RCA Engineer

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1968

OUR COVER

. . . illustrates how the letter "a" and how letters of any shape are formed by RCA's new Videocomp; electronically, the Videocomp provides final copy for the printing industry (for example, the inside cover message). A companion of the Videocomp, the Color Scannner produced the color separations (front cover) that are combined to produce the full-color scene below. Credit for cover art arrangement and direction goes to J. L. Parvin.

Graphic Systems and Devices

Studies made by RCA in 1964 indicated that the Graphic Arts Industry, which had for many years carried on with only minor changes in its basic technology, was ready for major technological changes which would improve quality, speed up the processes, reduce costs and provide added flexibility and capability. It also became obvious that improvement was necessary to cope with the massive buildup in quantity of printed material which has occurred over the past few years. As a direct result of the efforts of RCA engineers, many of the techniques required to effect these changes are now available.

The Graphic Systems Division was organized in early 1965 with its major objective to design and build modern graphic systems. The early stages of the effort are being concentrated on automating typesetting and composition procedures primarily through the use of the computer, rather complex software, cathode ray tubes, and associated electronics.

This message has been set on the RCA Graphic 70/820 Videocomp in twelve seconds. A conventional linotype machine would require eight minutes. Three typefonts have been used. The message has been hyphenated and justified with our Spectra 70 software.

A strong effort is being made to improve the techniques for making color separations. The RCA Graphic 70/8800 Color Scanner family of equipments is the initial result of this effort. Graphic Systems Division plans to apply the tremendous inventory of color know-how available as a result of RCA engineering research and development to improving procedures and equipment.

It is our goal ultimately to produce an RCA electronic printing system that will accept a manuscript as input and deliver printed copy—packaged, addressed and sorted—to the shipping dock.

S. W. Cochran, Division Vice President and General Manager, Graphic Systems Division, Information Systems

RCA Engineer

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Contents

PAPERS

NOTES

DEPARTMENTS

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

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

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

Effective meetings are an essential means for communication among engineers working on a common project. The accomplishment of an effective meeting requires thorough planning and competent implementing on the part of the chairman. This paper examines the nature of the small, informal type of group meeting involving persons assigned to a common project, the planning factors and sequence of steps for implementation, and the chairmanship characteristics essential to achieving effectiveness.

The Engineer and the Corporation

Planning and Implementing Effective Engineering Meetings

LYTTON BULWER
Project Engineering, Astro-Electronics Division, Princeton, N.J.

A WELL-MANAGED MEETING is a valuable tool for promoting the smooth and efficient group performance of an engineering project. Unfortunately, too many meetings fail to achieve any level of effectiveness. This failure explains why engineers readily damn meetings as the greatest of time-wasters. This condemnation is justly deserved every time that a poorly planned, badly implemented meeting occurs. Beyond wasting time, such meetings inject unfavorable elements of noise and distortion which lead to group confusion.

To the same extent that a poor meeting produces an adverse impact, the effective meeting makes a significant contribution toward the efficient and economical accomplishment of a project objective. An engineer who is competent in producing an effective meeting is an asset to his organization.

WHAT IS A GOOD MEETING AND WHAT IS IT GOOD FOR?

A meeting is a means of communication. To evaluate its effectiveness, it is useful to analyze the end result that the means are expected to produce.

Communication, regardless of the means producing it, is an essential element for an organization that expects to perform efficiently. The term *communication,* as used in this discussion, means *the transmission of information which is expected to guide the performance of the receiver.* This is a general description of the term; following paragraphs will indicate that various means of communicating are either unilateral or multilateral. Information is used in the sense of idea content rather than that of a pure "Information Theory" concept. Fig. 1 presents a basic communication model.

The objectives of an engineering project are accomplished through the combined and interacting efforts of the assigned individuals. Successful accomplishment results from the efficient performance of the group as a coherent whole. This requires having the right person doing the right thing, at the right time and place, and in the right amount.

A classic example of deficient project performance due to inadequate communication is the Bible story about the Tower of Babel. The personnel assigned to the project were craftsmen, each well developed in his technical skill. If these workers had lost their tools, the purchasing agent could have procured replacements. If they had lost their skills, a re-training program could have been established. Instead, the Lord removed their means of communication by giving each a different tongue. Without communication, the group could not perform as a coherent whole and the objectives of "Project Babel" were not accomplished.

While the Babel case illustrates well the necessity for communication, it does not explicitly establish the value of effective meetings. To do this, assume that the Babel group had retained their ability to speak and write to each other. The project still could have failed due to inadequate communication, because there is something more to communication than just the act of speaking or writing.

The transmission of information is necessary for effective communicating, but not in itself sufficient. Achieving effectiveness requires that the receiver arrives at the right meaning, or interpretation, of the sender's information. Fig. 2 presents the interpretation concept of communicating.

The reason why many attempts at communication fail to achieve effectiveness is best expressed in William H. Whyte's statement that "the great enemy of communication is the illusion of it." Individuals often wrongly assume that their speaking or writing constitutes communication. They fail to consider whether the receiver made the correct interpretation. Wrong interpretations are a continuing occurrence.

To oversimplify, each individual encodes his ideas for transmission through an encoder whose characteristics are based on the individual's unique background, experience, and personality. Conversely, each individual decodes received messages through a unique decoder.

Encoders and decoders vary as does each individual. Because of these mismatches, wrong interpretations are highly probable. Fig. 3 depicts a person acting on the basis of a wrong interpretation; the response intended by the sender does not happen. Instead the receiver's actions (based on wrong interpretations) will be useless and possibly disruptive to the coherent whole. Wrong actions by one individual ad-

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versely influence the actions of the others—and rarely in linear fashion!

It is in this all-important factor of correct interpretation that the meeting, rather than the oral presentation or the written directive, makes a significant contribution to communicating.

One way to determine whether an individual makes the right interpretation is to have the receiver feed his interpretation back to the sender. Obviously this must be accomplished before the receiver acts. Accomplishment of this transmission and feedback activity is a two-way exchange of information (Fig. 4).

The term *meeting* is used in this discussion to mean *a type of communication involving a two-way exchange of information among a group of individuals under the direction and control of a chairman.* Meeting effectiveness occurs whenever a "meeting of the bodies" serves to reach a "meeting of the minds."

WHAT MAKES A GOOD MEETING?

In an effective meeting, each participant must generate, as well as receive, relevant information and all must reach a common understanding of that information. An effective meeting does not just happen; it is achieved through individuals performing and performing well. The Program of activity that produces effective meetings is divided into two phases:

1) Careful, thorough *planning*, and
2) Competent *implementing.*

Each phase of this Program is related to required group performance and its accomplishment (Fig. 5).

PLANNING PHASE

Planning activity consists of defining an objective and the requirements necessary to achieve it. The principal factors involved in planning a meeting are: purpose, agenda, participants, location, and time.

Executing these five factors of the planning phase constitutes total planning by the chairman. Depending on the nature of a specific situation, each planning factor can be observed to a greater or lesser extent. Regardless of the situation, however, the meeting must be planned. Merely arranging for a conference room and notifying the participants lays the foundation for another Tower of Babel.

L. E. BULWER received the BS degree in Mathematics and Physics from the University of Dayton in 1950. In 1954 and 1955, he attended graduate courses in systems engineering at the New Mexico State University and Fort Bliss, Texas. From 1950 to 1958, Mr. Bulwer served as an officer with the U.S. Marine Corps. From 1952 to 1954, he was Officer in Charge at the Engineering School of the Marine Corps Institute, where he was responsible for adapting engineering and electronic courses for specific application to military training programs. From 1955 to 1958, Mr. Bulwer was a Project Officer on the Bumblebee Program and participated in the Marine Corps Terrier System Evaluation Program. Mr. Bulwer joined the Missile and Surface Radar Division of RCA in 1958. He was assigned as a Project Engineer to the Systems Evaluation Group working on the TALOS Defense Unit at White Sands Missile Radar. He was also Project Engineer responsible for the development of test and checkout, and operational procedures for the Atlas D Series operation. Later, he directed project operations of the Atlas E Series field installation at Warren Air Force Base, Wyoming. Mr. Bulwer joined the Astro-Electronics Division in 1962 as a Project Systems Engineer, where he was initially engaged in the orbital analysis and flight test evaluation on a classified Air Force program. His next assignment was that of lead systems engineer on NASA's Lunar Orbiter Program. Completion of this assignment led to a similar assignment on a classified Air Force program. He is currently Project Engineer studying TIROS program growth.

Purpose

The first step in planning for a meeting is the recognition of a need for the meeting. If any other means will satisfy the need, use *those* means! A meeting should be called only when other means would not serve the need as well. Many unnecessary and mediocre meetings occur because the chairman did not have a clear understanding of the purpose for the meeting he was convening.

A meeting is a means. The end result is accomplished after the meeting by the performance of individuals in accordance with correct information. Therefore, the purpose of convening a meeting is to exchange information essential to various categories of group performance. These three categories represent a purpose:

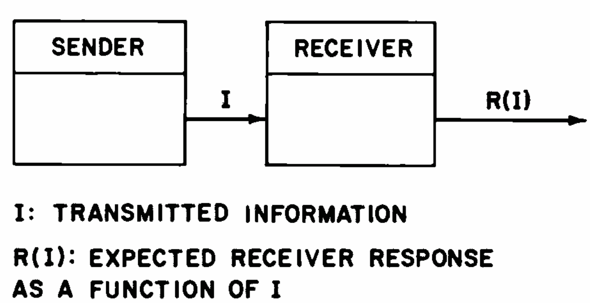
1) *Project or procedure initiation.* At this meeting, the chairman's purpose is to initiate a new project or procedure. The project may be the preparation of a proposal or the production of hardware. The procedure may be a new prescribed way of doing something. The chairman intends the participants to receive, discuss, understand, and act on his ideas in a way that will promote efficient group performance.
2) *Project progress.* As a project progresses, it is essential that each individual know and understand what the others have done and what they plan to do. Through this pooling and understanding of progress information, the participants can adjust their own performance accordingly. Norbert Wiener states in his book *Cybernetics* that a system is organized to the degree of information it possesses. The role of the progress meeting is to exchange and clarify information that leads to more effective organization. Usually these meetings occur on a periodic schedule.
3) *Problem definition.* This meeting is called to restore order to a situation which has deviated from the desired limits of performance. It makes use of the collective abilities, education, and experience of the participants in accurately defining the essence of the problem. Correctly defining the right problem is necessary, because the best possible solution is worthless when it solves the wrong problem. Once the problem is adequately defined, action items leading to a satisfactory solution can be generated.

Whatever the intended purpose of his proposed meeting, the chairman must clearly establish and accurately define that purpose. Failure to do so makes the chances for meeting effectiveness extremely doubtful.

Agenda

Having clearly defined what he wishes to accomplish, the chairman prepares the agenda of information topics to be presented and discussed.

Fig. 1—Basic communication model.



The dictionary meaning of agenda, "a memorandum of items for discussion," is significant. Because the agenda of an effective meeting carries only essential items, forgetting one of these items could be detrimental. Background and related data to each topic is important for arriving at correct interpretations. For this reason, the chairman should spend the time required in preparing an adequate memorandum of items for discussion.

Participants

An effective meeting depends upon attendance of the right participants. The agenda is a key means of determining who should attend. Unlike an open forum or town meeting, an engineering meeting must have a controlled attendance, the number of participants being a function of the subjects discussed.

The chairman should consciously consider and select each individual on the basis of that person:

1) Requiring information presented by the chairman or another participant,
2) Having timely and relevant information to present,
3) Representing another group that will be affected by the results of the meeting,
4) Having a required background of education and experience (or both) that will be of consultation benefit, and
5) Providing management approval and direction to those items that require it. Responsible managers should be advised, before the meeting, of items that will require their approval.

In some situations, it is advisable to request in advance that a certain person prepare a comment in depth on a particular topic. It is highly advantageous for the chairman to be familiar with the professional capabilities and personal characteristics of the persons he invites to participate. All individuals that are essential to accomplishing the purpose should attend and participate. But *only* those individuals!

Location and Facilities

Knowing the scope of the agenda and the number of participants, the chairman should acquire a suitable location and arrange for the required visual-aid and demonstration devices. A suitable location means an adequately illuminated, ventilated, disturbance-free room. It should be of a sufficient size, with a table and chairs for accommodating all the invited participants. If complex or detailed material is involved in the agenda, it is well to prepare a summary sheet for distribution to each participant. A chalk board is highly desirable. Although the meeting is not a formal presentation, a flip chart may be used to a favorable advantage in concentrating attention and encouraging close participation.

Time

The principal temporal factors are the date, starting time, and stopping time. Date and time should be coordinated in advance to ensure the required attendance.

Estimating the length of the meeting is most important. The chairman must not assume that it is all right for the meeting to run until each participant has nothing more to say. He should establish a time budget and adhere to it as closely as possible. However, agenda should not be sacrificed for brevity alone. The chairman should be conscious of the need for making economical use of the high priced technical and administrative personnel present. If the meeting must run longer than an hour, a short break should be included.

IMPLEMENTATION PHASE

Implementation of the meeting, according to plan, is carried out in a sequence of four steps: introduction, agenda, round-up, and conclusion. Before examining each step in individual detail, it is important to realize that tardiness and unpreparedness on the part of the chairman detracts from the possibility of effectiveness. He should arrive at the meeting sufficiently early to ensure that the physical layout is in order. Early arrival also permits him to post visual aids without having to disrupt the meeting to do so.

At the scheduled time, the chairman takes his place at the head of the table; this is a position that spatially identifies him as the meeting chairman and provides an optimum location for directing and controlling the meeting. He calls the group to order and focusses their attention in a distinct, positive fashion. Weak, trite statements as "I suppose we should probably get started now" or "Would anyone care to start things off?" do not focus attention and are anathema!

The Introduction

The chairman introduces himself, orients the group to the purpose of the meeting, along with the key points to be covered, and indicates the useful results that the meeting is expected to accomplish. The chairman's introduction includes the members present, briefly giving their respective roles as they relate to the purpose of the meeting. Otherwise, the participants are going to dissipate their attention by playing the "mystery-guest" guessing game.

The introduction must be brief and complete, comprising essential items only. A few key words on the chalk board will serve as a visual reference and can be used to check off progress. Meetings that are scheduled on a periodic, short-interval basis, and with the same members usually present, can have a modified introduction.

Fig. 2—Interpretation concept in communicating.

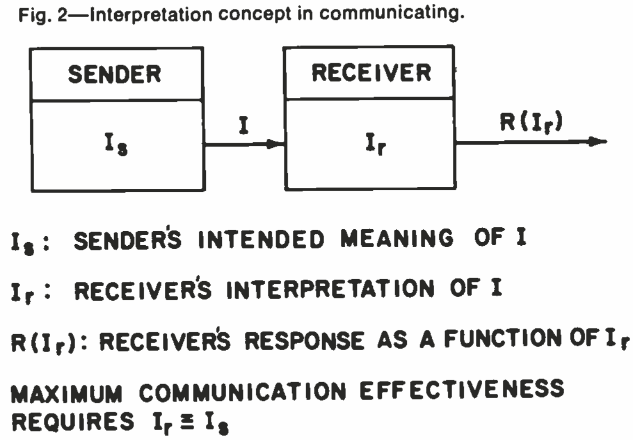
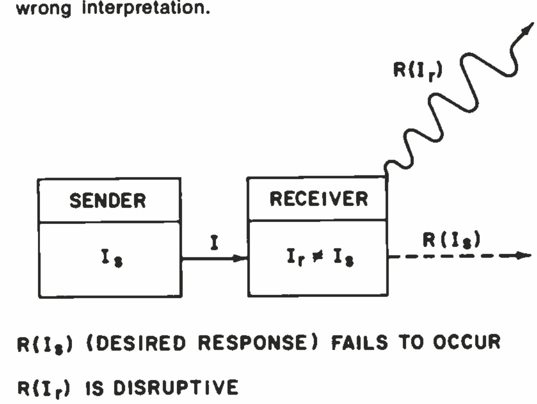


Fig. 3—Receiver's disruptive response as a function of wrong interpretation.



Regardless of its extent, a well-organized, compactly presented introduction establishes that favorable frame of collective minds from which useful activity results. Orienting the participants in this way is appreciated by them and is important to success. *A group that does not know where it is going cannot control where it ends up.*

Discussion of the Agenda

In covering the agenda, the chairman presents the prepared topics sequentially. His aim is to achieve a common understanding of each item that he and the others will present.

An immediately apparent way for a sender to learn the receiver's interpretation is to have the receiver discuss the received information. Therefore, on each item, the chairman should promote vigorous discussion for the sake of evoking and clarifying ideas. Many chairmen fail to do this. Repeatedly they run through the full course of their agenda and only at the end ask "Are there any questions?" Silence follows and the meeting terminates. (This was a lecture, not a meeting.) The participants had questions. Not all points were clear to them. They go forth to guide their subsequent behavior on information which is at best vague. Through lack of participation, this group assembly failed to become an effective meeting—it did not arrive at and impart a common understanding.

