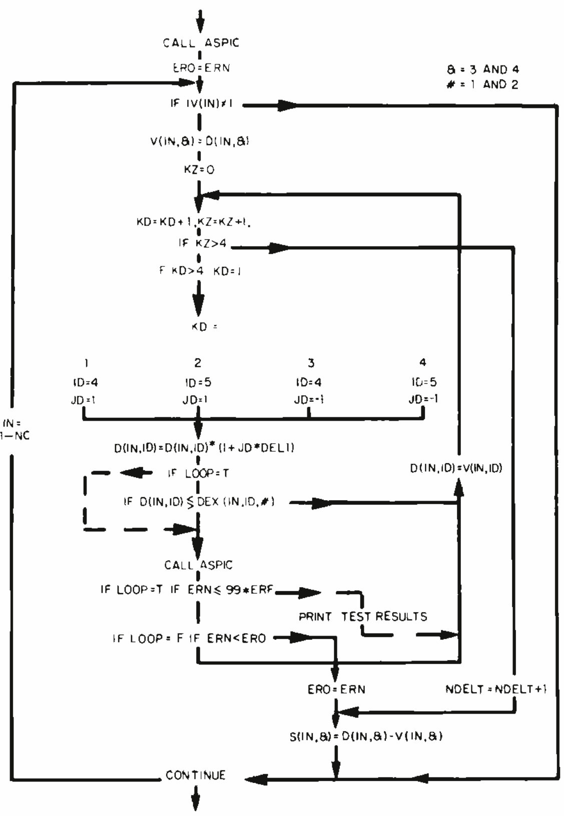


Fig. 12 — Flowchart of the Explore section of COSMIC.

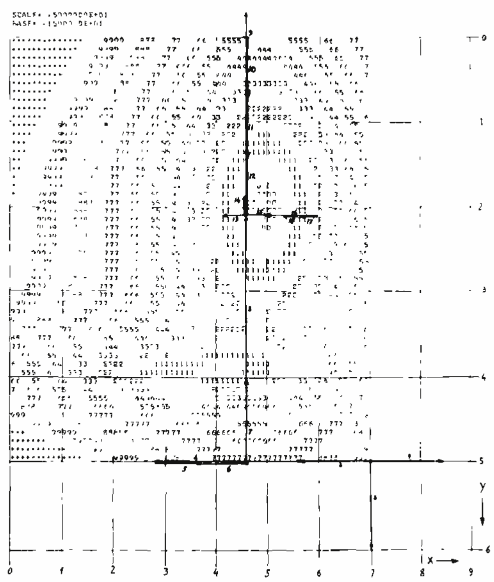
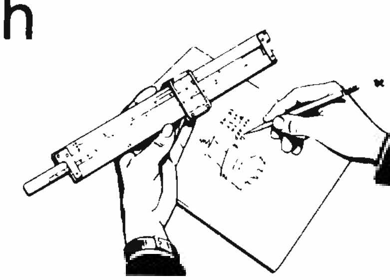


Fig. 13 — Example of a COSMIC search in the two dimensions.

Engineering and Research Notes



Pulse-width control circuit

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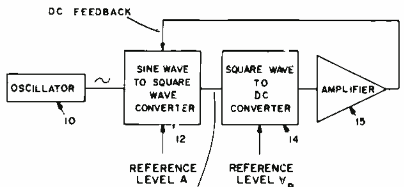
This note describes a circuit for controlling pulse width which is useful, for example, for driving a timing-pulse generator.

The sinewave produced by an oscillator (Fig. 1) is applied to a sinewave-to-squarewave converter. The squarewave drives a squarewave-to-dc converter.



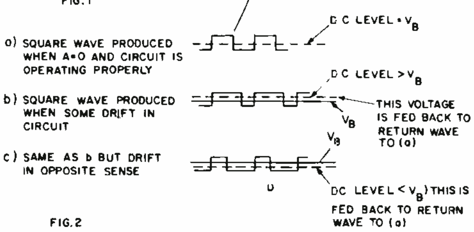


Fig. 1 — Pulse-width control circuit block diagram. **Fig. 2 — Waveforms.**

The dc output from the converter has an amplitude proportional to the asymmetry of the squarewave and a sign, plus or minus, dependent upon whether the positive-going portion of the cycle has a greater duration than the negative-going portion of the cycle or vice-versa (see Fig. 2). The dc amplifier feeds back an error voltage to the converter.

Fig. 3 is a block and schematic circuit diagram of the system. Transistors Q601, Q602 and Q603 make up the sinewave-to-squarewave conterter. The base of Q601A is referenced to ground and the base of Q601B is referenced to the output of the operational amplifier U601. The sinewave produced by the oscillator is applied to the base of transistor Q601B through capacitor C622 and the zero average value of the sinewave should center about the dc reference level.

Transistor Q603 is a level shifter and buffer and U19 is a complementary gate which develops the output drive level. Transistors Q609A, B and transistor Q611 make up the squarewave-to-dc converter. The base of transistor Q609B is referenced to a V_B=1.5-V dc level, which is the timing reference level for transistor-transistor logic (TTL). Since the collector load resistors R622 and R623 are of equal value, if the signal on the base of Q609A has equal duration half cycles and is symmetric about the 1.5-V reference level, no offset voltage will be developed across storage capacitor C619.

If drifting of the sinewave relative to the dc reference level should occur, the square wave becomes asymmetrical as shown in Fig. 2b or 2c, and transistors Q609A, Q609B charge capacitor C619 in a sense dependent on the direction of drift. Amplifier U601 amplifies the dc level stored at capacitor C619 and applies it to the base of transistor Q601B. This action causes the average dc level of the sinewave again to center at the dc reference level. Transistors Q604A and Q604B are simply buffers.

If duty cycles other than 50% are required, the ratio of R623/R622 can be changed to produce the required offset. The circuit of Fig. 3 is based on the use of TTL logic, hence the use of +1.5V as the reference level V_B at the base of transistor Q609B. The circuit, however, is adaptable to other logic types, provided V_B is chosen to be equal to the timing reference voltage of the logic used.

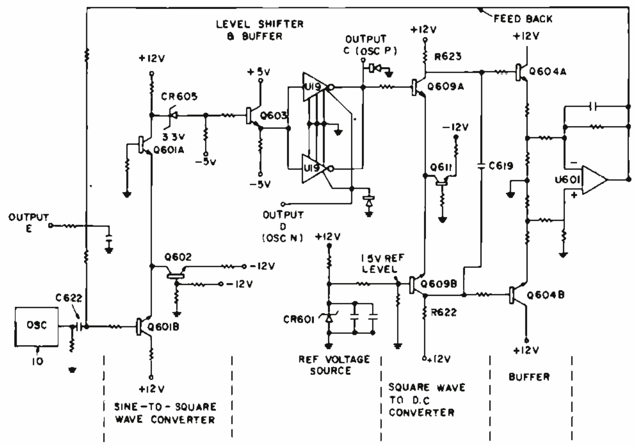


Fig. 3 — Circuit diagram.