Achieving participation in a two-way exchange of information is essential. By definition, each participant must contribute as well as receive. A reliable method, which the chairman may use to start discussion, is to ask a specific question of an individual who maintains an enthusiastic position on the questioned issue. Once started, discussion must be sustained.

Within every group are found individuals who are too reserved to speak up without encouragement, and others who could talk endlessly in an "open-loop" mode. Because the meeting must draw equally from the ability, experience, and information resources of each participant, the chairman has to control the discussion, keeping it on subject and schedule. The long-winded must be restrained, while the timid should be encouraged. (Being inarticulate does not imply that an individual lacks a valuable contribution to make.)

Discussion control holds a meeting on course and brings forth all relevant contributions. Orderly progress is established because the group more easily and readily follows a chairman who maintains this steady course. The chairman can exercise this control by allowing the overtalkative to make brief comments; then terminate him by summarizing and immediately calling on another participant by name to continue. The timid person is encouraged to participate by asking him a question about a subject directly related to his assignment, and with which he is familiar and at ease.

As the discussion of a particular agenda item progresses, the chairman must decide when adequate interpretation is reached and quickly move on to the next item. There is no justification to spend additional time on a mutually understood subject. When more than one satisfactory interpretation arises, it is better to select one and move on rather than to allow endless debate.

The primary principle of discussion control is *always: one subject, one speaker.* Maintaining this atmosphere, which fosters the one-subject, one-speaker principle, requires that the chairman recognize and control other possibly disruptive factors. On some occasions, the one speaker may inject a subject not related to the agenda item. Lacking the merit of relatedness, such a topic should be deferred until the round-up.

Discussion should be vigorous, with an open frankness of expression encouraged. A cooperative atmosphere evolves from an open and honest exchange of relevant information among all participants. Enthusiastic views and strongly held beliefs should be permitted. The chairman must not, however, allow the meeting to be used for name calling or the airing of private animosities. When personality differences are injected, the chairman must return to the impersonal atmosphere. "We are here to discuss issues, not personalities," usually accomplishes this desired result.

Especially in problem definition, the chairman should not allow the meeting to become a trial with the object of fixing guilt. Displays of irrational emotions belong in the popular fiction about executive suite melodramas. They do not belong in the engineering operation of intelligent persons, collectively seeking to achieve useful and worthwhile objectives.

When a sub-group becomes engrossed in a side meeting of its own, the chairman should move quickly to prevent secession from the main body. An approach toward preserving unity is to call on a secessionist member asking him to comment on the present subject, or requesting "May we have just *one* meeting, please?"

Sometimes interruptions occur through the intrusion of an uninvited individual who wishes to have a side discussion with one of the participants. The chairman should discourage the continuance of this interruption by asking "Is this something that can be taken up later?" If it is not, it is better for the participant and intruder to depart from the conference room.

Other times, a secretary will enter with the announcement that someone has a telephone call. Unless the importance of

Fig. 4—Receiver feedback of I_r in a two-way exchange of information.

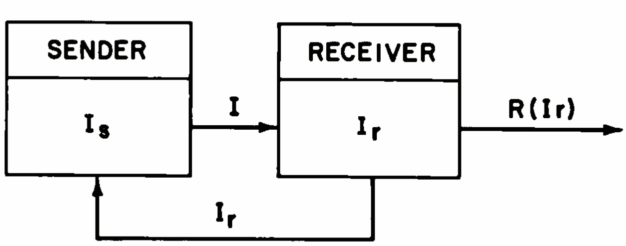
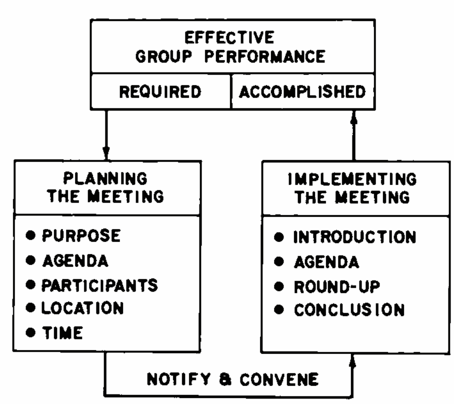


Fig. 5—The total program for an effective meeting.



the call overrides the meeting, the caller should be requested to call back later.

Throughout the course of the proceedings, it is wise for the chairman to keep a simple written record. Whether he chooses to publish the record for distribution is not consequential at this point. Keeping notes provides an account for reference or future agenda preparation.

Round-Up

The round-up serves several useful purposes. The chairman is able to keep the agenda on a strict course by deferring other merited topics to the round-up. Because the round-up permits a broader range of subjects, it allows the participants more freedom. Also, it permits the expression of any significant afterthought to the agenda discussion.

In rounding up stray bits of information, it is likely that a declaration is made containing the exact information for which the others were looking.

While not adhering to strict subject limits, as does the agenda, the round-up is time-limited and must move at a brisk pace. The chairman begins with the individual to his immediate left by inviting additional commentary or new topics. Each participant exercises his turn as he chooses, with the chairman enforcing rigid time restrictions. When the last participant has completed his commentary, the chairman immediately commences the conclusion.

Conclusion

The conclusion should bring the meeting to a definite and formal close. The chairman summarizes:

1) The principal topics covered,
2) Requirements for future meetings,
3) Scheduling of future meetings, and
4) Responsibility for major action items.

It is desirable to end with the group feeling a sense of productive accomplishment. A brief acknowledgement of thanks and compliments to the group for their constructive contribution is in order. The meeting, which began with a positive announcement, should close with one. "We stand adjourned" or "Thank you, gentlemen" indicates a definitive cutoff of the proceedings.

Meeting notes can be briefly summarized through use of such forms as Fig. 6, which was developed by E. W. Schlieben of the Astro-Electronics Division of RCA.

WHO MAKES A GOOD MEETING?

The techniques of planning and implementation are necessary to raise the level of meeting effectiveness, but alone are not sufficient. They are equivalent to high-quality precision tools, which require a competent human to apply them.

The term "leadership" is an extremely broad and all-encompassing concept. Certain characteristics within it can be identified as associated with the required qualities of a competent chairman. Basically these characteristics are:

1) *Sensitivity in human relations.* The chairman should listen to all comments courteously and attentively, and display a mature tolerance for opposition opinions. He should be aware that people wish to be recognized as individuals. He should make advantageous use of the fact that people have unused skills and abilities and that they welcome the opportunity to express them.
2) *Decision making.* The chairman should be a clear-cut decision maker and not rely on the group to act as a committee that makes decisions for him by popular vote.
3) *Articulate communicating.* The chairman must serve as a translater as well as a promoter of ideas. He has to remove the distortion of information so that a mutual understanding develops. He must restate ideas that participants may have distorted. He should be clear and concise in presenting concepts, describing tasks, defining problems, or synthesizing related ideas. He should use clear meaningful language. Worn-out clichés and trite jargon detract from accurate communication of ideas.
4) *Technical perception.* The chairman of an engineering meeting cannot be and need not be fluent in each of many technological disciplines which may be discussed. He must have a broad appreciation and comprehension of the meaning and levels of technical detail. For example, a discussion about the saturation current of a GaAs diode could be a most essential element in one situation, yet in another the same topic might be classified as trivia. A chairman who is unable to make this distinction stands to have his meeting veer off course.
5) *Assuming responsibility.* The chairman should assume and exercise the responsibility for performing the entire program of planning and implementing the meeting. Even though his bosses' boss may be present as a participant, the chairman is the individual who must bring the meeting through to a successful conclusion.

CONCLUSION

The program of planning and implementing a meeting, skillfully performed by a competent chairman, are the essential factors producing an effective meeting. Skill in planning and implementing of effective meetings, as any other skill, develops from the strong determination to make judicious use of resources in accomplishing useful, progressive results.

Although the majority of engineers do not have the formal organization-chart type of management responsibility, it is likely that the performance of their assigned functions will require the assumption of chairmanship responsibilities. Any engineer who is ill-prepared to execute this responsibility is a liability to his organization.

An engineering organization has the capacity for growth in its capability to better accomplish its goals. The use of effective meetings can materially contribute to that growth.

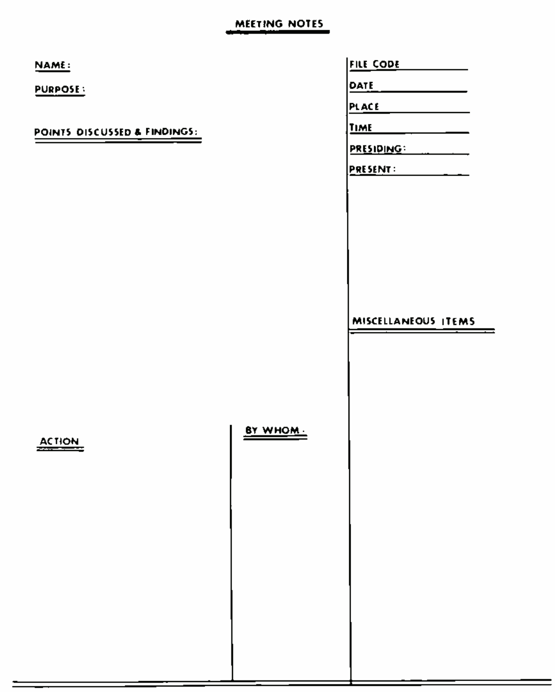
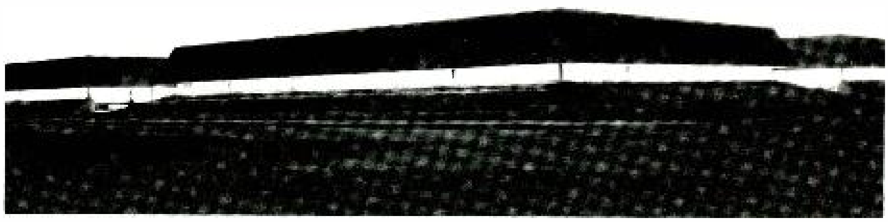

MEETING NOTES
NAME:
PURPOSE:
POINTS DISCUSSED & FINDINGS:
FILE CODE
DATE
PLACE
TIME
PRESIDING:
PRESENT:
MISCELLANEOUS ITEMS
ACTION
BY WHOM:

Fig. 6—Meeting summary form.

The Graphic Systems Division

JACK GOLD
Technical Publications Administrator
Graphic Systems Division, Dayton, N. J.

The Graphic Systems Division is a new division of RCA which meets the challenge of the information explosion by bringing electronics to the printing industry. This paper sets the stage for the other papers in this issue by briefly describing the purpose, the products, the facilities, and the engineering organization of the Graphic Systems Division. To complete the stage setting, a glossary of graphic-arts terms is also provided.



IN THIS COUNTRY, we consume over a billion books, over ten billion magazines, and more than twenty-five billion newspapers a year, and our massive appetite is increasing. To move ahead in our highly industrialized society, it is an economic and social necessity that more information reach more people—faster!

RCA Graphic Systems Division is discovering new approaches to meet this demand. Moving electrons instead of mechanical type, the RCA Graphic 70 Videocomp can write approximately 650 characters a second or 900 lines a minute, to set the text of a standard newspaper page in less than two minutes. Through electronics, the RCA Graphic 70 Color Scanner can make a set of four separations for plates used in color printing in as little as 35 minutes; conventional camera techniques require 4 to 30 hours. The RCA Videocomp and Color Scanner are part of the Graphic 70 line of products, designed for the seventies—in use today.

ENGINEERING ORGANIZATION

Engineers and scientists of the Graphic Systems Division work in product engineering, programming development, product development, applied research and advanced development (see the organization chart, Fig. 1).

Reprint RE-13-6-19/Final manuscript received February 19, 1968.

FACILITIES

The RCA Graphic Systems Division is housed in a new facility located on a 15-acre portion of a 102-acre tract on U.S. Highway Route 130 in Dayton, New Jersey. Initial accommodations are available for a staff of approximately 250 people, with parking for 220 cars. The architect, Vincent G. Kling and Associates, designed the RCA Graphic Systems Division building to meet three objectives: 1) accommodate the division's specific needs; 2) create distinctive identity for the division; and 3) establish a design prototype in the event of future buildings requirements on the property.

The low-slung, modern building appears, at first glance, to rise from the surrounding New Jersey farmland. One third of its one-story height is concealed by the grassy berm that slopes sharply from its perimeter (a photograph of the new building is shown above).

The steep plane of its overhung copper fascia, separated from the earth by a horizontal ribbon of glass, repeats the angle of the berm and provides a strong impression of unity between structure and site. The berm, fascia, and glass ribbon are all functional: the berm provides architectural strength; the fascia reduces the sun's glare and lessens air conditioning loads; and the windows provide a panoramic view of the countryside.

Three inset landscaped courts break the strong horizontal lines of the building: one at the main entrance, another between offices, and the third at the employees' entrance. The fourth wall, at the rear, has been left blank to facilitate an expected doubling of manufacturing facilities.

Inside, four rectangular units arranged symmetrically around a central core provide 56,700 square feet of floor space. At the core is the Graphic Systems computer center. The four sections house engineering, development, manufacturing, and sales, respectively.

LANGUAGE OF GRAPHIC ARTS

Because they serve the graphic-arts industry, engineers and scientists of the have added new terminology to their vocabulary. Therefore, the following glossary of graphic-arts terms is offered as an aid to understanding the articles which follow describing RCA activity in the graphic arts.

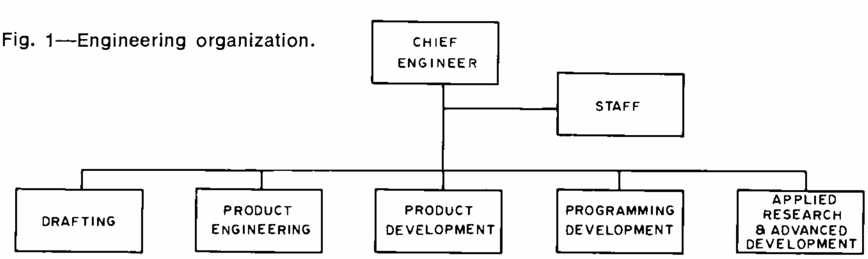


Fig. 1—Engineering organization.

J. L. GOLD received a bachelors degree in science and a masters degree in education from Temple University. He has taught in the public schools and held positions in the field of adult education in private and military organizations. Since joining RCA in 1951, Mr. Gold has served in engineering positions for approximately five years and in writing, editing, and management positions in the field of technical publications for approximately ten years. He has participated in major RCA projects, such as Talos, C-Stellarator, BMEWS, and SAM-D. He is currently responsible for technical publications and reports in the Engineering Department of the Graphic Systems Division. Also he is the Technical Publications Administrator for RCA Graphic Systems Division and is the RCA ENGINEER Editorial Representative.

Glossary of Graphic-Arts Terms

Albumen plate: Plate used in lithography coated with bichromated egg sensitizing solution.

Ascender: Part of a tall lower-case letter which extends above the body line.

Bad break: In composition, the setting of a hyphenated line as the first line of a page. Also, incorrect word division.

Base: In composition, all the metal below the shoulder of a piece of type. In letterpress, the metal or wood block on which printing plates are mounted to make them type high.

Blanket: In offset-lithography, a rubber-surfaced sheet clamped around the cylinder, which transfers the image from plate to paper.

Body lead: Refers to the spacing between successive lines of printed material.

Body type: Type used for the main body of a book, as distinguished from the headings.

Bold-face type: A name given to type that is heavier than the text type with which it is used.

Cap: A printer's term for capital or capitalize.

Capital letter: Any of the large letters, of a font of type.

Chase: (letterpress printing) A metal frame in which type forms are locked ready for the press.

Collate: In binding, the assembling of sheets or signatures.

Composition: The setting of type material for printing.

Condensed type: A narrow or slender type face.

Continuous tone: A photographic image which has not been screened and contains gradient tones from black to white.

Copy: Any furnished material (typewritten manuscript, pictures, artwork, etc.) to be used in the production of printing.

Crop: To eliminate portions of copy, usually on a photograph or plate.

Densitometer: A sensitive photoelectric instrument which measures the density of photographic images, or of colors in color printing. Used in quality control to determine accurately whether color is consistent throughout the run.

Diazo process: A method for printing by exposing paper treated with a diazo compound that disintegrates on exposure to light, then developing the unexposed areas by the use of diazo dyes.

Double-burn: The act of combining different images into a single reproduction by successively photographing the images in register on the same piece of photosensitized material.

Dot: The individual element of a halftone.

Dropout: A halftone with no screen dots in the highlights.

Dummy: A "preview" of a proposed piece of printing. A set of sheets or leaves made up to show in advance, size, shape, and form of the printed job.

Em: The square of the body of type, used as a unit of measurement for type matter.

En: A unit of measurement for type matter, being the same depth and one-half the breadth of an em in a body of type.

Expanded type: Type whose width is greater than normal; also called extended type.

Face: The part of a type character that appears in relief on the printing end of the type, and which produces the impression in printing.

Family: The complete group or collection of all the sizes and styles of type of the same design.

Font: A complete assortment of type of one size and style, including all letters of the alphabet, both large and small, points, accents, figures, etc.

Form: Type and other matter locked in a chase ready for printing.

Format: The size, style, type page, margins, printing requirements, etc., of any magazine, catalog, book or printed piece.

Foundry: The section of a printing plant or stereotyping house where matrices are made from type forms and plates and stereotypes are cast.

Galley: Flat metal tray in which type is placed after it is set.

Galley proof: A proof taken of type standing in a galley, before being made up into pages.

Gradation: In photographic originals and prints, the range of tones from the brightest highlights to the deepest shadows.

Gravure: An intaglio process of photomechanical printing such as rotogravure; the metal or wooden plate produced by engraving.

Gutenberg: The man given credit for the invention of movable metal type.

Halftone: A reproduction of continuous-tone artwork, such as a photograph, with the image formed by dots of various sizes. Photomechanical printing surface and impression made from this surface in which detail and tone values are shown by using a series of evenly spaced dots of varying size and shape. The dot area varies in direct proportion to the intensity of tones they represent.

Hanging indent: Indentation of all the lines of a paragraph except the first.

Heading: A title or caption of a page, chapter, or section.

Highlight: The lightest or whitest parts in a printed picture, represented in a halftone by the smallest dots or the absence of all dots.

Hot type: Type cast from molten metal.

Indenture: An indentation.

Intaglio: A process in which a design or text is engraved into the surface of a plate so that when ink is applied and the excess wiped off, ink remains in the grooves and is transferred to the pages in printing.

Justify: In composition, to space out lines uniformly to the correct length.

Kern: That part of the type face which projects beyond the body or shank.

Keyboard (verb): to compose type by operating the keyboards on a linotype machine or by punching a type for a photocomposer.

Leads: Thin strips of metal placed between lines of type to separate them vertically.

Letterpress printing: Printing from type or other raised surface.

Letterset (dry offset): The printing process which uses a blanket (like conventional offset) for transferring the image from paper to plate. Unlike offset, it uses a relief plate and requires no dampening system.

Letterspacing: The spacing between each letter of a word.

Ligature: A type character on which two or more letters are cast on a single body. A single character consisting of two or more letters or characters united.

Linecasting: The casting of an entire line of type in a slug.

Linotype: A typesetting machine that casts solid lines of type from brass dies, or matrices, which are selected automatically by actuating a keyboard.

Lithography: Method of reproducing graphic material by taking ink impressions from a specially prepared stone or metal plate.

Lower case: The small letters in type, as distinguished from the capital letters.

Markup: Writing specific instructions upon the manuscript, galleys, etc. The instructions are to be carried out in the keyboarding or makeup operations.

Mask: In color separation photography, an intermediate photographic negative or positive used in color correction. In offset-lithography, opaque material used to protect open or selected areas of printing plates during exposure.

Matrix: A mold in which type is cast in linecasting machines. In stereotyping, the paper mold made from a type form.

Measure: In composition, the width of type, usually expressed in picas.

Middletones: The tonal range between highlights and shadows of a photograph or reproduction.

Monotype: A machine for setting and casting type, consisting of a separate keyboard for producing a paper tape which is then used for casting the hot metal letters by special matrices.

Negative: In photography, a photographic image with tone values in reverse to those of the original copy.

Offset: Transfer of ink from a freshly printed sheet to the back of another sheet. Also, a form of lithographic printing.

Old style: A style of letter in which mechanically perfect lines are not attempted, and there is but slight contrast between the light and heavy elements.

Paginate: To indicate the sequence of pages by numbers or other characters on each leaf.

Pasteup: The result of pasting typeproofs, small sketches, and supplementary designs to the copy in the desired position.

Photocomposition: A method of composing reading matter by photographic methods instead of type.

Pica: Printer's unit of measurement, used principally for measuring column widths of type. There are 6 picas to an inch.

Point: Printer's unit of measurement, used principally for designating type sizes. There are 12 points to a pica; 72 points to an inch.

Point size: Refers to the height of a font, that is the distance, measured in points (72 points = 1 inch), from the top of the highest ascending character to the bottom of the lowest descending character of the font.

Point System: Printer's system of measurement 1-72 in., 12 points equal one pica.

Positive: Photographic image which shows light and dark shades the same as the original subject.

Primary colors: In printing inks, yellow, magenta (process red) and cyan (process blue). In light, the primary colors are red, green and blue.

Process printing: The printing from a series of two or more halftone plates to produce intermediate colors and shades. Usually in four-color process: yellow, red, blue, and black.

Proof: A trial printing impression used for examination and correcting errors.

Reproduction proof (repro): A clean, sharp proof that is pulled to be photographed. High quality proofs or reproductions which are photographed or pasted up with art work and thence photographed. The repro-proof serves as the source material for making the printing plate.

Rotogravure: Printing from an intaglio copper cylinder.

Running Head: A heading which is repeated on several consecutive pages of a book.

Scanner: An electronic device used in the making of color separations.

Screen: In photoengraving and offset-lithography, glass or film with cross-ruled opaque lines or vignetted dots used to reproduce continuous tone artwork such as photographs. Also, the number of lines or dots to the linear inch on printed illustrations.

Serif: Fine lines or cross strokes found at the tops and bottoms of Roman type faces.

Shoulder: That part of a type not covered by the letter which accommodates the descending part of the letter.

Signature: A printed sheet containing a number of pages, folded as one unit and forming a section of a book or pamphlet.

Slug: In composition, a one-piece line of type. Also a strip of metal, usually 6 points, used for spacing.

Small caps: An alphabet of small capital letters available in most roman type faces approximately the size of the lower case letters. Used in combination with larger capital letters.

Stripping: Similar to pasteup but using transparencies. Consists of the removal of collodion and stripfilm negatives from their temporary supports and transferring these images to the desired locations on a new or final support, usually in preparation for making a printing plate.

Transparency: A transparent positive or negative photograph.

Typeface: An assortment of type of one size and style.

Typography: The art of printing with type or of expressing by skillful use of type.

Upper case: The name applied to the capital letters of the alphabet.

The Computer and the Graphic Systems Division

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Font Process Development
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In addition to the direct applications to the Videocomp product line, the Graphic Systems Division (GSD) uses computers for business models, accounting, product development, and research and engineering studies. This paper describes these various applications of the computer at GSD.

TODAY we are experiencing a second industrial revolution as a result of automation, electronic technology, and computers. It is essential to utilize these revolutionary tools to compete in today's business world. RCA Graphics Systems Division (GSD) was formed with a mission to apply electronic technology to the printing industry and is keenly aware of the potential of the computer. Computer applications at GSD are significant both in their diversity and their novelty. This paper discusses some significant GSD applications and suggests further possibilities.

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WALTER STEPHAN received the B.A. in mathematics from Princeton University in 1952, and the M.S. in computer engineering from Stevens Institute in 1961. He entered the computer field in 1954. He has worked on many large real time systems including SAGE (air defense system), SACCS (SAC command & control system), Gemini and Apollo as well as diverse engineering and business applications. Since joining RCA in August 1965, he has been responsible for the programming development of font, T&M, demonstration, and composition programs. Mr. Stephan directed the implementation of the PAGE-1 language on the Spectra 70/35-45 Processor. He is currently responsible for the development of economical and effective font development processes.

The chart of Fig. 1 may provide some perspective for the comprehensiveness of GSD applications.

BUSINESS MODEL

The Graphic Systems Division is one of the first RCA divisions to employ a business model. Although the current model employs an RCA-601 computer, the use of a Spectra 70 processor is planned. The model calculates the projected profit and loss statements for the division, based on sales forecasts and man-loading estimates. Results are summarized in easy-to-read reports, so that the management can quickly evaluate alternate courses of action. Some of the factors evaluated in the model are competition between items within the division product line, sales versus leasing, and the effect of under- or over-staffing.

ACCOUNTING

The Graphic Systems Division is presently too small to do its payroll as a computer application. However, there are several important ways in which the GSD accounting activity utilizes the Spectra 70 processor: validation, inventory control, and labor distribution.

Accounting Validation

The Accounting Validation Program validates, organizes, and sums the items comprising the monthly statements of the Division. All journal entries are prepared on punched cards. In addition, a balancing entry is prepared for each batch of entries which is designated as the Zero Balance Account of the General Ledger. For example, six Business Expense Report Vouchers may be prepared totalling $125.99. An additional Zero Balance Card is prepared in the amount of $125.99. The Validation Program is run daily, providing a validity check on each entry and trial balances for each account. The validity check ensures that all necessary information has been provided and that all data have the proper format. The account number is an example of an item which must be provided for each transaction. This number must be an integer and fall between 10000 and 99999 to be valid. At the end of the month, a full report is made, giving the totals for each account maintained by the Division. It is then a simple matter to transfer the sums from the computer-produced reports to conventional balance sheets and profit-and-loss statements.

Inventory Control System

The Division has recently started an Inventory Control System. This system keeps track of all items in manufacturing, including finished parts, finished subassemblies, completed systems, and sold systems. A single catalog number is used to identify an item throughout the system, so that personnel never have to consult parts lists or catalogs at each step of assembly. The system is designed to account for both the quantities and costs of items in inventory.

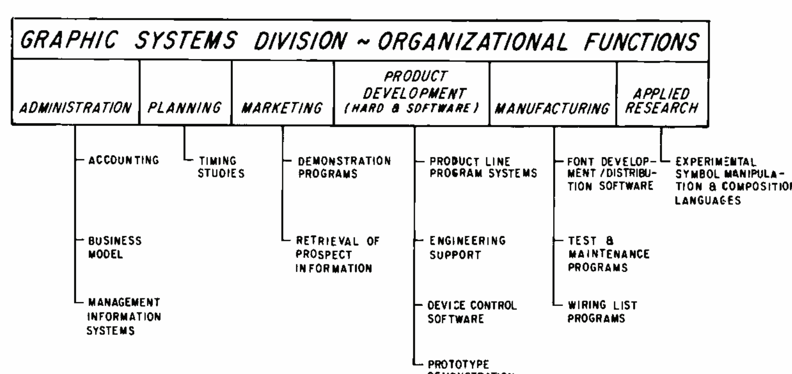


Fig. 1—Computer applications at the Graphic Systems Division.

Labor Distribution

The Labor Distribution Program validates, allocates, and balances the hours of direct labor worked by the Division. Validation includes a check of account numbers (holiday, vacation, illness, etc.), shop orders, employee number, and format (e.g. all numeric, negative, etc.). The labor allocation is presented in three reports: direct labor by section/department; direct labor by shop order/account; and a summary of hours worked by job classification within section. In addition, hours are extended by the employee's hourly rate and a nominal or estimated overhead applied. The result is a statement of labor costs analyzed by section, grade, and job. The program balances direct labor by summing hours worked in each department and proving against the figures provided by the Payroll Department.

PRODUCT DEVELOPMENT ENGINEERING AND PROGRAMMING

The Graphic Systems Division develops both hardware and software products. Programs are used to support the hardware products, such as Test and Maintenance Programs, and Prototype Demonstration Programs. There is also a significant new activity which has been termed "grayware" because it lies somewhere between hardware and software. The "grayware" deals with device-control programming which is described later in this article.

Test and Maintenance Programs

Graphic Systems Division has produced test and maintenance (T&M) programs for prototype and production of electronic CRT photocomposers (Videocomp). The programs systematically exercise equipments and detect and report malfunctions. They create periodic conditions through program looping; that is, repetition of the same instructions, enabling test personnel to use oscilloscopes. From the onset of the T&M activity, the guiding principle has been flexibility and ease of use. Consequently, "test generators" have been included in all program packages, enabling the engineer to specify his own tests directly to the test generator in simple command language. The program then generates the required test program.

Prototype Demonstration Programs

One of the first tasks of the Graphic Systems Division was to develop a prototype electronic CRT phototypesetter. A demonstration program was prepared to support the development effort. The program accepted text from an on-line keyboard, retrieved character-stroking data (digital fonts) from magnetic tape, and transmitted the appropriate information to an on-line phototypesetter. It successfully demonstrated that GSD possessed the necessary hardware and programming capability required to support electronic CRT phototypesetting systems. This program was subsequently used for customer demonstrations and the engineering development of camera and film transports.

PROTOTYPE COMPOSITION PROGRAMS

To verify the design of 70/35-45 composition programs for systems which included a Videocomp Photocopy Unit, a Prototype Composition Program was developed. This program has a complete inventory of composition control commands including letterspacing, type expansion and condensing, and baseline movement. In addition, a GSD Hyphenation Program was integrated into the Prototype Composition Program.

The Prototype Composition Program became a workhorse for the Division with the arrival of the first RCA Graphic 70 Videocomp. It was used originally in the production of sample copy for customer demonstrations and for printing and publishing conventions. Among the accomplishments of the program was the setting of the RCA Stockholders' Report. An additional benefit of this program was its use to check the output phase of the 70/9300 Graphic Programming System by using the output of the prototype program as input to the output phase. This combination produced simultaneous three-column classified advertising copy on the 70/822 Videocomp System by sorting the print lines from all three columns in top-to-bottom order.

Font Development Programs

Font Development Programs (Fig. 2) play a vital role in the operations of the Division: Videocomp photocomposers cannot operate without fonts. The font development function is equivalent to the function of a type foundry in the design and production of typefonts. Font development programs perform the following tasks: digitizing and quantizing (generation), display, correction, proofing (output), and formatting (retrieval).

Letter Frequency Test

An important aspect of font development is letter fitting; that is, establishing the amount of white space between adjacent characters. The fitting of adjacent letters is just as important a legibility factor as letter form. GSD has developed a special computer program to systematically explore letter combinations in conformance to letter frequencies as a means of verifying letter fit. The program displays four-letter combinations with the more common combinations appearing more frequently. This program is used to adjust the character side bearings (white space on either side of a letter) of exceptionally high-quality fonts, when extensive proofs are warranted and the cost of keyboarding a random sample would be prohibitive.

70/9300 GRAPHIC PROGRAMMING SYSTEM

The 70/9300 Programming System is a general purpose composition system based on a configuration which includes a Spectra 70/35-45 processor and a Videocomp. A composition system is an organic collection of computer programs which stores, retrieves, and edits keyboarded manuscripts and prepares hyphenated, justified, and paginated output. It features the PAGE-1 Composition Language, which is the software required to drive the Videocomp. The first phase of the system has been developed and installed at customer sites. PAGE-1 provides a composition system oriented to book publishing which consists of large-volume, slow-turnover jobs. The system operates in batch-processing mode with one master file (magnetic tape) for each book job. Fig. 3 depicts the flow through the system which consists of the following five stages: Manuscript Edit, PAGE-1 Language Analysis, Line Composition, Page Composition, and Typesetting.

Manuscript Edit

The Manuscript Edit (MS) stage begins with the preparation of copy on perforated paper tape. Keyboard perforators are commonly used for this purpose. The paper tape is read by the Edit Program and displayed on the line printer. The Edit Program identifies the copy by character number within line number. The display is proofread and corrections are introduced to revise the copy. The corrected copy is recorded on Tape A, the input file. Some customers will produce Tape A by another program, for example, file maintenance programs (for telephone directories) or information retrieval programs (for library catalogs).

PAGE-1 Language Analysis

The PAGE-1 Language Analysis stage compiles the composition commands imbedded in the MS according to the syntax of the PAGE-1 Language creating Tape B. This stage retrieves all the format and synonym definitions referenced in the MS, relieving the user of the need to explicitly write all commands. Furthermore, formats are stored from job to job on a disc storage unit attached to the 70/35-45 Processor, so that commonly recurring typographic procedures are always on call.

Line Composition

The Line Composition stage executes most of the PAGE-1 Language Analysis commands compiled by the preceding stage. The result of this stage—justified print lines—is recorded on Tape C, the job master file. Line Composition retrieves set-width and hyphenation exception words from the disc as required to perform justification.

Page Composition

The Page Composition stage completes the composition process by organizing printing lines into pages. Lines are sorted in top-to-bottom order. The leading (white space) between lines is calculated; proof-line numbers for keying corrections are attached; digital fonts are retrieved; and copy is converted to Videocomp language. The result is Tape D which is ready for typesetting.

Typesetting

The typesetting stage is performed using electronic phototypesetting by the Videocomp. Digital fonts are stored in the Videocomp memory. Text and commands are interpreted directly. The result of typesetting is either proofing copy (stabilization paper) or final copy (film) as desired. Corrections to the MS are keyed to the proof-line numbers assigned by Page Composition. Correction commands and the job master file (Tape C) are processed by the PAGE-1 Language Analysis Program which performs the indicated corrections. The revised MS is then processed through the remaining stages, producing revised proof copy. The entire cycle may be repeated until all errors have been eliminated and final copy can be generated.