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*Since this note written, Mr. Mancini has left RCA.

High-precision distance-measuring laser

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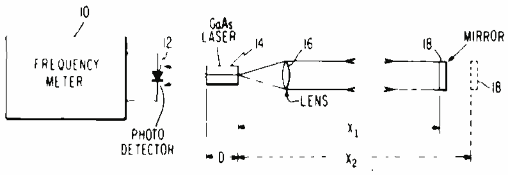
Distance measuring, with an accuracy of the order or better than one part in 10^7, is achieved with an injection laser. The time of flight of a coherent wave is converted into a frequency that can be measured with an accuracy of better than one part in 10^{10}. The apparatus implementing the technique described here can be used for precision metrological length measurements and related parameters such as indices of refraction.

Gallium arsenide (*GaAs*) injection lasers can be operated in a spiking mode consisting of recurrent pulses of coherent radiation with a repetition rate in the order of one GHz. Optical feedback of these spikes delayed by a transit time slightly shorter than the spiking period, stabilizes the spiking frequency and "pulls" it to make the period equal to the external transit time.

In the apparatus shown in Fig. 1, a frequency meter is coupled to a photo detector, and a *GaAs* laser is positioned as shown with respect to the photo detector and lens and the mirror.

The spiking frequency $f = c/(2x + d)$, where c is the velocity of light; d is an effective distance corresponding to the transit through the diode of length D. Thus, d is equal to $2nD$, where n is the index of refraction of the $GaAs$ laser in the active region.



If the position of the mirror iw changed from x_1 to x_2, then the spiking frequency will change from f_1 to f_2. Typically, the changes developed by such mirror changes are in the order of 15 MHz/cm at an average distance of 10 meters. The change in path length can then be determined from the change in frequency as follows:

$$f_1 = c/(2x_1 + d) \text{ and } f_2 = c/(2x_2 + d)$$
$$f_2^{-1} - f_1^{-1} = (2x_2 + d - 2x_1 - d)/c = 2(x_2 - x_1)/c$$

hence

$$x_2 - x_1 = c(f_1 - f_2)/2 f_1 f_2$$

Knowing the velocity of light (c) with a present uncertainty of 3 parts in 10^7 (while the expected future uncertainty is one part in 10^{10}) and the two frequencies (f_1 and f_2) measurable with an accuracy of one part in 10^{10}, the change in position can be determined with an accuracy of 3 parts in 10^7 using the present uncertainty limitations of the velocity of light. The measurement can be simply read from a digital display counter by a frequency meter or a suitable spike counter. This apparatus and the method of using it provides a means for quite accurate measurements of small distances in a simple and relatively inexpensive way.

In practice, a movable mirror is lined up with each facet of the specimen, in turn, for measuring the two distances x_1 and x_2. The sample length is: $L = x_1 - x_2$.

This method may also be used to determine the index of refraction η' of a specimen, provided the material is transparent to a wavelength of $0.9\ \mu$. If the length of the specimen is L, and the refractive index is $\eta' > 1$, the apparent optical path is increased by $2(\eta' - 1)L$ when the specimen is inserted in the optical system. From the resulting change in frequency, one obtains the refractive index η by way of:

$$f_2^{-1} - f_1^{-1} = 2(\eta' - 1)L/c \quad \text{or} \quad \eta' = (c/2L)[(f_1 - f_2)/f_1 f_2] + 1$$

Radiation detector using a Geiger tube and micropower integrated circuits

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This cigarette-case size Geiger Counter uses only three micropower integrated circuits, and was designed as a survey device to monitor radiation-luminous clocks, watches and other potentially hazardous sources of ionizing radiation.

Both aural and visual indications are provided by a built-in speaker and meter. Power is supplied from a single 6.75-V mercury battery. The use of micropower IC's permits the circuit to "idle" with micropower consumption and yet provide capability for operation at high peak power when the counter-tube detects the presence of radiation. The small speaker is coupled directly to a potentiometer that controls the volume of the output signal from the power one-shot multivibrator. In addition to driving the speaker, this one-shot also operates the meter, which is calibrated for a full-scale deflection of 5,000 counts per minute.

To ensure stable operation of the Geiger-Mueller counter-tube, a regulated 900-V supply is included within the unit. A unique micropower amplifier switch IC, the RCA type CA3094T, is used as a power-multivibrator to drive a step-up transformer for this supply. Another micropower comparator, the RCA type CA3080A, is used as the control element for the supply. This comparator, while consuming less than $30\mu W$, maintains a constant high voltage by varying the duty-cycle of the multivibrator. Total supply-current for this regulated 900-V supply is under 2mA.

The other one-shot multivibrator provides pulses of constant amplitude and constant pulse-width to operate both the speaker and meter. Thus, the average current through the meter is directly proportional to the pulse-rate output from the counter-tube. Full-scale meter deflection (1mA) represents 5,000 counts/minute or 83.3 pulses/second. A convenient calibration check-point is also provided on the meter-scale for 3600 pulses/minute (60 pulses/second). This input is externally introduced by touching a small external contact on the case (TP on Fig. 1) to introduce a signal of the frequency of the power line.

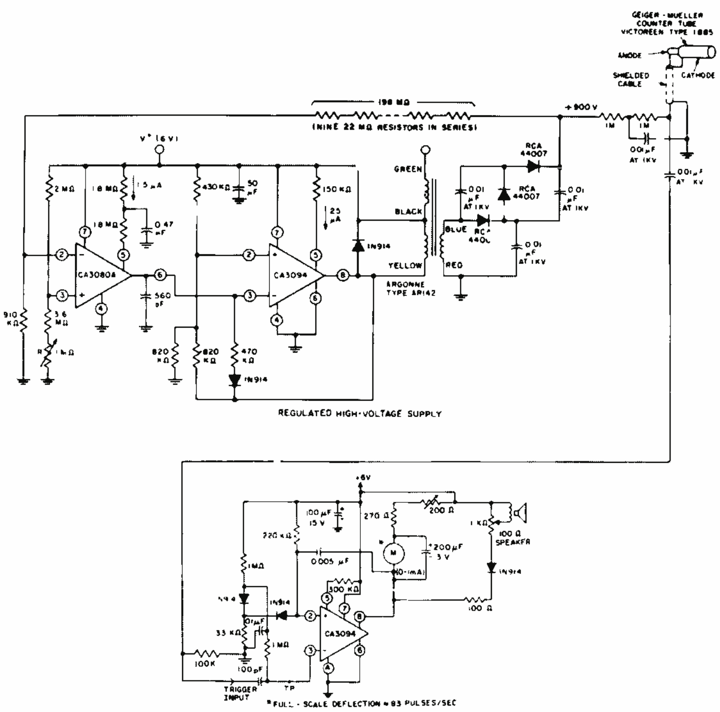

Fig. 1 — Geiger Counter schematic.