DEVICE-CONTROL PROGRAMS

Device-control programs are used by GSD to replace device-control electronics with a general-purpose stored-program computer, currently referred to as the Series-1600 computer. The advantage of this approach is that a single device, the Series-1600, can serve many purposes, becoming adapted to each purpose by a stored program. The Series-1600 can be adapted better to an application than an instruction-level computer. The Series-1600 is currently incorporated into the latest Videocomps, magnetic-tape and on-line (DXC) systems.

The Device Control Program performs the following operations:

1) Controls the device input/output;
2) Stores and retrieves digital fonts;
3) Interprets device commands;
4) Executes device commands including:
   a) Beam velocity selection
   b) Interstroke delay section
   c) Beam positioning (word spacing and tabbing)
   d) Type size adjustments
   e) Type base line adjustments
   f) Type slant adjustments
5) Controls font format;
6) Controls and monitors film advance;
7) Report status; and
8) Interprets manual control.

The Device Control Program cannot completely replace all device-control electronics because extremely high-speed digital/analog circuits are required to precisely control the CRT beam. However, many complicated digital circuits have been replaced by this approach.

ENGINEERING STUDIES

During the course of product planning and development, it is frequently necessary to evaluate the performance of proposed systems. GSD has used computer programs to support these engineering studies. A typical study is a timing analysis of a proposed photocomposer, assuming values for the critical performance parameters (such as beam velocity, character granularity, memory capacity, and film-advance speed). These programs are conveniently prepared using FORTRAN. As a result, studies have been completed quickly, enabling management to select the best equipment design parameters.

PRODUCTION

The GSD production activity utilizes Spectra 70 processors for inventory control, test and maintenance, and for wiring checks. GSD inventory control and test and maintenance (T & M) programs have been previously described. In addition to the Design-Check-Programs used by RCA Electronic Data Processing, GSD uses a common-point wiring-list program. This program prepares a listing of terminals with all pins having common connections grouped together. This listing is used to "buzz out" equipment. Since pins are checked by groups, rather than pairs the operation is fast.

The production activity also uses Spectra 70 processors to compose internal publications. For example, the *GSD Family* and TREND have been typeset with the aid of the Spectra 70/45, the 70/9300 Graphic Programming System, and the Videocomp.

APPLIED RESEARCH

The Graphic Systems Division has an associated applied-research activity at RCA Laboratories. This activity performs both hardware and software research. At present, an advanced text-processing language, SNAP-1, is under investigation. The language provides the capability to manipulate text in a general manner, so that a broad spectrum of editing functions can be performed on manuscripts. An experimental model of the language is now running on the Spectra 70/45.

FUTURE USES OF SPECTRA PROCESSORS

The future growth of GSD will require computer applications of a diverse and comprehensive nature. Business applications such as payroll will be initiated. Extensive engineering studies requiring computer use will be launched by research and development. Continuing font development will include the development of Japanese characters and special symbols of all kinds. Computer applications will still be required for device-control programming, and Series-1600 application programs. These requirements will increase with the advent of new, advanced graphic systems.

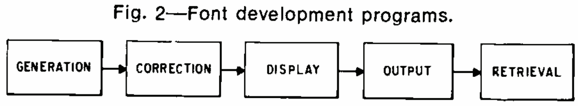


Fig. 2—Font development programs.

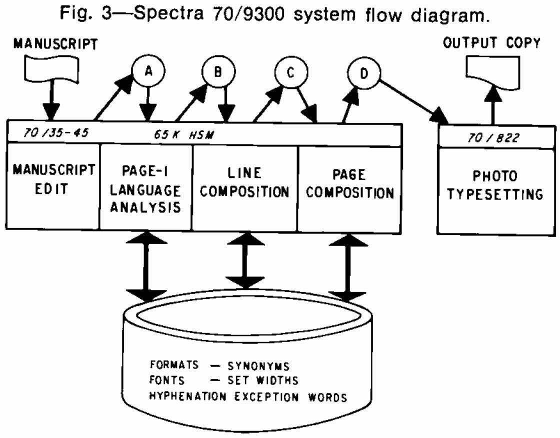


Fig. 3—Spectra 70/9300 system flow diagram.

A Review of the Graphic Arts Industry

JOHN J. WALSH
Graphic Systems Division, Dayton, N.J.

This article—part historical, part survey, and part technical—describes the products, methods, and equipments of the graphic arts industry. Although the three main printing processes (letterpress, gravure, and lithography) are emphasized, descriptions of such newer processes as flexography and electrography and electrostatic printing are covered. This paper may provide the reader with some appreciation of the environment into which RCA is moving.

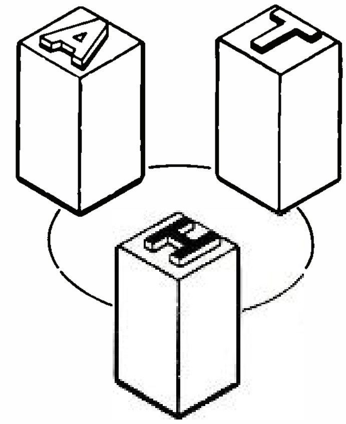


Fig. 1—Block letters of Gutenberg's time.

From rather narrow and cloistered beginnings, the printing industry has become both vast and versatile. It supplies us with a wide variety of items in our everyday life and influences our choice of product. In addition to the printed books, magazines, and papers, a large segment of the industry is devoted to printing cartons, labels, and tags and such specialty items as cans, bottles, and television and radio dial numerals. Engineering reports and technical papers make up a surprising percentage of the total volume of printing. Soon your wife may be interested in the purchase of a printed paper dress.

From inception, the graphic arts industry has been an artisan effort. Only those monks with the proper training could handle the brush in the pre-Gutenberg era. Still in question are the originators of ancient hieroglyphics and cuneiforms, but they certainly must have been the artisans of their day. Until the 1950's the industry while envolving from guild to trade shop remained secretive except for the marvelous scientific and engineering contributions of Gutenberg and Mergenthaler.

Both here and abroad, few engineers were found in printing plants until after World War II. Some machine designers were employed by printing press manufacturers before this, but they were mainly concerned with the design of machines to transport paper. The presses they built were not guaranteed to print, but only to run mechanically at a given speed. It was considered the problem of the printer to make them print.

LETTERPRESS

The earliest wood engravings existing today were made in China about 220 A.D. Many engravings are preserved from 8th century Japan. These engravings were cut from a flat block of wood by carving away the non-printing surface. Remaining are the letters or designs as a raised flat surface. this surface is inked and made to contact the paper or material to be printed thus transferring the ink to paper. This process is relief or letterpress printing.

Wood engravings were introduced in Europe in the early 15th century. Johannes Gutenberg started his development of movable type in 1435. There is evidence however that both the Chinese and Koreans had movable type; the Chinese used porcelain, and the Koreans used bronze.

The system that Gutenberg devised consisted of wood blocks of uniform dimensions with a letter cut in relief on the end (Fig. 1). These type pieces were then set in a chase, or vise-like holder that squeezed the sides of the blocks together and held them for printing.

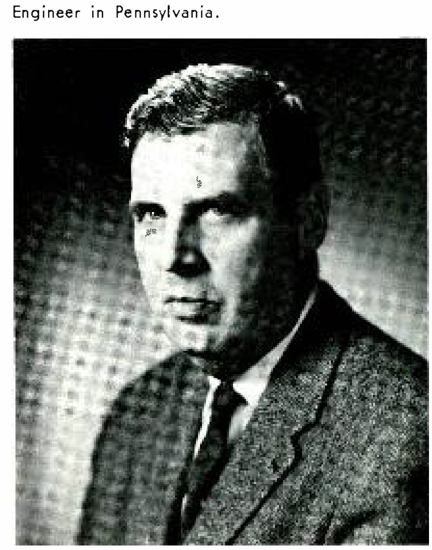
The chase used in this system brought about the development of justifying the lines of type. To hold all the lines of type of different length in the chase, filler-block material containing no raised letters was added to bring the lines to an even mechanical length. The results looked best when the filler-block material was distributed between the words and letters, rather than only at the right-hand edge. At present, most printing is done with justification (space additions), rather than an unjustified right (ragged right) margin.

TYPE

Before Gutenberg only two styles of type existed. They were standard block Roman letters in both upper and lower case and handwritten letters from manuscript books. The upper-lower case terminology used today is derived from the printer's case that holds caps and small letters. From these two basic type styles Jenson developed the basic Venetian style of which there are so many variations today. Gothic was used by Gutenberg. It became the standard for northern Europe. In 1692, William Caslon of England designed the typeface that bears his name.

John Baskerville in about 1750 was the second man to look at printing as a system concept. He established a paper-mill, printing plant, and type foundry. Dissatisfied with contemporary type styles, he designed the style that bears his name about 1758. His was a transition type, but certainly marked the beginning of modern type styles. Probably the first modern type was Bodoni (the type used in the body of this article).

JOHN J. WALSH received the BSEE from Oklahoma A&M in 1949 and the MSEE from the University of Pennsylvania in 1956. Mr. Walsh spent 15 years in the Gravure Printing Industry at Triangle Publications, Parade Publications, Publication Corporation, and Detroit Gravure where he held various engineering and production positions. He was associated with early installations of electronic register control systems and electronic press drives. In 1959 he was responsible for the introduction of the first solid state register control system in the industry. In 1964 he became associated with the U. S. Agency for International Development and served in Istanbul, Turkey as a printing and electric-electronic advisor. In 1966 he joined RCA's newly formed Graphic Systems Division in marketing and product planning. Presently he is on loan to the Graphic Systems Applied Research group at the Laboratories. He is a registered Professional Engineer in Pennsylvania.



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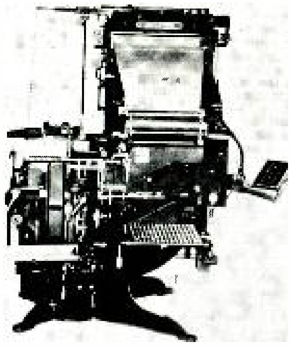


Fig. 2—Linotype machine.

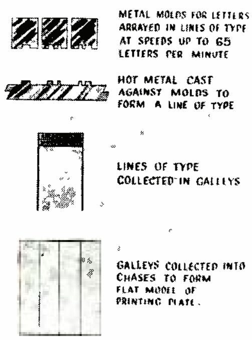


Fig. 3—Hot-metal composition.

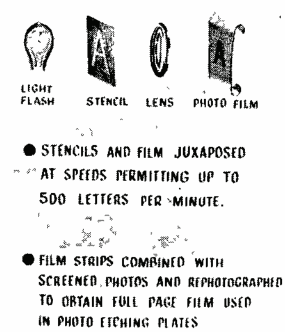


Fig. 4—Cold-type composition.

Today more than 1000 typefaces are in existence. A large typesetting house may have 200 to 300 typefaces available in the more common type sizes.

Type-Casting Machines

Until 1888 most printing was done with the system developed by Gutenberg. The only improvement was the substitution of metal blocks for wood. Type was set by picking type pieces from the upper or lower cases. This system is still used today, particularly in mathematics and chemical-formula typesetting.

Ottmar Mergenthaler first mechanized typesetting. His machine, the linotype (Fig. 2) uses matrices or molds that are transported from an overhead rack when typewriter-like keys are struck. The matrices are collected and a line of type is made up. The line of type is cast in molten lead, cooled, and fed to the chase. The matrices are returned to the proper case and slot by an intricate key coding system (Fig. 3).

About the same time Tolbert Lanston developed the monotype system that casts individual pieces of type into justified lines. This is a two-part system having a keyboard that punches paper tape with character and spacing information, and a casting machine to produce the type.

Phototypesetting

Phototypesetting was born to the industry in 1950. Most machines use a photographic matrix, a light source, and mechanically-controlled optics to produce a character on a piece of film or photosensitive paper. (Fig. 4)

Electronic Type Generators

In June 1966 RCA introduced the first electronic typesetting machine called the Videocomp. It generates characters from memory on the face of a CRT to expose a piece of film.

The speed of mechanical typesetting machines approaches 15 lines/minute; photosetters run as high as 300 lines/minute, and the Videocomp can run as fast as 900 lines/minute.

GRAPHICS

The Halftone Process

Hand engravings were used to reproduce carvings; lithography was used to reproduce artistic drawings; but for a long time no one could reproduce a photograph. Many attempts were made, but both type and a tonal photograph were not produced on the same press until 1886. Fredrick Eugene Ives of Philadelphia introduced the idea of breaking a picture into very small tonal dots by using a glass cross-line screen. The size and shape of the dots vary according to the amount of light transmitted by the screen. Large opaque dots in the negative produce light gray tones in the positive and smaller negative dots produce darker positive tones.

Three theories have been advanced to explain the halftone process—penumbra, pinhole, and diffraction. None is considered completely satisfactory. Today screens are produced photographically on film and placed in contact with lith film (high gamma) during exposure. Screens used today vary from 65 lines/inch for newspaper photographs to 200 lines/inch for fine-art reproduction.

Photoengraving

Application of a light-sensitive material to a metal plate is done by pouring the liquid photoresist over a whirling metal plate to ensure even distribution of the liquid. The halftone positive placed on the plate serves to shadow the resist from the exposing arc lamp. The soft (shadowed) photoresist is washed away and the light-hardened resist is hardened further with heat. The plate is placed in the etching machine and acid is splashed on it with considerable force. This dissolves the metal which is not covered with resist (Fig. 5).

Zinc is the common engraving metal, but magnesium and copper are required for higher screen density work. The etched plate is backed up by hardwood and is then known as a cut. The cut is added to the chase with the type.

Color Printing

Without going deeply into color theory, it is known that the subtractive colors are yellow (blue absorbing), cyan (red absorbing) and magenta (green absorbing). Printing transparent inks of these colors on a white background causes absorption of blue, red and green light even as black absorbs white light. Different quality inks vary in spectral response, the cyans and magentas being less pure than yellow. Inks are not truly transparent either, some additive color combinations exist on the printed sheet.

By photographing the original copy or transparency through blue, red and green light filters, the original can be separated into its components for printing. These resulting photographic films are called color separations and represent in shadow and clear the amount of a particular ink required to print the color picture.

Color separations can be corrected to improve or modify their appearance in many ways. Today electronic color scanners are producing color separations faster and better than photographic masking methods. The RCA Color Scanner is the leader in this field.

The separations follow the halftone process through to the plate. Both the halftone process and color printing sections are not limited to the letterpress process. Graphics in lithography and gravure are handled in a similar manner.

LETTERPRESS PRINTING PRESSES

Flat-Bed Press

Not much information is available about presses used previous to the screw jack press. This wine-press-like device pressed the printing plate to the paper

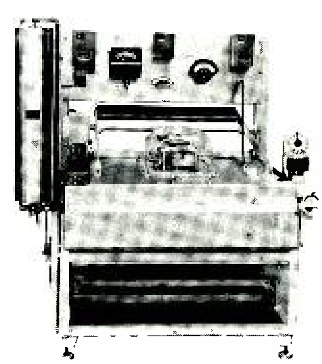


Fig. 5—A powderless etching machine for zinc or magnesium letterpress plates. The plate is rotated beneath the lid and paddles splash the acid from the bath below. The tank to the left dispenses acid to maintain uniform etching rate.

on a flat bed below. The flat-bed letterpress of today is not drastically changed from that of the Gutenberg era. In 1683 the Stephen Daye press was the first press brought to America. By 1850 metal was used in its construction and steam engines were built-in to drive the presses.

Platen Press

The Gordon press developed before the Civil War is probably the forerunner of today's modern platen press. For job-shop printing the clamshell platen press is probably most common. Here the platen and bed come together like a clamshell. The form is inked by rollers when the shell is open.

Cylinder Press

Cylinder presses were invented by Nicholson in England before 1800. This press used a cylinder rolling the paper on the form which rested on the flat bed. Some designs have the bed horizontal while others move the form and the cylinder in a vertical reciprocating motion. The *London Times* was printed at over 1000 sheets an hour in 1814. Addition of grippers to feed the sheet under impression improved both quality and production. Flat bed cylinder presses produce more than 5000 impressions per hour today.

Rotary Presses

Robert Hoe, founder of R. Hoe & Co., New York, perfected the first rotary press. The type forms were placed on satellite cylinders around the main impression cylinder. Sheets were fed from the top and delivered alternately on the bottom. The press was three stories high and the impression cylinder was 12 feet in diameter. History says it ran at 8000 impressions per hour. Problems in mounting typeforms were extreme and the inertia of the cast iron cylinders made this an extremely dangerous machine.

To better understand the types of rotary letterpresses used today it is necessary to digress momentarily on their applications. A newspaper requires a lot of papers on the street in a short time, this obviously means parallel operation and many presses are used for a large circulation daily. Plate requirements are for many plates with the same information. The economical stereotype plate process fits these requirements.

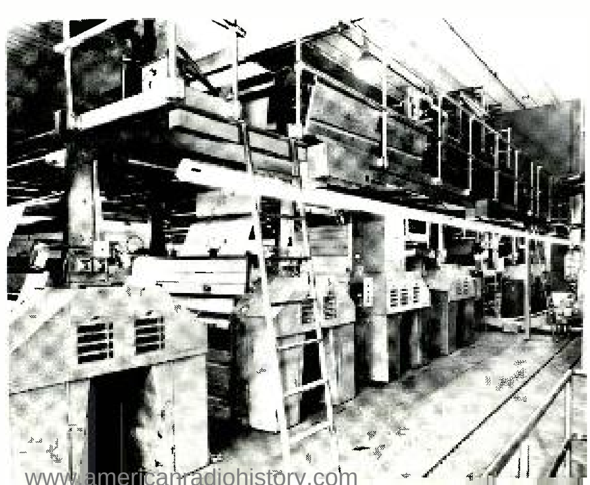


Fig. 6—A newspaper letterpress. The plate cylinder is visible to the left of the ladder. The stereo plate is not on the extreme right position but the plate is just visible in the next position. The driven roller conveyor on the floor is for transportation of the half round stereotype plates. Courtesy, the Hoe Company.

Magazines however are less time-dependent and quality is the main consideration. Electrotype and wrap-around and synthetic plates are used on magazine presses. Magazine presses do not require the flexibility in number of pages that newspapers do since they are collated and bound in a separate operation.

NEWSPAPER PROCESS

Stereotype Reproduction Process

When a page plate is formed in hot type (trade jargon for metal type) a need exists in newspapers for replication of this plate. A wet paper-maché mat is placed on the locked up chase of the metal type; a reverse image of the metal type is thus produced in the paper-maché. By curving this paper mache mold to the size of half the press cylinder and casting lead on it, a semi-cylindrical one-piece lead plate is formed which is almost an exact duplicate of the original type material. Successive castings produce the required number of plates for many presses. Today's casting machines usually produce a two-page plate which is locked on half of the press cylinder.

Newspaper Presses

Printing is accomplished between two cylinders or a printing couple. The plate cylinder holds the stereotype plate. The impression cylinder is surfaced with a hard rubber blanket. The ink is applied to the plates by two soft rubber rollers which are fed by an ink metering pump. Using a continuous web or roll of paper permits continuous operation and considerably improves production. The high production, high speed presses are all web (roll) fed. (Fig. 6)

MAGAZINE PROCESS

Electrotype Plate Process

Electrotyping process starts with the locked chase which may include photoengravings. The molding material is sprayed on the chase. The mold is removed, curved, and placed in a copper electroplating bath where a thin shell of copper is deposited. The original mold is removed, exposing the copper printing surface. The copper is then placed in a cylindrical mold, and lead is centrifugally cast to serve as a mechanical support behind the copper. Thin chrome plate is applied to produce a more durable printing surface. The plate is then ready for a magazine press. Several variations of this process are being field tested.

Wraparound Letterpress Plates

A reasonably new development in letterpress is a pre-sensitized plate that when processed is used for direct printing. DuPont developed Dycril for this application. Time-Life Laboratories as well as BASF in West Germany use photosensitive nylon. Kodak has a silver halide on an acetate base plate. Several presensitized coatings on metal (particularly zinc) are used. Each system has its own automated "etching" techniques. The major drawbacks with these systems is high cost of the plate materials.

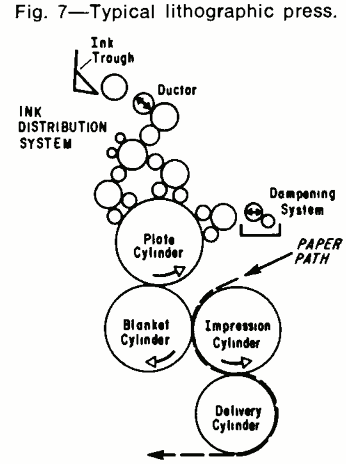
Magazine Presses

Magazine presses resemble the Robert Hoe press previously mentioned. There is one large impression cylinder with satellite plate cylinders around it. Usually there are five or six plate cylinders for the various colors required. Since heat-set inks are used, large flame dryers are required. As the paper web passes through the dryer, it is almost scorched. These presses are sometimes 40-ft high and are very impressive when the colored ink rollers are visible. The ink is applied to the plates by rollers as in the newspaper press, but the ink is fed by trough and blade to the first or ductor roller and transferred to the inking roller. The ink has about the same viscosity as calking and is handled with putty knives.

FOLDERS

Folders are mechanical devices which take the collected ribbons of paper, fold and cut them into a newspaper, a book, or a part of a book called a signature. Two basic types of folders exist today—newspaper and magazine or jaw folder.

Fig. 7—Typical lithographic press.



The nomenclature is by no means exact. All newspapers are folded on newspaper folders (Fig. 9) but many magazines are also folded on them. The magazine folders are more intricate but produce more accurate and tighter folds (Fig. 11).

OTHER LETTERPRESS PRODUCTS

In addition to newspapers, letterpress printing is used for such quality magazines as *Life*, *Better Homes and Gardens*, *McCall's*, and *Saturday Evening Post*. The news magazines and most of the monthly technical magazines are also printed by letterpress.

FLEXOGRAPHY

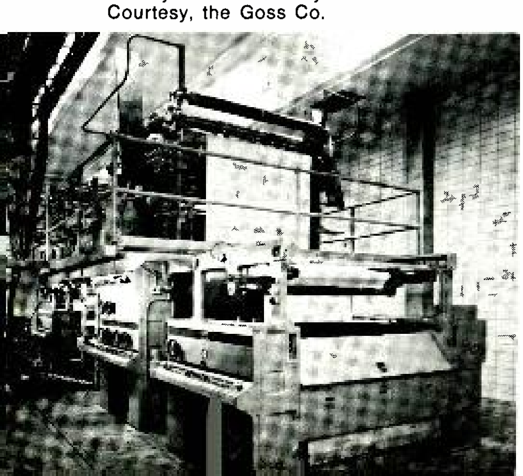
Formerly known as Aniline Printing, flexography is relief printing and may be grouped under letterpress, although it is distinct from it in many ways. This rubber-plate printing process is the baby of the industry having been introduced in the 1920's. *Flexography* was coined in 1952. A plate similar to a rubber stamp is stuck to a steel cylinder with double-face adhesive tape. More complicated plates and color plates requiring register are usually metal backed and strapped to the cylinder. The impression cylinder may be steel or contain a blanket depending on the nature of the material to be printed.

The latest method for casting or vulcanizing of the plates is to use a photosensitive glass mold. Rubbers and plastics have been developed to produce higher resolution and longer run plates but the process is generally limited by resolution of the plate.

Flexography offers major advantages in its flexibility. Plates can be edited on the press with a razor blade. New lines can be dropped in if changes are required, without remaking the entire plate. Plates can readily be changed from press to press, even where plate cylinder diameters differ.

Flexography offers an excellent method for printing on cartons as well as cellophane and foils. Many telephone books are printed on flexographic presses.

Fig. 8—The first four-page wide offset newspaper press at the Dubuque, Iowa, *Telegraph-Herald*. A blanket cylinder is visible in the first unit. The plate cylinder is below the sloping door. Printed papers are in the conveyor on the way to the mail room. Courtesy, the Goss Co.



LITHOGRAPHY

Alois Senefelder discovered the lithographic principle in 1798 in Prague, then Austria. He used a grease crayon to draw on natural Bavarian limestone. Rolling the stone with a water-wet roller and then with an oil-wet ink roller produced the mutual attraction-repulsion combination to supply ink to the image area only. Unlike other inventors of that day, he was completely recognized and esteemed by his contemporaries. In 1799 he was given what amounted to 15-year patent privileges by the crown. From 1809 he was the Royal Inspector of Lithography, and 1817 found his lithographic press improved with automatic inking and dampening. Later he experimented with paper-printing plates to replace the cumbersome stones.

The *Anelectic* Magazine, August 1819, published the first lithographic print in America. A description of the process was included. Lithography progressed slowly in both Europe and America until about 1873 when J. Merrit Ives, the artist, started to produce drawings on lithographic stones and Nathaniel Currier printed and sold them.

The Transfer Process

The word offset is used today synonymously with lithography. It is true that Senefelder transferred from the stone to a non-absorbent blanket and then to the paper. It may be that Senefelder invented the transfer process, but offsetting to a blanket and transferring to paper is not necessary for lithography. Offset (printing to a blanket) is used to a limited extent in gravure printing and is an important new method of letterpress printing. Most lithography produced commercially today is offset. Since the lithographic plate is planeographic, direct lithography tends to wear the plate rapidly with the abrasive paper. A soft rubber roller or blanket intermediary extends the life of the plate considerably. Fig. 7 shows a typical transfer process for a lithographic press.

Fig. 9—A small community newspaper offset perfecting press. Each unit prints eight pages on the roll of paper held beneath. The dampening system is about eye level and the inking system at the top of each unit. The newspaper type folder is to the right. Courtesy, the Goss Co.

Lithographic Plates

Lithographic stones are not used for printing today. The lithographic-plate field may be divided in three categories —long run bimetallic plates, medium run photosensitized plates, and paper plates for short runs (both photo and pressure sensitive). The latter is the office-copy field because of the poorer quality.

The long-run plates consist of a laminate of chrome on copper (other combinations are available). The photoresist is applied and softened with light in the printing area. The chrome is chemically etched away exposing the oleophillic copper area. Runs of a half million copies are commonplace with this type plate.

Early in this decade several manufacturers offered a presensitized aluminum based plate. These plates require only exposure and simple two step development to be press ready. Automatic development is now available for several plates.

Offset Boom

Starting in the mid 1950's offset lithography has made considerable strides in the graphic arts industry. This has been due to both technological advances and economics. Many of the technological factors are contributions from the industry-supported Graphic Arts Technical Foundation. The economical factors include the lower capital investment for an offset plant, particularly the press. Less cost per plate in the pre-press area is also a factor. One of the major technological advantages aiding lithography is cold type. With photocomposition the type as well as the graphics can be merged and photographed together to expose the offset plate. Use of hot type requires a transfer film but this route is more costly. Today offset lithography is used for nearly all areas of printing.

OFFSET PRESSES

Just like letterpress, offset lithography has sheet-fed as well as web-fed presses. The sheet-fed presses are not unlike the types from letterpress. They have the additional blanket cylinder for offsetting; but flat-bed, horizontal, and vertical presses are the sheet-fed types.

One particular advantage of offset is the ability to print on both sides of the web at the same impression (Fig. 8). Most web-fed presses print blanket to blanket (with the web in between). Only four units are necessary for process color on both sides. The inking and dampening systems are separate and the dryer, if used, is after the last impression. This makes an extremely compact and economical press.

Part of the recent offset boom has been in the newspaper field. The Goss Company makes four sizes of presses for this market. Fig. 9 shows one of the small presses. The Vineland, New Jersey, *Times Journal* has been a pioneer in the field. Many weeklys are printed offset. The Dubuque, Iowa *Telegraph-Herald* installed the first four-page-wide offset press (Fig. 8). The use of even a cheap plate on the press produces major quality improvements in the product over the stereotype letterpress. This is even more apparent when color is used.

DRY OFFSET

With the advent of prepared photosensitive plates for letterpress (described above) a new hybrid process was born. Dry offset, letterset, offset letterpress, and other names have been coined to sell the process. The plates were made available in a much shallower relief at a much lower cost. The wear problem was eliminated by the transfer process on conventional "offset" presses. The plates are currently limited in their ability to produce a fine tone or vignette.

ROTOGRAVURE

Soon after the discovery of the photographic process, J. Nicephore Niepce, about 1814, used light sensitive bitumen and sunlight to produce a positive image on metal. The metal, in the area protected from the light, was etched after the still soft bitumen was washed away. This produced an image etched in the plate or an intaglio plate (Fig. 10). By applying ink and wiping the surface clear, leaving ink in the etched holes, a printing surface was produced. Application of paper blotted the ink from the holes.

About 1835 Fox Talbot started experimentations that lead to the basic gravure patents in 1858. Using dichromated gelatin, Talbot coated a copper sheet. Daylight hardened the area not protected by the image and permitted washing away of the image area. Etching with ferric chloride produced cavities to hold ink. Swann developed "carbon" tissue in 1864. This is a pigmented gelatin on a paper base which is sensitized with potassium dichromate. No carbon is used. Karl Klietsch in 1879, used this material to transfer the exposed resist to the copper base. Developing away the soft gelatin exposed the metal to the etch. This exact process is used today with many refinements.

Klietsch first applied the process to rotary cylinders and brought the process to England. Klietsch and Samuel Fawcett founded the Rembrandt Intaglio Printing Company in 1895. The cylinders were rotated in a trough of ink and the surface wiped clean with a steel "doctor" blade (Fig. 11). The *Illustrated London News*, a weekly, was printed by this process in 1912. Here inks containing volatile solvents were used in combination with steam drums to permit higher speed drying.

The standard halftoning techniques from letterpress could not be used for graphics since a support is required for the doctor blade. Mertens developed the first gravure tonal screen in 1910. Prior to this, continuous crossed-line screens provided only cell depth tonal variations. Merten's screen provided two dimensional variations in dot size. His screen is known as the "conventional" screen and is used for reproducing type today.

Many other screens have been introduced to the process but Arthur Dultgen of the New York News introduced in 1937 the process which bears his name. The result is a three dimensional control of the cell. This substantially increased the tonal range and produced an additional control of the amount of ink on the paper not available in other processes.

GRAVURE PRESSES

Each color printed on the web requires one gravure press unit. To print four process colors on both sides of the web requires eight units. The press could be 150 feet long and may have 800 feet of paper at any moment in the process of printing. (Fig. 11)

Each unit contains a printing couple, cylinder and pressure roller; ink system, doctor blade and dryer (Fig. 12). The pressure rubber roller will apply from 100 to 400 pounds per linear inch across the cylinder to contact the material with the ink. The ink system circulates the volatile ink to the trough or fountain where the cylinder rotates. The doctor blade, a piece of thin spring steel, wipes the surface of the cylinder clean. It is necessary for it to oscillate across the cylinder to reduce local wear.

The dryer consists of an air supply and exhaust system to evaporate and remove the solvent from the ink and the paper. Air handling systems may require upwards of 150 horsepower. Several systems to recover the solvent from the exhausted air are in operation. Cur-

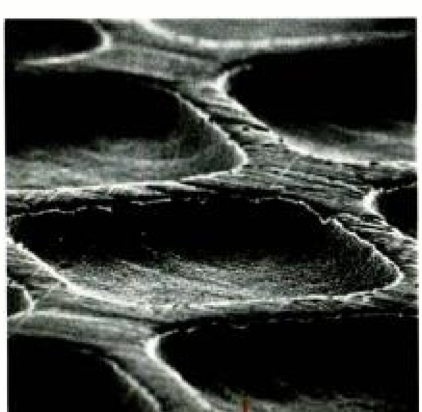


Fig. 10—This is a scanning microscope picture of gravure cells as they are run in the press. The viewing angle is 70° and the magnification is 620 times. Before the impression the cells are filled with ink and the top surface is cleaned by the doctor blade.

Fig. 11—An eight-unit rotogravure press with jaw type folder. This press produces four different 16-page signatures per revolution of the cylinder. *Family Circle* and *Woman's Day* are produced on this press. Courtesy John C. Motter Printing Press Co.

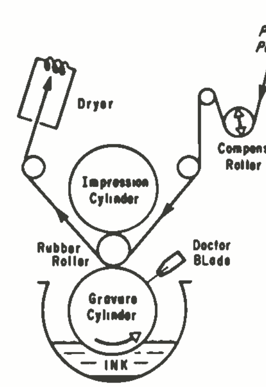


Fig. 12—Section of a typical gravure unit.

rent thinking in air pollution will make these systems more popular.

REGISTER CONTROL

Register is the ability to print one color directly on top of the previous colors. Each cylinder must have the image placed on that cylinder in exact relationship to all other images on all cylinders of a color set. Mis-register causes a fuzzy appearance. Registration of the plate is common to all processes.

The long length of web and the paper shrinkage in the dryers between colors makes a register control system almost mandatory on the press. In both other processes the web length between colors is considerably shorter and the dryer is necessary only after the printing is complete.

About 1939, both the General Electric Company and Hurletron Co. developed photo-electric, electronic motor control systems to maintain register in the direction of web travel.

GRAVURE PRODUCTS

Almost all newspaper Sunday supplements are printed in rotogravure. Such syndicated supplements as *This Week* and *Parade* print nearly 15 million copies per week each. *Weekend* is printed for 44 Canadian papers each week. Such locally edited supplements as *The New York Times Magazine*, *Today* of the *Philadelphia Inquirer*, *Tribune Magazine* of the *Chicago Tribune* are excellent examples of locally edited gravure magazines that weekly print about a million and a half copies each. The *Times* alone had nearly 12 thousand different pages printed a million and a half times in 1966. Of these 3600 were in four color.