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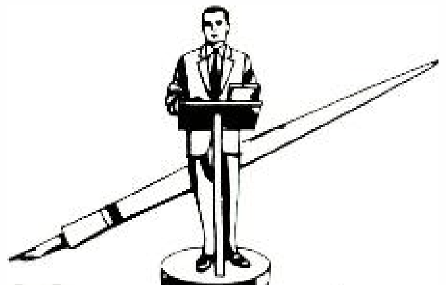

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160 Laboratory Techniques and Equipment

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X-RAY SPECTROMETRIC ANALYSIS, Principles, Instrumentation, and Applications of — E.P. Bertin (Labs,Pr) Annual Two-Day Educational Seminar for the Local Scientific Community. spons. by Reading, Pa. Chemists Club.; 3/21-22/73

170 Manufacturing and Fabrication

production techniques for materials, devices and equipment

LIQUID PHASE EPITAXY — Techniques and Applications — H. Kressel (Labs,Pr) *J. Vacuum Science and Tech.*, Vol 10, No. 1, p. 262. 1-2/73

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PRODUCTION CONTROL SYSTEMS, Utilizing Time-Share Computers in — R H. Higgins (EC,Har) IEEE Conv., New York. NY; 3/27 73

175 Reliability, Quality Control and Standardization

value analysis, reliability analysis, standards for design and production.

INTERCONNECTIONS — B R. Schwartz (M&SR,Mrstn) *Electromechanical Design;* 3/73 and 4/73

QUALITY CONTROL TRAINING — G.G Allen (M&SR,Mrstn) Northwestern Indiana Section of ASQC, Fort Wayne, Indiana; 4/24/73

180 Management and Business Operations

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SERIES 200 MATERIALS, DEVICES, & COMPONENTS

205 Materials Electronic

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ABSORBED OZONE, Charge Transfer of — H. Kiess, T. Freund (Labs,Pr) *J. of Physical Chemistry*, Vol. 77, No. 4, p. 556, 2/15/73

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Si/Cs/O SURFACE, Structural and Electronic Model of Negative Electron Affinity on the — J.D. Levine (Labs,Pr) *Surface Science*. Vol. 34, No 1, p 90; 1/1/73

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210 Circuit Devices and Microcircuits

electron tubes and solid-state devices active and passive, integrated, array and hybrid micro-circuits, field-effect devices, resistors and capacitors, modular and printed circuits, circuit inter-connection, waveguides and transmission lines

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215 Circuit and Network Designs

analog and digital functions in electronic equipment, amplifiers, filters, modulators, microwave circuits, A-D converters, encoders, oscillators, switches, masers, logic networks, timing and control functions, fluidic circuits

AMPLIFIER, 1-2 GHz High-Power Linear Transistor — AA. Presser, E.F. Belohoubek (Labs,Pr) *RCA Review*, Vol. 33, No 4, p. 737, 12/72

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I/O SUBSYSTEM, Radiation Hardened — L. Dillon (ATL,Cam) Hardened Guidance & Weapon Delivery Technology Mtg., Palos Verdes Peninsula, Calif.; 4/10-12/73

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RECURSIVE FILTERS, Design of Two-Dimensional — M.S. Corrington (ATL,Cam) '73 IEEE Int'l Symposium on Circuit Theory, Toronto, Canada; 4/10/73

SYNTHESIZER, Fast Frequency Hopping — E.J. Nossen (GCS,Cam) NELC, San Diego, Calif.; 3/13-16/73

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220 Energy and Power Sources

batteries, solar cells, generators, reactors, power supplies

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240 Lasers, Electro-Optical and Optical Devices

design and characteristics of lasers, components used with lasers, electro-optical systems, lenses, etc. excludes: masers

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INJECTION LASERS: Experimental Properties of Modal Distribution of Laser Power — H.S. Sommers, Jr. (Labs,Pr) *J. App. Phys.,* Vol. 44, No. 3, p. 1263; 3/73

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245 Displays

equipment for the display of graphic, alphanumeric, and other data in communications, computer, military, and other systems, CRT devices, solid state displays, holographic displays, etc.

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LASER SCANNER, Television Rate — II. Recent Developments — I.Gorog, J.D. Knox, P.V. Goedertier, I. Shidlovsky (Labs,Pr) *RCA Review,* Vol. 33, No. 4, p. 667; 12/72

250 Recording Components and Equipment

disk, drum, tape, film, holographic and other assemblies for audio, image, and data systems

CARTRIDGE SYSTEM for 16MM Television Film — A.H. Lind, A.E. Jackson (CSD,Cam) NAB Convention, Washington, DC; 3/27/73

DIGITAL RECORDER, Ultra High Data Rate — J.S. Griffin (GCS, Cam) Military Airborne Video Recording Symposium (SPIE), Dayton, Ohio; 4/3-4/73

MAGNETIC MEDIA for Video Recording, Introduction to a Discussion on — E.F. Hockings (Labs,Pr) Intermag Conf., Washington, DC; 4/24/73

MULTISPECTRAL RECORDING on Black and White Film, Color of — S.L. Corsover (ATL,Cam) SPIE — Military Airborne Video Recording Seminar Dayton, Ohio; 4/3-5/73

VIDEO TAPE RECORDER/REPRODUCER, A Basic Highly Maintainable Airborne — P.F. Muraco (GCS,Cam) Dayton, Ohio; 4/3-4/73 cateogry 270

FILM COVERAGE of Severe Topography — J.L. Vossen, W. Kern (Labs,Pr) 9th Annual Symp. of the New Mexico Chapter, American Vacuum Soc., Albuquerque, N.M.; 4/9/73

SERIES 300 SYSTEMS, EQUIPMENT, & APPLICATIONS

310 Spacecraft and Ground Support

spacecraft and satellite design, launch vehicles, payloads, space missions, space navigation