The next largest group-printed gravure is the mail order catalog. Sears, Montgomery Ward, Spiegel, Aldens have all of their work in gravure. Sears alone printed 3000 four color pages in an almost infinite number of books in 1966 (about 20 million big catalogs and nearly 40 million fliers). Nearly 46 million copies of RCA's annual eight-page color television announcement is printed in four colors for insertion into Sunday newspapers twice each year.

Printing on containers is a major segment of gravure industry. General Foods has a large printing plant in Michigan. Most cigarette packs are printed in gravure. Printing on plastic is a gravure specialty. The wood grain patterns on wall board, formica, and building materials are gravure printed. Linoleum rugs (9 x 12 ft) are gravure printed on a 12-ft wide web.

A recent stamp issue, the beginning of an art series, "The Biglin Brothers Racing" is the first U.S. stamp to be gravure printed. These are printed on sheet-fed presses using a wrap-around gravure plate. Expected volume of output from gravure presses in 1967 may reach two billion dollars.

SCREEN PROCESS

The process called silk-screen printing has become the largest growing segment of the Graphic Arts Industry. Silk has been replaced by synthetics and resists are prepared photographically. The old "art" once used in making electronic instrument faceplates has come into its own.

The system, now mechanized, uses a piece of metal or synthetic screen material stretched over a frame. By plugging the proper holes, metering ink into it, and squeezing the ink through the holes, a screened image is produced on the surface in contact. Addition of hot air dryers permits 3600 impressions per hour. Much work in the bottling industry is done with screen, and bottle rotating squeeze stationary. The same technique is used on a larger scale in a rotary web-fed system to print or dye, selectively, wool rugs.

ELECTROSTATIC PRINTING

The Electrofax Process developed at the RCA Laboratories and now widely licensed is familiar to most. Electrostatic charging of zinc oxide coatings to attract pigments is in wide use today in office copiers. Direct selective charging of a plate behind a sheet of paper and selectively precipitating ink with fusing is a process that will print on almost anything. This feature was forcefully demonstrated recently by printing "Good Morning" on the fried egg yolk.

Thermography and Xerography are other office copy reproduction methods which might be classified as printing. Electrostatic transfer of dry pigment from gravure cells with a heat fusion is another recent development.

SUMMARY

Several problems exist in the printing industry today. Some are specific to one process while others are general drawbacks. The one single area today which is a problem to all printers is submitted copy. Editors and advertisers alike submit copy to the printer with a list of desired changes. If these changes are typographic, positive information usually can produce desired results. With graphic material and color there is no way to communicate positive information. The printer tries to please, but judgement is a factor. How far should he go and how much do the changes cost? Usually the printer makes his profit printing and not in changing copy, but still he must please the customer.

Making changes leads to the other area which is a major drawback: the time lag from copy submission until the first copy comes off the press. This is more or less common to all processes and is compounded by the previously mentioned problem.

The labor management relations have in the past had two serious problems. Strikes have put both management and unions out of business. Featherbedding exists in some areas.

Letterpress has its problems in high cost of capital equipment as well as production. In reproduction it cannot produce the fine tones which the other processes can. For type reproduction it is unbeatable.

In lithography, the fastest growing process of the big three, it is being found that the economical presses purchased a few years ago need replacement. They have not lasted as long as their letterpress counterparts. Despite many technological developments, it is still harassed with the ink-water balance problem which limits production speed.

The type of paper used for offset is considerably higher cost than standard newsprint. This is a major factor for any newspaper considering the change since paper is the largest cost factor in the operation.

Gravure has been growing very steadily over the past 25 years. It is limited in the economical ability to print short runs. Where quality is not the prime concern, some work has been lost to offset. Gravure is not as flexible as the other processes. A large segment of today's market is local advertisement and editions. It is not possible to change several pages of a book by changing plates. The entire printing cylinder must be changed.

There is no one best process. Each process has and will keep its share of the market based on the economic law. Each process can produce fine quality printing and each can produce cut-price printing.

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Electronic Composition System

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Electronic composition systems which are presently becoming available may be as revolutionary to the Graphic Arts Industry as was the introduction of the linecasting machine. These systems will eventually effect the complete publication cycle—from author's manuscript to, and including, plate making and distribution. The initial impact of the electronic systems will be felt primarily by the editorial and composing departments. The following is a very brief discussion limited to the effect of such an electronic composition system.

THE HEART of the electronic composition system is a third generation computer (RCA Spectra 70) with a relatively small set of associated peripheral equipments, a set of programs specifically designed for the Graphic Arts Industry, and high speed highly flexible photocomposing equipment (Videocomp). The function of the data processing equipment is to accept text (basic manuscript data), control and format instructions, and correction data, and to operate upon the text and correction data according to the control and format instructions. The data processor will automatically justify and hyphenate the text, format the text, insert corrections, and generate data which will drive the high speed photocomposing equipment. The output of the photocomposing equipment will be properly formatted (in the corrected typeface and point size) galleys or page proofs on paper or film. The final high quality pages may also be produced either on film or paper by the Videocomp equipment. The data processing capability of the system will allow a relatively large percentage of the manuscripts to be converted directly to page proofs without the intermediate galley operation—that is, those manuscripts for which page composition rules can be established, galley proofs need not be created. For those manuscripts which require sophisticated aesthetic human judgments, galley proofs may be generated and pagination instructions determined, input, and then executed by the system.

PRESENT PUBLISHING/COMPOSITION OPERATION

To describe briefly the effect of such a system, consider a typical non-computerized publishing/composition operation. A very simplified data flow is illustrated in Fig. 1 and a more detailed flow of operations is shown in Fig. 2. The author's manuscript, after receipt by the publisher and decision to publish, is reviewed by the book designer. The book designer determines and specifies the detailed characteristics of the final printed product. This is accomplished by the job specification (sometimes referred to as style specification). The job specification is a form, which when filled out by the book designer, describes in detail the desired characteristics of the final book: e.g., typeface, point size, and body lead for text, footnotes, paragraph heads, style of pages, position of page numbers, location of footnotes. When making decisions, the book designer makes use of the house style as well as previously printed books. The *house style* is a list of rules, written or unwritten, which expresses the preferred style of the publisher. The house style consists of such items as preferred word spacing, spacing around punctuation marks, rules for positioning and breaking equations, and ligatures. Upon completion of the job specification, both the job specification and the manuscript are forwarded to the copy editor who also has familiarity with the house style. It is the copy editor's job to see that the book designer's wishes (the job spec) are implemented. Thus, the copy editor must translate the job spec into terms that the keyboard (usually linotype or monotype) operators can operate from efficiently. The copy editor marks up the manuscript with detailed instructions for the composing operation indicating all typeface changes, indentures, location of chapter heads, etc. The marked up manuscript and the job specification are then given to the composing room for typesetting. To minimize undesirable effects, the composing room personnel must also have familiarity with the house style.

The manuscript is keyboarded according to the marked up instructions, job specification, and house style to produce lines of type in either metal or film. The keyboard may be attached directly to the machine which casts or sets the type (linecaster or phototypesetter), or may produce paper tape to drive automated (paper tape-driven) equipment. The individual page, or pages, may be set piece-meal on various typesetting machines because of differences in typefaces or sizes. For example, chapter titles, running heads, footnotes, and captions may all be set separately. The finished lines are then

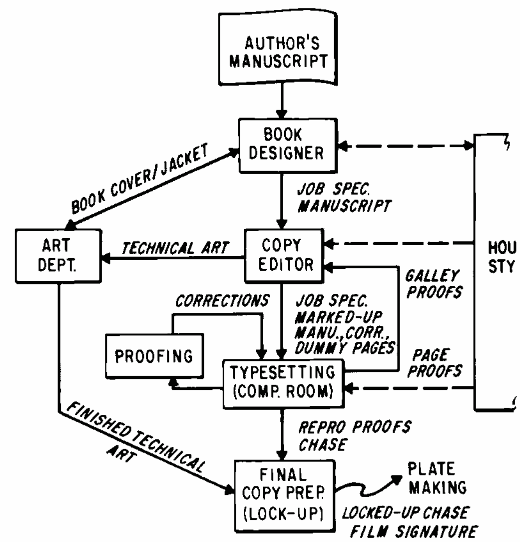

Fig. 1—Typical publishing/composition operation.

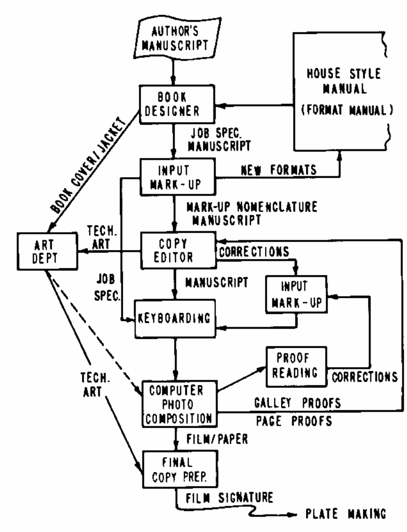

Fig. 3—Electronic publishing/composition operation.

Reprint RE-13-6-2/ Final manuscript received February 22, 1968.

all assembled in galleys or columns of lines (not necessarily the arrangement of lines that will appear in the final book). The galleys are then placed in a proof press; the type is inked; and galley proofs are printed. The galley proofs are proofread for errors in keyboarding, the errors are noted, and correction lines set. Since lines of type are normally justified, the addition of a single word to one line may result in a number of lines being rekeyboarded. The incorrect lines of type are manually replaced by the individual corrected lines.

When all keyboarding errors have been corrected, the updated galley proofs are sent back to the copy editor for further proofing, correction, and pagination decisions. (The composing room may actually make the pagination decisions when pagination rules can be specified.) Proofs may also be sent to the authors for proofing and corrections. The copy editor then incorporates author corrections onto the galley proof. The marked-up proofs are returned to the composing room along with specific pagination instructions. The pagination instructions may take the form of a paste-up where the galley has been cut and pasted, along with proofs of artwork, footnotes, etc., into the desired page form.

The composing room then keyboards and sets corrections and changes as marked on the galley proofs. This may include resetting of lines to different lengths to fit around illustrations, as well as corrections to material which has been set erroneously, or reworded by the author.

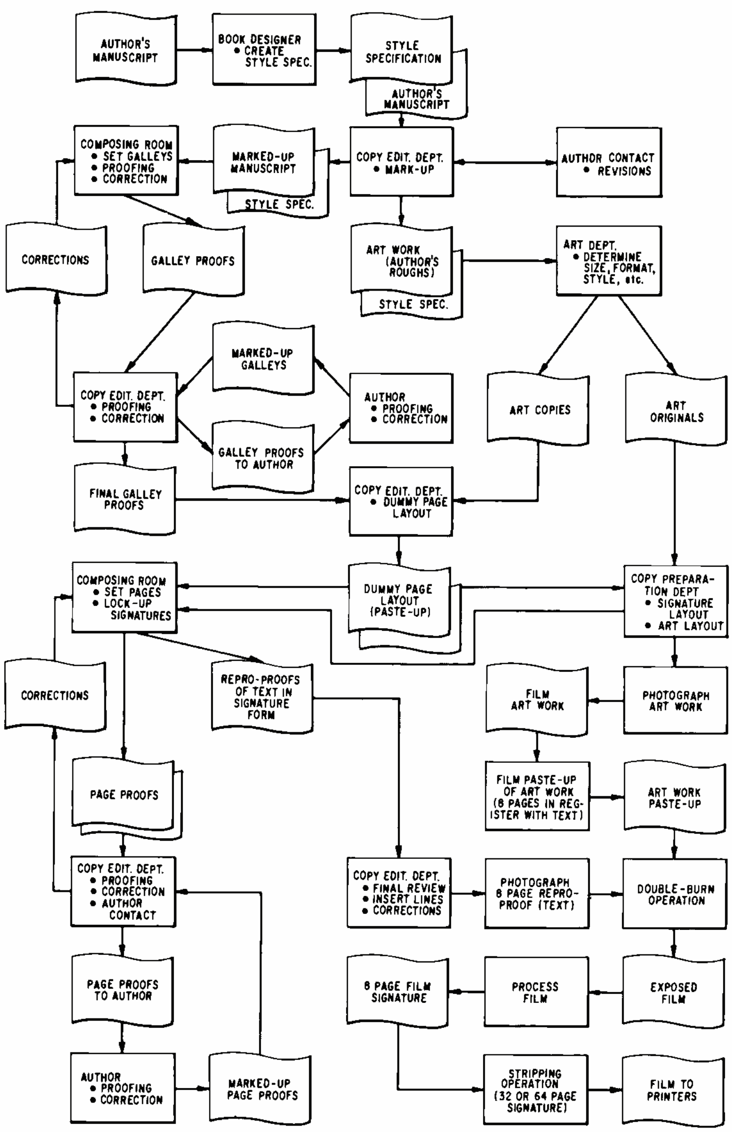

Fig. 2—Detailed publishing/composition cycle.

The corrected lines are merged with the original lines and the galleys are separated into pages. Running heads, page numbers, and captions are set and combined with the text lines according to the pagination instructions. (Frequently it is not possible to set captions prior to pagination since caption physical dimensions are known only after pagination decisions as to the size and location of artwork.) Art work is then placed in its proper position and page proofs generated. The page proofs then proceed through another correction cycle or cycles (including composing room, copy editor, and author). The manuscript is now ready, in the form of a locked up chase, film, or paper paste-up, for plate making and printing.

ELECTRONIC PUBLISHING/COMPOSITION SYSTEM OPERATION

Consider now the operation of an electronic publishing/composition system (Fig. 3). Manuscripts, after receipt and acceptance by the publisher, will be reviewed by the book designer. The book designer will provide data for the job specification which eventually (prior to entry into the computer) must appear in a high-level language developed specifically for the printing/publishing industry, which the computer is able to recognize unambiguously.

The house style manual will be somewhat different than described in the previous section. The house style manual will consist of a relatively large collection of anticipated, as well as previously used formats (Fig. 4), and the specific data which must be supplied for the job specification (i.e., a listing of the general variables for which data must be supplied prior to the use of the format). This will allow the book designer to choose from previously coded formats (to minimize input markup) by specifying the name or number of the formats to be employed. Hence, the house style manual becomes a collection of formats—the "format manual." The computer-coded version of the format manual, termed the "format file," will be stored in computer memory (disc storage) so that the format subroutines will be available as required by the job being processed. The formats are by nature very general and thus are applicable to many jobs. The formats, however, must be made specific for each job. This is accomplished through the use of the specific values given to the general variables in the job specification.

The specific coding of the job specification may be done by the book designer or a related operation (indicated as input markup). The job specification contains a list of the formats to be used in the job being set and a list of parameters (termed "general variables") to which specific values must be assigned. This will be elaborated upon in the following paragraphs.

New formats may be outlined by the book designer and put in computer language by him or the input markup man and stored in computer memory (disc storage—the format file). The new format will then be available for the manuscript being processed as well as becoming a new entry into the house style manual (the format manual) for use in future jobs.

The job specification (Fig. 5) which makes the general formats applicable to the specific job under consideration contains details of the size and style of type and vertical spacing that will be used for text, chapter headings, paragraph heads, running heads, footnotes, and captions to figures, and details for placing these items relative to each other. These details are entered as values or parameters for the general variables used in the previously generated and computer-stored formats. For example, specifying values for general variables *gv1* through *gv9* determines the point size, body lead, and typeface to be used for primary text, primary paragraph heads, and secondary paragraph heads. Also contained in the job specification and/or the format manual is a listing of the markup nomenclature to be used by the copy editor when marking up the manuscript.

The copy editor will markup the manuscript; that is, he will write the abbreviated typographic (style and format) instructions on the manuscript where necessary. For example *C1* will be marked at the start of the primary text. This will automatically call into effect the point size, body lead, and typeface specified by *gv1*, *gv2*, and *gv3*, respectively (see Figs. 4 and 5). Code *C1* also designates that the data following is text and is to be acted upon according to the layout specified within the format in force. Code *C2* will be marked at the start of a paragraph and *C1* after the paragraph head. The job specification containing the page layout code *F1*, values for the general variables, and the marked-up text, will be keyboarded and sent to the computer. Not all instructions need be marked on the manuscript. A number of instructions such as new paragraph code, new line code, upper case, etc., may be inserted by the keyboard operator. In general, the keyboard operator will keyboard exactly what is on the manuscript—text and instructions. He will undoubtedly operate more efficiently since he will not have to stop and interpret the copy editor's instructions and will not have to worry about justification and hyphenation.

All the keyboarded paper tape for a manuscript (including the job specification containing the values for general variables, the basic text, and the control or format names marked on the manuscript) will be read by the electronic composition system. The manuscript can be divided into logical units defined as reference points. These units are generally chapters or sections, which start a new page of text regardless of whether or not the text for the preceding unit fills a complete page. These units may be distributed to several keyboards for punching and each unit fed into the computer and stored in the disc memory until the entire manuscript is ready for processing.

When all units have been read and stored, the manuscript is composed and page proofs are produced. (If pagination rules cannot be established *a priori*, galley proofs may be generated.) As the units are retrieved from disc storage and sequenced onto magnetic tape, the formats are extracted from the data string and translated into their basic control words. For example, whenever a format name (*F1*, *C1*, etc.) is encountered in the data string, the format statement is retrieved from the format file on the disc a the basic controls are placed into the data string and executed.

The format statements contain all the information required to describe the placement of text on a page. Control words are included to describe typeface, point size, top, left, right, and bottom boundaries, and boundary procedures. These controls are used, not only to set individual lines, but also to automatically combine these lines into complete pages. Since each text character of a particular typeface and point size has a known height and width, the system has the ability to determine just how much text will fit on a page, prior to its being actually set. This means that running heads, page numbers, subheads, italicized words, can all be measured and placed on the page during the first composition pass.

The output of the computer composition run consists of two magnetic tapes. One is a master tape containing all the original control information and composed lines of text, so numbered as to allow future alteration and connection. The second tape contains setting instructions and text characters to drive the Videocomp and produce page proofs. If multiple typefaces are required, they are extracted from disc storage and also in-

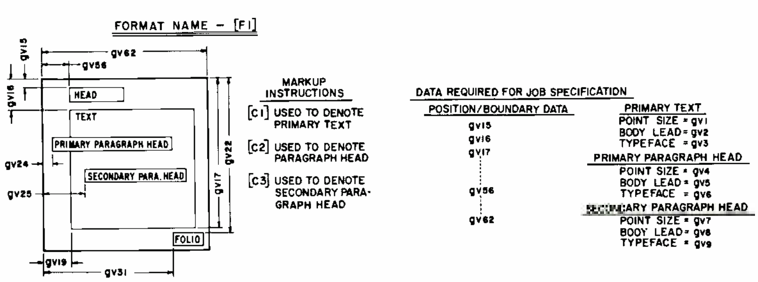

Fig. 4—Conceptual format manual.

JOB NAME: ____________

AUTHOR: ____________

TITLE: ____________

F1

gv1, 10;

gv2, 12;

gv3, 46;

.
.
.

gv16, 72;

gv17, 960;

.
.
.

gv56, 60;

gv62, 360;

Fig. 5—Conceptual job specification.

cluded on this tape. These are used by the Videocomp to produce the proper typefaces and point sizes, wherever they occur in the book.

The output of the Videocomp is fully formated and composed page proofs on exposed and processed typesetting paper. Each page is identified, and each line of text is numbered. The numbers correspond to those on the master file for the book. The proofs are now proofread for keyboarding errors and returned to the copy editor and the author for corrections.

Any single word or a string of words can be replaced, inserted, or deleted. All corrections are keyboarded and read into the computer. The master file is altered with the corrections and recomposed, producing new pages. All alterations affecting multiple pages are automatically effected during recomposition. Complete and/or partial lines are moved from page to page as required, all under format control. This correction cycle may be repeated as many times as required, and when all corrections have been applied, final pages are produced on the Videocomp in the form of film ready for plate-making.

The initial photocomposition devices will handle only text. Therefore the artwork must be merged in by stripping, paste-up, double-burn, etc. Photocomposition systems will undoubtedly be available in the future which will have a graphics capability—that is the graphics will be scanned and stored in the data processing system and output on the photocomposition device. The text and graphics will be merged together automatically.

The previous discussion was concerned with the operation of an integrated publishing/composition system. It was implied that the publisher was directly involved in the composition cycle—i.e. the publisher furnished the job spec and the marked-up manuscript to the composition system in the language acceptable by the electronic system. When this is not the case, that is when the publisher continues to supply the job spec and marked-up manuscript to the composing room in the style of present operations, the composing room (typesetter) will prepare the format manual and job spec and perform the necessary input markup. The composing operation thus will take over the task of translating the publisher's desires into the language acceptable by the electronic system.

JOEL S. GREENBERG received the BEE from the Polytechnic Institute of Brooklyn in 1952 and the MEE from Syracuse University in 1960. From 1952 to 1961, he was employed by Rome Air Development Center, Griffiss AFB, Rome, New York, where he was engaged in the general areas of radar development and systems analysis. He worked for several years on missile guidance and control systems and supervised a systems group responsible for the analysis and synthesis of space surveillance, ballistic missile early warning, and ballistic missile and satellite intercept systems. He also analyzed future Air Force system requirements and outlined the necessary R & D programs. In 1961 Mr. Greenberg joined the staff of RCA's Advanced Military Systems Group (later Technical Programs) where he performed system studies pertaining to future commercial and military satellite communication systems. He also performed "new business" studies in several areas. The study of new business opportunities in the field of Graphics Arts culminated in the formation of the Graphic Systems Division which Mr. Greenberg subsequently joined as Manager of Customer Systems Engineering. He was responsible for the industrial analysis of the Graphics Arts industry and for the analysis, design, and specification of systems for automating composing room and related operations. Mr. Greenberg joined the Operations Research Group at the end of 1966 and has been engaged in the design of mathematical models to be used for new business planning.

ROGER E. SCHUBERT received the BA from Wesleyan University in 1952, with Honor and Distinction in Mathematics. From 1952 to 1959, he was employed by General Electric in Pittsfield, Massachusetts, in various financial positions. He is a graduate of the General Electric Company's Business Training Course. Mr. Schubert joined the Teleregister Corporation in Stamford, Connecticut in 1959 as a Senior Systems Analyst, engaged in systems design and programming for on-line systems. In 1963, he was promoted to Group Supervisor of Banking Systems with responsibility for system and equipment specifications, customer proposals, and system implementation and acceptance. In 1965, Mr. Schubert joined RCA's Graphic Systems Division as a Senior Project Member, Technical Staff, with the responsibility for developing newspaper composition systems. At Graphic Systems Division he has worked in Customer Systems Engineering and Home Office Systems Support and was recently appointed Manager, Home Office Systems Support.

J. S. Greenberg

R. E. Schubert

SUMMARY

Electronic composition systems as previously described, will require a detailed formalism of the job specification and style manual. This formulation will require some small amount of additional work—a typical job specification may be several typewritten pages. This, it must be remembered, will be keyboarded only once per manuscript.

Changes to the job specification will cause the manuscript to be completely reformated according to the new or modified job specification without rekeyboarding the manuscript. Thus, for example, paperback editions based on original hardbound books will be possible without rekeyboarding and proofreading manuscript data.

Another result of the job specification and house style formalism may be the elimination of the intermediate galley stage for those manuscripts which are amenable to specifying page makeup rules. Thus, the considerable time and effort involved in the intermediate galley stage may be eliminated.

The ability to generate composed galleys, page proofs, and final high quality pages will eliminate the considerable time and effort required for the manipulation of the slugs in the chase. Corrections, for example, will be made without moving, cutting, and fitting metal and rekeyboarding lines whose length has changed. It will only be necessary to keyboard the changes and let the computer manipulate the data and output the new galleys or pages on the photocomposition equipment.

The formalism of the job specification will also provide an assurance that the title will be produced in strict accord with the publisher's desires.

The Development and Design of Typefaces

ALAN TAYLOR, Mgr.

Font Development Graphic Systems Division, Princeton, N. J.

The development of letterform followed a disciplined course. Through the demand of literate people, letterform became a main source of communication and recent advances in television and computer technology have added a new dimension to letterform design. With the Videocomp phototypsetter, the design of typefaces assumed a dynamic visual form. This paper reviews the design and development of typefaces—from Gothics to Twentieth-Century Romans—and describes some type-design criteria (including the limitations of present mechanical typesetters).

PRINTING as we know it was introduced by a German, Johann Gensfleisch Gutenberg, about 1450. He invented a mold which made provision to cast types on different bodies by the use of movable sides. For hundreds of years before Gutenberg, the only form of printing was accomplished through the use of hand-carved wood blocks. Prayers were cut into wood blocks, inked, and printed. The first block printing was achieved by the Chinese in the year 400.

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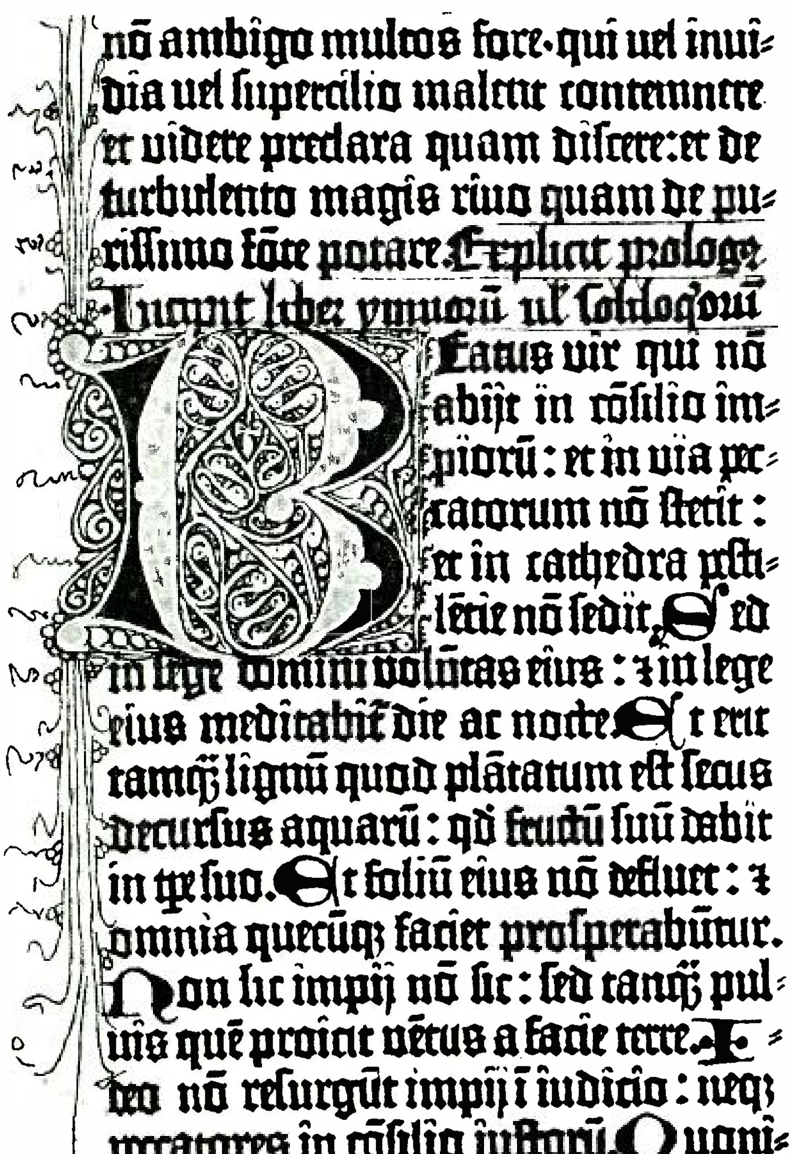
Before the evolution of movable type, the only books available were those of a liturgical nature being produced in monasteries. Scriptoria were divided into various groups, such as Scribes, Rubricators, and Binders. The first book using movable type was printed by Gutenberg in 1454 (Fig. 1). It was based on existing lettering and book methods employed by scribes. Gutenberg, the inventor of movable type, used as his model the contemporary form of writing in Germany at that time. It was called Fraktur; we know it as Gothic. The next four hundred years saw improvements in type design, such as the evolution of Fraktur from Antiqua to the Fat Faces of the 19th century.

Fig. 1—Portion of a page from the Gutenberg bible.


nō ambigo multos fore·qui uel inui-
dia uel supercilio malent contemnere
et uidere preclara quam discere: et de
turbulento magis riuo quam de pu-
rissimo fonte potare. Explicit prologus.
Incipit liber ymnorū ul' soliloquiorum
Beatus vir qui nō
abijt in cōsilio im-
piorū: et in uia pec-
catorum nō stetit:
et in cathedra pesti-
lencie nō sedit. Sed
in lege domini volūtas eius: et in lege
eius meditabit' die ac nocte. Et erit
tamq̄ lignū quod plātatum est secus
decursus aquarū: qd fructū suū dabit
in tpe suo. Et foliū eius nō defluet: et
omnia quecūq; faciet prosperabūtur.
Non sic impij nō sic: sed tamq̄ pul-
uis quē proicit uētus a facie terre. Id-
eo nō resurgūt impij i iudicio: neq;
peccatores in cōsilio iustorū. Quoni-

TYPEFACE GROUPS

Typefaces can be divided into twelve basic groups, presented below in chronological order.

Gothics

Gothic letters are based on the formal European handwriting of the fifteenth century. Known also as 'Black Letter' and 'Old English', this typeface dates from 1440. There were many forms of Gothic letters, including the Batarde used by William Caxton, the first English printer, in his 1487 indulgence.

Venetians

Based on the pre-Aldine Roman of Nicolas Jenson of Venice c. 1470, this face was influenced by writing of Italian scribes. At the time of its introduction, it was called "White Letter" to distinguish it from "Black Letter".

Old Faces

This typeface was based on the Roman of Aldus Manutius of 1495 (considered to be a refinement and improvement on Jenson's design), and was the basic Roman-type design until c. 1760.

Transitionals

This face was an intermediate between old face and modern face. John Baskerville was the first English typefounder to design, cut, and use this modification of old face in 1751.

Moderns

This was the characteristic text of the nineteenth century, but it originated in 1698 and was developed by 1875. It is easily recognizable by its vertical stress, hair-lines, serifs, and considerable difference between the thick and thin strokes.

Outlines

The terms 'outline' and 'inline' are used by founders rather indiscriminately, and mean very much the same. The first such letter was cut in France about 1750.

Egyptians

First cast in 1815, this slab-seriffed fat face was a brilliant innovation and even more suitable for rough presswork and massive display. Egyptians appeared in all heights and in elongated, expanded and shadow forms. They were revived in the 1920's when many new variations were produced.

Antiques

'Antiques' or 'Latin Antiques' is the name given to various versions of nineteenth-century Egyptians. The square-slab serif of the Egyptian is modified into angled serifs curving into the upright strokes.

Old Styles

These were mechanically regularized adaptations of old face, developed after 1850 under modern face influences.

Sans Serifs

First cut in 1816, these faces were originally called Dorics, Gothics, and Grotesques. By the 1850's, they were very popular and shadow and ornamented forms appeared. Sans Serifs were revived in the 1920's; Futura in Germany in 1928. This was a precise and mechanical type. Gill Sans appeared in England in the same year. The modern grotesques are revivals or redrawings of the nineteenth-century types which were produced under the influence of the Gothic revival.

Scripts and Rondes

These types are based on formal or informal handwriting. Formal scripts are copies of engraved, copperplate writing. Rondes are the transitional step between a formal script and the informal script.

Twentieth-Century Romans

Twentieth-Century Roman types are designs in the traditional styles, but are not derived directly from historical models.

BASIC TYPE DESIGN

The basic principle in the design of a typeface is readability and legibility. The function of these abstract shapes, vertical and horizontal lines, curves, strokes, swells, thick and thins of typefaces is to enable the reader to read words, not letterform. In a poorly designed typeface, the reader concentrates on the letterform, rather than the literary content.

Legibility

The definition of legibility is: plain, easily made out. All the letters in an alphabet must be clear and readily comprehensible. For example, it must not be possible to confuse an *e* for an *o* or a *c*. Similarity of form is only one of the characteristics affecting legibility. Other characteristics are size of the characters, leading [the space between lines], the amount of white space between the main strokes or in the counters, the measure, the paper, the color of the ink, and the printing process.

Gothics

BCFLW
abcefgilmps

Egyptians

BCFMX
abcefgil

Venetians

BCFMXI
abcefgils

Antiques

abcdefg
ABCDE

Old Faces

ABCDEF
abcdefghij

Old Styles

ABCDEFG
abcdefghijk

Transitionals

BCFMOX
abcefgilmp

Sans Serifs

BCFMO
abcefg

Moderns

BCFMOX
abcefgilmp

Scripts and Rondes

BFMOX
abcefgilm

Outlines

BCFMO
abcefgi

Twentieth-Century Romans

ABCDEF
abcdefghi

ALAN TAYLOR graduated from the London College of Printing and Graphic Arts in 1960. He was employed as type director with Charles Hobson and Grey, Ltd., London, from 1960 to 1964. Mr. Taylor was also a part-time lecturer in graphic and typographic design at the London College of Printing and Graphic Arts from 1960 to 1964. He then went to Sydney Australia, from 1964 to 1966, working for a large British-based advertising agency while free-lancing in typedesign and graphic design. Since January 1967, he has been art director and manager of font development for the Graphic Systems Division. A member of the Society of Typographic Design, he holds the City and Guilds of London Institute Degree in Typographic Design.