ATMOSPHERE EXPLORER SPACECRAFT, Dynamic Analysis of — W.W. Metzger, R.A. Kenny (AED,Pr) ICES User's Group Conf., St. Louis, Mo.; 6/15/73

DUAL-SPIN SPACECRAFT Incorporating Flexible Appendages, Application of Optimal Control Techniques — F.J. Hughes, Jr., (AED,Pr) *BS/MS Thesis for MIT*

DUAL-SPIN SPACECRAFT, Constant and Variable Amplitude Limit Cycles in — G.T Tseng (AED,Pr) *J. of Spacecraft and Rockets;* 11/72

SURFACE TENSION PROPELLANT MANAGEMENT TANK on a Spinning Spacecraft, Energy Dissipation in a — R.J. Lake, Jr., AED,Pr) 1973 JANNAF Propulsion Mtg., Las Vegas, Nev.; 11/6-8/73

INTEGRATED LOGISTICS, Seven Workshops in — J.W. Hurley (M&SR,Mrstn) Philadelphia Engineers Club, Philadelphia, Pa.; 4/23/73

312 Land and Water Transportation

navigation systems, automotive electronics, etc.

HATRIC—A Multi-Function System for Navigation in Surveillance in Rivers and Harbors at the Radio Technical Commission for Maritime Service — E. Jellinek (GPSD,Cam) Seattle, Washington; 4/27/73

320 Radar, Sonar, and Tracking

microwave, optical, and other systems for detection, acquisition, tracking, and position indication

RADAR CLUTTER, The Effect of Limiting Upon the Mean Cross Section of Lognormal — H. Urkowitz (M&SR,Mrstn) *IEEE Trransactions on Aerospace and Electronic Systems;* 3/73

340 Communications

industrial, military, commercial systems, telephony, telegraphy and telemetry, excludes: television, and broadcast radio

SINUSOIDAL CARRIER in Atmospheric Radio Noise, A Simple Analytical Model for the Envelope Distribution of — C.V. Greenman (GCS,Cam) *IEEE Transactions on Comm. Technology,* Vol. COM-21, Issue 3, page 254; 3/73

345 Television and Broadcast

television and radio broadcasting, receivers, transmitters, and systems, television cameras, recorders, studio equipment

MAGNETIC VIDEO RECORDING TECHNOLOGY, Selected Topics on Modern — K. Sadashige (CSD,Cam) Conf. on Video & Data Rec., Univ. of Birmingham England; 7/10/73; Proc. of the Inst. of Electronic & Radio Engineers

TV LOGGING SYSTEM, A Low-cost — R.H. Barnaby (NBC, NY) 27th NAB Broadcast Engineering Conf., Washington, DC; 3/27/73

360 Computer Equipment

processors, memories, and peripherals

CMOS/LSI COMPUTER Fabrication — SUMC/DV — A. Feller (ATL,Cam) Solid-State Circuits Conf.; Phila Pa.; 2/14-16/73

CPU DESIGN, Hard CMOS Computer Specifications and — R. Bernal (AED,Pr) Hardened Guidance and Weapons Delivery Technology Mtg., Northrop Corp., Palos Verdes Peninsula, Calif.; 4/12/73

LSI COMPUTER DESIGN — SUMC/DV — W.A. Clapp (ATL,Cam) Solid-State Circuits Conf., Phila. Pa.; 2)14-16/73

OPTICAL MEMORIES — R.D. Lohman (Labs,Pr) SPIE Seminar, Boston, Mass.; 4/30-5/1/73

Author Index

Subject listed opposite each author's name indicates where complete citation to his paper may be found in the subject index. An author may have more than one paper for each subject category.

Dates and Deadlines

As an industry leader, RCA must be well represented in major professional conferences . . . to display its skills and abilities to both commercial and government interests.

How can you and your manager, leader, or chief-engineer do this for RCA?

Plan ahead! Watch these columns every issue for advance notices of upcoming meetings and "calls for papers". Formulate plans at staff meetings—and select pertinent topics to represent you and your group professionally. Every engineer and scientist is urged to scan these columns; call attention of important meetings to your Technical Publications Administrator (TPA) or your manager. Always work closely with your TPA who can help with scheduling and supplement contacts between engineers and professional societies. Inform your TPA whenever you present or publish a paper. These professional accomplishments will be cited in the "Pen and Podium" section of the *RCA Engineer*, as reported by your TPA.

Dates of upcoming meetings—plan ahead.

Ed. Note: Meetings are listed chronologically. Listed after the meeting title (in italic type) are the sponsor(s), the location, and the person to contact for more information.

JULY 9/27, 1973 — *Science and the Unfolding of Technology* — IEEE Mexico Section, AAS, Conacyt, Mexico City, Mexico. *Prog info:* Bruno DeVecchi, Martin Mendalde No. 1054, Mexico City 12, Mexico.

JULY 10/12, 1973 — *Video & Data Recording Conference* — IERE, IEEE UKRI Section *et al*, Univ. of Birmingham, Birmingham, England. *Prog info:* IERE, 8-9 Bedford Square, London W.C. 1 B 3RG England.

JULY 10/12, 1973 — *Joint Space Mission, Planning and Execution Meeting* — AIAA, ASME, and SAE, Stauffer's Denver Inn, Denver, Colorado. *Prog info:* Maurice Jones, Manager, Information Services, ASME, United Engineering Center, 345 E. 47th., New York, NY 10017

JULY 10/12, 1973 — *Space Mission Planning and Execution Meeting* — AIAA, ASME, SAE, Brown Palace Hotel, Denver, Colorado. *Prog info:* Paul Drummond, Manager Conferences and Divisions, ASME, 345 East 47th St., New York, NY 10017.

JULY 15/20, 1973 — *IEEE Power Engineering Society Summer Meeting & EHV/UHV Conference* — S-PE, Vancouver Hotel, Vancouver, B.C. Canada. *Prog info:* D. G. McFarlane, British Columbia Hydro & Pwr., Auth., 970 Burrard St., Vancouver 1 B.C. Canada.

JULY 16/19, 1973 — *Intersociety Conference on Environmental Systems* — SAE, ASME, AIAA, AIChE, Hilton Inn, San Diego, CA. *Prog info:* Maurice Jones, Manager Information, 345 E. 47th Street, New York, NY 10017.

JULY 15/20, 1973 — *Summer Meeting of the Power Engineering Society* — IEEE, City of Vancouver, British Columbia, Canada. *Prog info:* D J Turland, Publicity Chairman, IEEE Summer Meeting 1973, Box 2189, Vancouver 3, B.C.

JULY 18/20, 1973 — *Acoustical Holography and Imaging International Symposium* — G-SU, Stanford Res. Inst., ASA, Rickeys Hyatt House, Palo Alto, Calif. *Prog info:* P. S. Green, Stanford Res. Inst., Menlo Park, Calif. 94025.

JULY 23/26, 1973 — *Nuclear & Space Radiation Effects Conference* — S-NAPS, USAF, DNA, USAEC, Utah State Univ., Logan, Utah. *Prog info:* D. K. Myers, Fairchild Semiconductor, 545 Whisman Rd., Mountain View, Calif. 94040.

AUG. 12/17, 1973 — *Intersociety Energy Conversion Engineering Conference* — G-ED, S-AES, AIAA, et al, Univ. of Penna., Phila., Penna. *Prog info:* Dan Mager, POB 443, Lexington, Mass. 02173.

AUG. 14/16, 1973 — *Microwave Semiconductor Devices, Circuits and Applications* — The Office of Naval Res. and IEEE (G-CT, G-ED, G-MT&T) Ithaca Section, Cornell University, Ithaca, New York *Prog info:* Herbert J. Carlin, School of Electrical Engineering, Phillips Hall, Cornell University, Ithaca, New York 14850.

AUG. 13/17, 1973 — *8th Intersociety Energy Conversion Engineering Conference* — AIAA, ACS, AIChE, ANS, ASME, IEEE and SAE, University of Pennsylvania, Philadelphia, PA. *Prog info:* Maurice Jones, Manager Information, 345 E. 47th Street, New York, NY 10017

AUG. 22/24, 1973 — *Product Liability Prevention Conference* — G-R et al, Newark College of Engineering, Newark, NJ. *Prog info:* IEEE, 345 E. 47th St., New York, NY 10017.

AUG. 27/30, 1973 — *Electrical Signals from the Brain* — IEE, IEEE UKRI Section, EEG Soc., Univ. of Oxford, Oxford, England. *Prog info:* IEE, Savoy Place, London W.C. 2R OBL, England.

SEPT. 9/12, 1973 — *Fall Meeting of the American Ceramic Society, Elec. Div.* — Sheraton-Biltmore, Atlanta, GA. *Prog info.* Dr. David L. Wilcox, Program Chairman, IBM Corporation, Dept. K16, Bldg. 282, Monterey & Cottle Roads, San Jose, CA 95193 and Dr. Richard M. Rosenberg, Assistant Program Chairman, E.I. duPont de Nemours & Co., Inc., Electronic Products Div., Wilmington, DE 19898.

SEPT. 10/12, 1973 — *The Fifth International Congress on Instrumentation in Aerospace Simulation Facilities* — IEEE, California Institute of Technology, Main Campus, Pasadena, CA. *Prog info:* Mr. H. F. Swift, Head, Materials Physics Research, University of Dayton Research Institute, Dayton, OH 45469.

SEPT. 10/12, 1973 — *Petroleum & Chemical Industry Technical Conf.* — S-IA, Regency Hyatt Hotel, Houston, TX. *Prog info:* R. H. Cunningham, Atlantic Richfield Co., POB 2451, Houston, TX 77001.

SEPT. 10/12, 1973 — *Int'l Congress on Instrumentation in Aerospace Simulation Facil.* — S-AES, Calif. Inst. of Tech., Pasadena, Calif *Prog info:* H. F. Swift, Univ. of Dayton Res. Inst., Dayton, OH 45469.

SEPT. 11/14, 1973 — *Western Electronic Show & Convention (WESCON)* — Region 6, WEMA, Civic Audt., & Brooks Hall, San Francisco, CA *Prog info:* WESCON, 3600 Wilshire Blvd., Los Angeles, CA 90010

SEPT. 16/20, 1973 — *Jt. Power Generation Technical Conference* — S-PE, ASME, Marriott Hotel, New Orleans, LA. *Prog info:* L C. Grundmann, Jr., New Orleans Public Svc., Inc., 317 Baronne St., New Orleans, LA 70160.

SEPT. 18/19, 1973 — *Modulator Symposium* — G-ED, U. S. Army, United Engrg. Ctr., New York, NY. *Prog info:* S. Schneider, USAEC, Fort Monmouth, NJ 07703.

SEPT. 19/22, 1973 — *Fall Meeting of the American Ceramic Society, Structural Clay Prod. Div.* — TraveLodge at 6th South, Salt Lake City, Utah. *Prog info:* The American Ceramic Society, Inc., 65 Ceramic Drive, Columbus, OH 43214.

SEPT. 23/26, 1973 — *Fall Meeting of the American Ceramic Society, Basic Science and Ceramic-Metal Systems Div.* — William Penn Hotel, Pittsburgh, PA. *Prog info:* The American Ceramic Society, Inc., 65 Ceramic Drive, Columbus, OH 43214.

SEPT. 24/27, 1973 — *Intersociety Conference on Transportation* — ASME, Brown Palace Hotel, Denver, Colorado. *Prog info:* Ms. Marion Churchill, Manager, Conferences and Divisions, ASME, 345 E 47th St., New York, NY 10017.

SEPT. 26/29, 1973 — *Fall Meeting of the American Ceramic Society, Materials & Equipment & White Wares Divs.* — Bedford Springs Hotel Bedford, PA *Prog info:* The American Ceramic Society, Inc., 65 Ceramic Drive, Columbus, OH 43214.

SEPT. 25/28, 1973 — *Automatic Control in Glass* — IFAC, Purdue University, West Lafayette, Indiana. *Prog info:* Purdue University, Div. of Conf. and Continuation Svcs., West Lafayette, IN 47907.

Calls for papers—be sure deadlines are met.

Ed. note: Calls are listed chronologically by meeting date. Listed after the meeting title (in italic type) are the sponsor(s), the location, and the deadline information for submittals.

APR. 21/25, 1974 — *Int'l Circuits & Systems Theory Symposium* — S-CAS, *et al* Sir Francis Drake Hotel, San Francisco, Calif. *Deadline info:* (ms) 10/15/73 *to* L. O. Chua, Dept. of EE, Univ. of Calif., Berkeley, Calif. 94720.

APR. 22/26, 1974 — *1974 European Conference on Electrotechnics (EUROCON)* — IEEE, Reg. 8 and Convention of Nat'l Soc of Engrs in Western Europe, Amsterdam, The Netherlands. *Deadline info:* (abst) 10/15/73 300-500 word threefold *to* EUROCON '74 Office, Local Secretary, Ing. G. Gaikhorst, c/o F.M.E., Nassaulaan 13, the Haugue, the Netherlands.

MAY 5/8, 1974 — *Offshore Technology Conference* — TAB Oceanography coor Comm., *et al*, Astrohall, Houston, Texas *Deadline info:* (abst) 9/1073 *to* J. A. Klotz, Union Oil Co., Box 76, Brea, Cal. 92621

MAY 20/23, 1974 — *1974 International Symposium on Subscriber Loops and Services* — Comm. Soc. of the IEEE Can Dept of Comm & Bell-Northern Res., Ottawa, Canada. *Deadline info.* (abst) 7/1/73 (papers) 12/15/73 *to* General Chairman: Mr Alex Curran, Bell-Northern Research, P. O. Box 3511, Station C, Ottawa, Canada.

JUNE 1974 — *Special Issue on Microwave Control Devices for Array Antenna Systems* — *G-MTT Transactions. Deadline info:* (papers) triplicate 9/1/73 *to* Dr L. R. Whicker, Code 5250, Naval Research Laboratory, Washington, DC 20390

JULY 14/19, 1974 — *IEEE Power Engineering Society Summer Meeting* — S-PE Disneyland Hotel, Anaheim Conv Ctr., Anaheim, Calif *Deadline info:* (ms) 2/1/74 *to* S. H. Gold, Southern Calif Edison Co., POB 800, Rosemead, Calif 91770

JULY 15/19, 1974 — *Frontiers in Education* — IEEE, IEEE G-Ed, IEEE United Kingdom and Rep. of Ireland Sect., IEE Ed and Management Div., ASEE-Ed Res & Methods Div. City University, London England. *Deadline info:* (papers) 10/5/73 (250-word syn) *to* 1974 Frontiers in Education Secretariat, c/o The Conference Department, The Institution of Electrical Engineers, Savoy Place, London, England WC2R OBL and Lindon E Saline, Manager, Corporate Education Services, General Electric Company, Crotonville, PO Box 151, Ossining, NY 10562 USA

SEPT. *18/19, 1973* — *Eleventh Modulator Symposium* — IEEE, G-ED, Belmont Plaza Hotel, Lexington Avenue & 49th Street, New York, NY *Deadline info.* 6/22/73 (abst) original and 10 copies *to* Program Chairman, Sol Schneider, Electronics Technology and Devices Laboratory (ECOM), Ft Monmouth, NJ 07703.

NOV. 11/13, 1973 — *Photovoltaic Specialists Conference* — G-ED, Stanford University, Rickey's Hyatt House, Stanford, Calif *Deadline info:* 6/1/73 (abst) *to* Richard Statler, Naval Res Lab Washington, DC 20390.

NOV. 13/16, 1973 — *Magnetism & Magnetic Materials Conference* — S-MAG, AIP, Statler Hilton Hotel, Boston, Mass. *Deadline info:* (abst) 7/20/73 *to* A. F. Mayadas, IBM Res. Ctr., POB 218, Yorktown Heights, NY 10598.

NOV. 14/16, 1973 — *Nuclear Science Symposium* — S-NPS£ USAEC, NASA, Sheraton Palace Hotel, San Francisco, Cal. *Deadline info.* (A&S) 6/15/73 *to* P. L. Phelps, Lawrence Livermore Labs., Livermore, Cal.

JAN. 27/FEB. 1, 1973 — *IEEE Power Engineering Society Winter Meeting* — S-PE, Statler Hilton Hotel, New York, NY. *Deadline info:* (ms) 9/1/73 *to* J. G. Derse, 1030 Country Club Rd., Somerville, NJ 08876

MARCH 1974 — *Special issue on Computer-Oriented Microwave Practices — The IEEE Transactions on Microwave Theory and Techniques.* G-MTT *Deadline info:* (MS) 7/2/73 *to* Guest Editor, Dr J. W Bandler, Dept. of Electrical Engineering, McNaster University, Hamilton, Ontario, Canada.

APR *1/5, 1974* — *IEEE Power Engineering Society Underground Transmission and Distribution Conference* — S-PE, Dallas Convention Ctr., Dallas, Texas *Deadline info:* (abst) 3/1/73 *to* N. E. Piccione, L. I. Lighting Co., 175 E. Old Country Rd., Hicksville, NY 11801

Abbreviations of Sponsor Agencies

AAS	American Astronautical Society
AAAS	American Association for the Advancement of Science
ACS	American Chemical Society
AEA	American Economic Association
AIAA	American Institute of Aeronautics and Astronautics
AIChE	American Institute of Chemical Engineering
AIIE	American Institute of Industrial Engineers
AIP	American Institute of Physics
ANS	American Nuclear Society
ASCE	American Society of Civil Engineers
ASM	American Society for Metals
ASMA	Aerospace Medical Association
ASME	American Society of Mechanical Engineers
ASQC	American Society for Quality Control
IEE	Institute of Electrical Engineers
IEEE	Institute of Electrical and Electronic Engineers (Group and Society Names are also abbreviated) *e.g.* G-EM for group on Engineering Management or S-PE for Power Engineering Society)
IERE	Institute of Electronics and Radio Engineers
IES	Industrial Engineering Society
IFAC	International Federation of Automatic Control
ISA	Instrument Society of America
NSPE	National Society of Professional Engineers
ORSA	Operations Research Society of America
OSA	Optical Society of America
SAE	Society of Automation Engineering
SME	Society of Manufacturing Engineers
SMPTE	Society of Motion Picture and Television Engineers
USNC/URSI	United States National Committee/*Union Radio Scientifique Internationale*
WEMA	Western Electronic Manufacturers Association

Patents Granted

to RCA Engineers

Aerospace Systems Division

High Power Laser System — T. E. Nolan (ASD, Burlington) U.S. Pat. 3725817, April 3 1973

Astro-Electronics Division

Differential Amplifier — H. Amemiya (AED, Hightstown) U.S. Pat. 3737797, June 5, 1973

Electromagnetic and Aviation Systems Division

Simultaneous Digital Transmission in Both Directions Over One Line — W. J. Davis (EASD, Van Nuys) U.S. Pat. 3725582, April 3, 1973

Missile & Surface Radar Division

Multifrequency Antenna System Including an Isolation Section Open Circuited at Both Ends — O. M. Woodward (MSRD, Mrstn.) U.S. Pat. 3735413, May 22, 1973

Government Engineering

Means for Superimposing a Marker Signal onto a Composite Video Signal — R. L. Loper (G&CS Staff Adv, Van Nuys) U.S. Pat. 3735038, May 22, 1973

Method for Making a Kinescope Comprising a Color Selection Mask with Temporary Corridors — G. R. Fadner, Jr. (EC, Lancaster) U.S. Pat. 372065, April 3, 1973

Magnetic Beam Adjusting Arrangements — R. L. Barbin (EC, Lancaster) U.S. Pat. 3725831, April 3, 1973

Electrophoretic Deposition of Powdered Material on an Insulating Support — D. R. Tshudy (EC, Lancaster) U.S. Pat. 3734847 May 22, 1973

High Voltage Processing of Cathode Ra Tubes — E. A. Gronka (EC, Scranton) U.S Pat. 3698786, October 17, 1972

Numerical Display Device Having Filamei tary Light Sources — N. L. Lindburg, R. / Bonnette, T. E. Deegan (EC, Harrison) U.S Pat. 3737706, June 5, 1973

Color Television Deflection Yoke Having Reduced Variation in Beam Trio Distortion — J. Gross, W. H. Barkow (EC, Princeton) U.S. Pat. 3735299, May 22, 1973

Consumer Electronics

Common Base Amplifier Terminating Circuit for High Impedance Detecting Apparatus — J. M. Yongue (CE, Indpls.) U.S. Pat. 3725577, April 3, 1973

Automatic Chroma Control Circuits — L. A. Harwood (CE, Som.) U.S. Pat. 3732358, May 8, 1973

Solid State Division

Voltage Driver Circuit — H. R. Beelitz (SSD, Somerville) U.S. Pat. 3725801, April 3, 1973

Phase Shift Oscillators Using Insulated-Gate Field-Effect Transistors — S. S. Eaton, Jr. (SSD, Somerville) U.S. Pat. 3725822, April 3, 1973

Method for Dicing Materials Having a Hexagonal Crystal Structure — R. E. Busch (SSD, Somerville) U.S. Pat. 3731861, May 8, 1973

Thermal Fatigue Lead-Soldered Semiconductor Device — A. E. Rosewell, G. K. Clymer (SSD, Somerville) U.S. Pat. 3735208, May 22, 1973

Zener Diode for Monolithic Integrated Circuits — I. H. Kalish, H. Khajezadeh (SSD, Somerville) U.S. Pat. 3735210, May 22, 1973

Triggered Flip-Flop — A. A. Ahmed (SSD, Somerville) U.S. Pat. 3737682, June 5, 1973

RCA Limited

Vertical Deflection Circuits Utilizing Both Regenerative and Degenerative Feedback for Generating Parabolic Voltages — L. R. Avery (Ltd., England) U.S. Pat. 3735192, May 22, 1973

Engineering News and Highlights

Audio pioneer receives A.E.S. gold medal

H. E. (Ed) Roys recently received the Gold Medal Award of the Audio Engineering Society. This award was established by the Audio Engineering Society in 1971 and is given in recognition of outstanding achievements, sustained over a period of years, in audio engineering. It was formerly known as the John H. Potts Memorial Award, established by his widow in his memory in 1949.

Mr. Roys retired from RCA in 1967 after having been Chief Engineer of the Record Division for more than ten years. He started his career with the General Electric Company at Schenectady, N.Y., after graduating with honors in electrical engineering from the University of Colorado in 1925.

At RCA in Camden, in 1930, he developed the first equipment for evaluation of phonograph performance—the wow meter. This remains one of the most basic industry tools for the attainment of motion fidelity in reproduction. The professional 2-speed transcription turntable for broadcast use was a product of his engineering. 1941 found Mr. Roys with RCA in Indianapolis concentrating on disc record improvements. His use of a fm system to monitor and calibrate the movement of the stylus during the cutting of lacquers was as basic to the fidelity of the signal in the record groove as the wow-meter was to the motion of the record itself.

The 45 rpm 7 inch record introduced in 1948 embodied much of the earlier work of Mr. Roys on fine grooves and intermodulation distortion studies.

Anti-static vinyl record compound was a major improvement in record quality directed by Mr. Roys. This was followed by the simultaneous introduction by members of the record industry of stereophonic recordings in 1958-59. Mr. Roys, as chairman of the EIA committee directly related to disc recording, realized the most urgent need was standardization of the stereo product. He inaugurated a series of technical studies that evaluated the different alternatives and, on the basis of the results, obtained world-wide industry agreement to the 45-45° groove modulation system before the first disc was sold to the consumer.

Mr. Roys added to the literature of his profession by publishing more than twenty-six articles. He holds thirteen United States patents.

His productive career was frequently highlighted by his peers. At the University of Colorado, in addition to graduating with honors, he was elected to membership in Tau Beta Pi and Eta Kappa Nu. He received these awards: Fellow, Audio Engineering Society, 1953; Fellow, Acoustical Society of America, 1954; Fellow, IRE, 1955; IRE-PGA Achievement Award, 1956; and the Engineer of the Year Award, University ofColorado, 1967.

Professional activities

Solid State Division

Dr. H. S. Veloric was appointed vice chairman of the North Jersey Microwave Theory and Techniques Group of the IEEE.

Frequency Allocations book available

The RCA Frequency Bureau has published a new edition of *Frequency Allocations*. Revised to July 15, 1973, this book gives the International, Federal Communications Commission, and U.S. Government allocations, including Final Acts of the World Administrative Radio Conference for Space (1971). The FCC Allocation Table inlcudes several recent changes affecting Land Mobile Services. Of particular interest are the changes to the 470- to 512- MHz and 806- to 960- MHz bands.

This valuable book also contains convenient lists of domestic tv, a.m., and fm broadcast channeling and frequency assignments, and a new feature — excerpts from the technical standards of the private Land Mobile Radio Service Rules.

As with previous editions, this newly revised pocketsized book will be valued for its wide range of communications information. *Frequency Allocations* is available at a cost of $3.00 each. Copies may be obtained by contacting the RCA Frequency Bureau Offices at

Bldg. 204-2
Cherry Hill, NJ 08101

or

60 Broad St.
New York, NY 10004

or
2000 L St. NW
Washington, DC 20036.

Awards

Aerospace Systems Division

M. William Stewick of Radiation Systems Engineering was selected Engineer of the Month for May for his outstanding technical accomplishments and his unique measurements program that demonstrated servo performance for the Spacetrack Augmentation Satellite II (SAS II) follow-on program.

The Team of **R. C. Bever, H. U. Burri, W. X. Johnson, T. G. O'Brien** and **E. P. Wallner, Jr.** received the Technical Excellence Team Award for May. The team was recognized for its accomplishments in developing a new and unique RCA computer program for determining the orbits of extra-terrestrial objects from angle-only data supplied by an observer located either on the earth's surface or in earth orbit.

John Munzer of Data Systems Engineering was selected by the Technical Excellence Committee as Engineer of the Month for June. His work on the development and application of a simulation program for a proposed Remote Video Encoding System (RVES) for the United States Postal Service was an outstanding example of creative, timely and effective technical excellence.

Staff announcements

Laboratories

Dr. William M. Webster, Vice President, RCA Laboratories has announced the following appointments: **Dr. Jerome Kurshan** as Manager, Administrative Services; **George C. Hennessy** as Manager, Marketing; **Richard E. Quinn** as Director, Finance and Technical Services; and **Ralph H. Myers** as Manager, Finance.

Distributor and Commercial Relations

Martin F. Bennett, Vice President, Distributor and Commercial Relations has announced the appointments of **Ralph E. Bates** as Staff Vice President, International Distributor Relations and Services and **Robert W. Redecker** as Staff Vice President, Distributor Operations.

Electronic Components

Joseph H. Colgrove, Division Vice President and General Manager, Entertainment Tube Division has announced the following organization **Donald R. Bronson,** Director, International Operations; **Joseph H. Colgrove,** Acting Manager, Financial Planning and Controls; **Leonard Gillon,** Division Vice President; **William G. Hartzell,** Division Vice President, Engineering; and **Charles W. Thierfelder,** Division Vice President, Manufacturing.

Gordon W. Farmer, Director, Manufacturing Receiving Tubes has announced the Receiving Tube Manufacturing organization as follows: **Robert H. Handler,** Administrator, International Planning; **Charles W. Hear,** Manager, Production Harrison and Woodbridge; and **Austin F. Pheasant,** Manager, Purchasing.

William G. Hartzell, Division Vice President, Engineering has announced the organization of Engineering as follows: **Harold B. Law,** Director, Materials and Display Devices Laboratory - Princeton; **Edward K. Madenford,** Administrator, Engineering Administration; **C. Phillips Pfleeger,** Manager Glass Development Programs; **Clifford E. Shedd,** Manager, Equipment Design and Development Engineering; **Alton J. Torre,** Manager, Picture Tube Applications and Reliability Engineering; **David D. VanOrmer,** Manager, Picture Tube Development Engineering; **W. Hoyt Warren,** Manager, Receiving Tube Engineering; and **Richard H. Zachariason,** Manager, Picture Tube Product Support Engineering.

Charles W. Thierfelder, Division Vice President, Manufacturing has announced the following organization: **Gordon W. Farmer,** Director, Manufacturing Receiving Tubes; **Rex E. McNickle,** Manager, Quality and Reliability Assurance; and **Stanley S. Stefanski,** Director, Manufacturing Television Picture Tubes.

The Hertz Corporation

Robert L. Stone, Chairman of the Board and President, has announced the following organization of The Hertz Corporation: **Garth H. Colling,** Vice President and General Manager, Hertz Europe, Ltd.; **Dennis R. Israel** is elected Vice President and General Manager, Car Leasing Division; **Frank A. Olson** is elected Executive Vice President and General Manager, Rent A Car Division.

In addition to Mr. Olson's current responsibility for Rent A Car Division, he will assume responsibility for: **Ronald J. Lenney,** Vice President and Area General Manager; **Edward J. Kollins,** Vice President, Fleet Administration; **Larry Shore,** Vice President, Operations Services.

Stephen Russell is elected Executive Vice President and General Manager, Truck and Equipment Rental Division. In addition to Mr. Russell's current responsbility for the Truck Division, he will assume responsibility for: **Edward J. Andrle,** President, Hertz Equipment Rental Corporation.

Robert L. Stone is Acting General Manager, Subsidiary Operations. The Subsidiary Operations organization will include: **Samuel Katz,** President, United Exposition Services; **Robert F. Thurston,** General Manager, Hertz Skycenter, Inc.; **Joseph Adlerman,** Vice President and General Counsel; **Earl S. Kauffman,** Vice President, Finance; **Richard B. Niles,** Vice President, Industrial Relations; and **Donald M. Noyes,** Acting Director, Public Relations.

Government and Commercial Systems

Irving K. Kessler, Executive Vice President, Government and Commercial Systems has appointed **Nicholas J. Cappello** Division Vice President, Manufacturing Services.

Missile and Surface Radar Division

Max Lehrer, Division Vice President and General Manager has announced the appointment of **James J. Dougherty** as Manager, Materials

Promotions

Astro-Electronics Division

J. M. L. Holman from Mgr., Systems Analysis & Scientific Programming to Mgr., Software Development & Computer Aided Design (W. P. Manger, Hightstown)

F. Gargione from Sr. Engr. To Mgr., Computer Aided Design & Test (J. M. L. Holman, Hightstown)

H. N. Hurlburt from Engr. to Mgr., Environmental Engineering (F. J. Yannotti, Hightstown)

D. G. Shipley from Sr. Engr. to Mgr., Equipment Engineering (J. J. Newman, Hightstown)

RCA Alaska Communications, Inc.

G. O. Ekberg from Engr. to Mgr. , Radio and Multiplex Engineering (V. B. Robinett, Anchorage)

J. A. Rexelman from Engr. to Mgr., Switching Projects (E. F. McGill, Anchorage)

Consumer Electronics

R. S. Degenkolb from Sr. Member, Engineering Staff to Ldr., Engineering Staff (R. E. Hurley, Indianapolis)

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R. Kolc from Sr. Mem. Engr. Staff to Ldr., Des. & Dev. Eng. (M. Korsen, Moorestown)

W. Luebkemann from Ldr., Digital Comp. to Mgr., Computer Center Operations (A. W. Carroll, Moorestown)

Electronic Components

E. A. Gronka from Engr., Equipment Engrg. to Engrg. Ldr., Equipment Engrg. (K. D. Scearce, Lanc.)

E. J. Klovensky from Quality Control Mgr., Parts and Materials to Engrg. Ldr., Production Engrg. (J. I. Nubani, Scranton)

RCA Engineering Conference

A Corporate Engineering Management Conference, convened at the Treadway Resort Inn, Lancaster, Pa., May 9-11, adopted as its theme the need for early and continuous companion planning throughout RCA.

More than 160 individuals participated, including members of top corporate and division management groups, market planners, product specialists, chief engineering managers, and research directors throughout RCA concerned with the effective application of RCA's technical resources. The three-day conference was sponsored by Research and Engineering.

A summary of the conference appears in the June issue of *TREND*. A more complete version of the conference proceedings will appear in the next issue of the *RCA Engineer*.

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