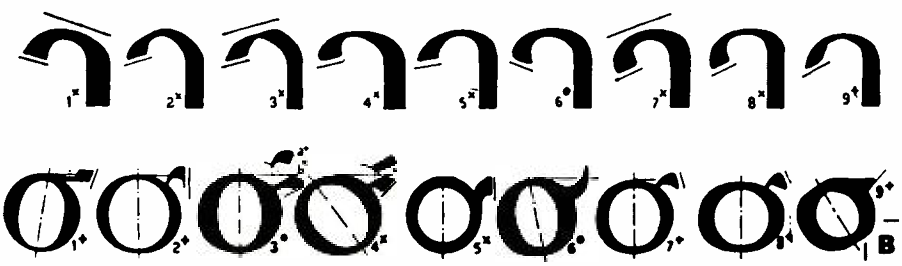


Fig. 2—Differences in letterforms in the upper portions of the characters "a" and "g".

Fig. 3—Conceptual drawing of the formation of an "a" by vertical strokes.

Readability

An illegible type cannot be made readable, no matter how it is typeset. However, the most legible of types can be unreadable if typeset at too wide a measure, or in too large or too small a size. The term "readable" means "capable of being read." Factors which affect readability are the design of the typeface, the measure, the leading, and the quality of the typesetting.

LETTERFORM

The term letterform defines an aesthetic plastic form abstract shapes of lines, curves, and circles which make up a typeface character. Each character has its own variation in thickness, height, and length. Each should be organized into a form which has harmony and evenness of color, weight, readability, and legibility to be considered a typeface in its truest sense. Fig. 2 illustrates basic peculiarities in a given typeface. In comparing typefaces, the difference in a basic letterform becomes apparent. See how the ear of a lower-case g varies and how a single curve varies in the upper stroke of the lower-case a.

MECHANICAL INFLUENCE ON TYPE DESIGN

Foundry Type

Foundry type is metal type cast by a type foundry in oblong units called "types" or "characters." Printers purchase foundry type in fonts, which are complete collections of letters, figures, and punctuation marks in one size and typeface style. Excellent reproductions of classic typefaces can be easily produced on metal foundry type. The hard metal enables difficult characteristics to be produced. Foundry type has advantages in producing perfectly proportioned Romans and Italics with normal kerns. The word "kern" refers to the head, tail, or any part of a letter (usually Italic) that overlaps the type body and has to rest adjacent to the shoulder of the next letter as illustrated in the following example:

fgnj

Monotype

Monotype is similar to foundry type consisting of individual pieces of metal type. However, it differs in that it is cast as required in the print shop by manually operating a keyboard to produce a tape which drives a typecasting machine. In Monotype composition, no arbitrary expanding or condensing is required to adapt a fine typeface to these machines which provides excellent reproduction. Some of the larger typefaces in the Monotype range inherently have excessive letter spacing when compared with foundry type. This is illustrated with 36-pt Garamond Bold Italic in the example below (the top letters are monotype—below them, foundry type):

defgopqrsy
defgopqrsy

It should be noted that the fitting of the foundry type is much closer.

Linotype

The Linotype is a manually-operated keyboard-driven linecasting machine. It casts solid pieces of metal containing the characters for an entire line. Like Monotype, it may be cast in the print shop when needed. The unfortunate inability of the Linotype to cast a kerned *f* requires that no fewer than 26 f-ligatures (tied letters, such as ff, fl, etc. cast on one body to save space and avoid damage to kerning letters) be available for use. Because Italics are confined to the rectangle on the face of the matrix, they cannot be kerned, and a normally designed italic is impossible to create. Hence, the button hook *f* was developed. Compare the button-hooked *f* of the linotype (below left) with the beautiful kerning of the *fg* in Monotype Bembo (below right):

fff fgnj

Videocomp

The RCA Graphic 70 is a computer-driven electronic, phototypesetter. The type produced is called VideoFont. The singular peculiarity of VideoFont is the makeup of the letterform; each character is produced by a number of strokes as shown in Fig. 3. An electron beam in a cathode-ray tube is switched *on* and *off* at a predetermined time to produce the various stroke lengths required to form each individual character.

VideoFont typefaces are stored in the computer memory. Because of the digital (rather than mechanical) storage of matrices of type and the generation of electronic (rather than metallic) typefaces, the Videocomp is capable of the high-speed, large-scale, yet flexible operation characteristic of computer devices. With Videocomp, the range of typeface groups available is practically unlimited; some examples are given in Fig. 4.

ABCDEFGHI
ABCDEFGHIJ
ABCDEFGHI
ABCDEFGHIJK
ABCDEFGHI

Fig. 4—VideoFont typefaces shown above are (top to bottom) Janson, Video Gothic Bold, Video Primer, Video Gothic, and Video Century Expanded.

Typographical Fonts for the RCA Videocomp System

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Graphic Systems Division
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This paper discusses the basic considerations for the production of digitally-coded typographical fonts of graphic-arts quality. Practical parameters of legibility, aesthetics, and letter design, as well as basic systems parameters are covered.

The RCA Graphic 70 Videocomp is classified as a nomic (non-metallic), high-speed, graphic-arts phototypesetter. The first recorded invention of a phototypesetter (optomechanical) occurred in France at the turn of the century. Since the generation of typographical matter by photographic means was introduced long after the inception of metal type-casting machines, phototypesetting machines have been designed from the beginning to duplicate, as exactly as possible, the capabilities of the metal-casting machines. One of the basic reasons for the successful introduction of phototypesetting machines in the printing industry is their capability of handling a greater variety of typographical fonts at a greater speed than metal-casting machines. Metal-casting machines can contain a maximum of eight different typefonts of a limited size range because of their bulk and the difficulty of moving relatively heavy casting forms (matrices). Phototypesetting machines produced in the last 15 years are capable of storing up to 24 typographical fonts in master photographic matrixes on glass plates or drums. Up to eight different type sizes can be obtained by optical enlargement from each matrix, so that a typical phototypesetting machine today theoretically has on short recall up to 192 different typographic fonts available. In one such machine where each font consists of 88 characters, there are available up to 16,896 characters representing eight different sizes and 24 different styles. This is quite an improvement over metal linecasting machines which usually have available only 480 characters in four different styles within a narrow size range. Modern phototypesetting machines also present, besides their versatility in type storage, a great advantage in composition speed. A typical phototypesetting machine today will generate 25 to 30 mixed characters per second, on the average, which is approximately ten times the speed of a modern tape-driven metal linecasting machine.

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The RCA Videocomp has the capability of practically unlimited storage of different fonts. Each font can be recalled in much faster time than the recall time in a conventional phototypesetting machine. Typesetting speed of the RCA Videocomp is approximately 500 to 600 characters per second. The basic design concept of the Videocomp is capable of generating as many as 10,000 characters per second. The reason for this capability is the digital storage of typographical fonts in core memory and magnetic disc which permits the manipulation of font-generation data by conventional digital-computer methods.

TYPOGRAPHICAL EXCELLENCE

Before discussing the merits of digital-font storage or the methods of digitizing the character generation data, the subject of "typographical excellence", also called graphic-arts quality, must be considered. If we were dealing with the storage of generation data for a device, such as a bar-scan printer, special considerations would not be necessary. We are, however, dealing with the presentation of typographical images which must satisfy the high standards of the artistically-oriented typographical industry. This industry will not accept a device which is not capable of fulfilling these high aesthetic and artistic standards. The significance of these standards can be appreciated with an understanding of basic graphic-arts concepts described below.

GERARD O. WALTER studied mechanical engineering at St. John's University, Lvov, Poland, and received a diploma in mechanical engineering and Dr. cans, in applied physics from the Institute of Technology in Zurich, Switzerland, in 1945. From 1950 to 1953 he did graduate and post graduate work at the School of Physics, New York University. Mr. Walter was Assistant Professor at the New York Institute of Optics and taught at other colleges and trade schools. He is the author of books on applied optics, photography, and physical-research technology, and he holds patents in the field of automated typesetting, optical tooling and data-retrieval technology. Mr. Walter was an R & D Leader with Mergenthaler Linotype; a Technical Director of Standard Camera Corporation; and a Manager of Advanced Development Engineering in the Sperry Rand Remington Division. He joined RCA in October 1965 as Manager, Product Engineering, Graphic Systems Division, Princeton, N. J. He was appointed Chief Engineer of the Graphic Systems Division in May, 1966.

FONTS OF TYPE

The standard assortment of type characters as required for general printing is called a font of type. It consists of several kinds of letters, such as capitals, small capitals, and lower-case letters; ligatures and accented letters; figures; marks of punctuation; marks of reference; and possibly symbols. In the font these are all of the same design or face, and of the same size. Most typefonts are made in two versions for the composition of bulk reading matter as needed in book, newspaper, and magazine composition. In one typefont called Roman the characters are upright; in the other called Italic they are slanted. Roman and Italic typefonts are usually available in most type designs of typefaces. As our rules of style prescribe that foreign works, and certain others too, be printed in Italics, the composition of books may require both versions, Roman and Italic types.[1] Type is, in addition, available as signs and symbols for scientific, commercial, and other purposes.

TYPE DESIGNS AND THEIR NAMES

Type designs are made in almost unlimited variety. In the graphic arts a type design is usually called a typeface. Each contemporary design, or typeface, has its own name by which it is identified. However, there is considerable similarity between type designs which are offered under different names. Therefore, typographers classify typefaces into families or into a small number of groups. Because there are no objective standards for the grouping of type designs and because experts differ on what is essential and what not, this subject is rather controversial.[2]

TYPE SIZES

Most typefaces are available in a wide range of different sizes, for example from a 6-point size to a 36-point size; a point is approximately equal to 0.014 inch. Typefaces are also available in smaller and larger sizes, such as 48, 72, or even 96 points. However, not all typefaces can be reproduced in all sizes because of the aesthetics of their design.

DIFFERENCES IN CHARACTER WIDTHS

Width differences in typeface letters have their root in our alphabet and in the way we write. The "l" and the "M" illustrate this point. Type designers recognize the condition that two typefaces can be very different in their design, but the proportions of character width must remain approximately the same.

THE AMERICAN POINT SYSTEM

The point measure is used to express differences in type size. The term "point" is part of a measuring system peculiar to typesetting and printing. In the United States and other English-speaking countries the American Point System is used. "The American Point System was initiated in 1886 at Niagara by the United States Type Founders Association. It was established that 83 picas would be equal to 35 centimeters (13.780 inches). The American Point System follows the method of Fournier and Didot differing from them only in its selection of another body of pica as its basis."[3]

The two basic units of measurement of the American Point System are the point and the pica. The dimension measured from the top to bottom of a typeface, referred to as body size, is specified in points. The lengths of lines and the depth of composition are measured in picas. One typographic point is equal to precisely 0.013832 inch.[4] Twelve points are equal in length to one pica. One pica equals 0.166 inch.

Several other typographic systems exist. Outside the English-speaking world, the French Didot system is most widely used. In Germany it is called the Didot-Berthold system. The Didot point is considerably larger than the American point.

LETTER SPACING

Good proportional letter spacing is one of the most essential aspects of typography. In book composition, tight spacing (small spaces between letters and words) is widely practiced. Uneven spacing is considered objectionable. Electronic letter composition systems must be capable of very precise spacing of letters.

The object of proper spacing is to form a word "of uniform color". This can be illustrated by holding this magazine approximately 18 inches away from the eyes and squinting slightly, while looking at a word of many letters. If the word appears as a uniform grey color, proper spacing is indicated. There are aesthetic reasons as well as reasons of legibility for this. Since we are dealing with letters which are actually irregular geometric figures which can be combined in as many different combinations as there are characters in a typefont, it is quite difficult to achieve good uniform letter spacing.

Several mathematical treatices have been written on this subject. Attempts have been made to develop formulas based on the integration of the white and black areas for the purpose of lightening the task of the type designer who presently achieves proper spacing through a combination of intuition and trial and error.

Fig. 1 shows an assembly of characters which are proportionally spaced and the same assembly of characters uniformly spaced. This illustration makes it apparent that the proportionally spaced assembly of characters is not only more aesthetic in appearance, but much more legible. A most important additional benefit of the proportional spacing of characters is the saving of up to one-third of the bulk of paper needed to record printed text. This reduction in bulk through proportional spacing has prompted many large producers of computer impact-printer data to take a close look at Videocomp type-character generation.

READABILITY AND LEGIBILITY

The terms "readability" and "legibility" are used interchangeably by most people who are not concerned with typography. For our purpose, it is necessary to distinguish between the two: *readability* signifies the ease of reading the printed page or message; *legibility* refers to the speed with which each individual character can be recognized. Legibility is a consideration of type design; in electronic-type generation it is analogous to the high-fidelity reproductions of properly designed characters. Readability refers to the choice and arrangement of typefaces, and becomes our concern when designing composition software. Most established typefaces are of good legibility reducing our digitizing process to that of obtaining proper generation of characters and shapes.

Beatrice Warde goes to the heart of the problem when she writes: "The legibility of the typeface has an exact parallel to the audibility of the human voice. A lecturer must make every word audible and distinct, yet within the limits of audibility lies a whole range of speaking tones from a metallic twang through the infinitely flexible persuasive tones of the good speaker. The printed page can be legible and dull or legible and fascinating according to its design and treatment. In other words what the book designer calls readability is not the synonym for what the optician calls legibility."[5]

THE CHARACTER IMAGE

The image of a typographical character must be examined to understand the digitizing process. Refer to Fig. 2, and observe the three Roman lower-case characters **j**, **h**, and **o**. They have been placed on a grid of lines which represent uniform boundaries. The line labeled *O* is the baseline for all flat-bottomed characters, in our case the **h**. The line O_1 is the baseline for all round or v-bottomed characters, in our case the character **o**. In all typefaces the round and v-bottomed characters rest below the baseline. The distance from *0* to *+1* is the body height of the character. The distance from *+1* to *+2* is the ascender height. The distance from *0* to *−1* is the descender height. The vertical lines *A*, *B*, *C*, and *D* are the width boundary lines. The character **h** has a width equal to the distance *AB*. The character **h** has a width equal to the distance *BC*, etc. Note that each character image consist of a black image of the character itself and a white image represented by the space in front of the character to its left-boundary line and the space in back of the character to the right-boundary lines. The black character is in many cases not centered within its two boundary lines. However, its placement within the boundary is fixed regardless of the combination of characters that is printed and regardless of the word that is assembled from these characters. The black character is always in a fixed position within its own boundary lines. The proper placement of the character within its boundary lines permits it to be used in combination with any other character which is also properly spaced within its boundary line, to produce a proportionally-spaced, aesthetically-correct combination image. Some typographers refer to the white space in front of the character as *leading bearing*

T h i s i s a s a m p l e o f 1 0 - p o i n t V i d e o N e w s G o t h i c t y p e s e t u s i n g u n i f o r m s p a c i n g .

This is a sample of 10-point Video News Gothic type set using proportional spacing.

Fig. 1—Samples of uniform and proportional spacing.

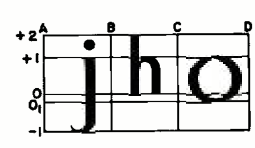

Fig. 2—Typographical characters.

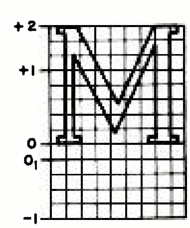

Fig. 3—Roman capital "M" on dual grid.

and to the white space in back of the character as *trailing bearing*.[4] In electronic generation of character images the white space, as well as the black character form, must be generated. Therefore the amount of white space must be precisely coded; it is measured in multiples of 8×10^{-4} inches in our electronic high-quality generation mode.

THE DIGITIZING PROCESS

Conceptually, digitizing of type characters is the reverse of the Videocomp writing process. In the Videocomp, characters are generated on the face of a CRT by moving the electron beam (focused to a fine spot) in a vertical (up/down) direction, unblanking it for the black character areas. Reversing this writing process, characters could be digitized using a flying-spot scanning method. Other methods are possible, such as mechanical scanning in facsimile fashion, plotting with a plotting board, or manual coding by counting the sections on an overlay grid. A combination of these methods is used in the Graphic Systems Division depending on the granularity mode, size of characters, and form of initial artwork that is available or is generated. The actual method selected is less important than the tradeoffs that have to be made between resolution (granularity mode), writing speed, and memory requirements which are discussed below.

Fig. 3 shows a Roman capital **M** superimposed on a dual grid. The heavy grid lines are the same as those shown in Fig. 2. The finer grid lines are called the scanning grid. For one of the several granularity modes there are 100 lines in the horizontal and 120 lines in the vertical direction. In generating the character on the CRT face of the Videocomp in this granularity mode, 100 vertical strokes are required with a choice of 120 positions in each stroke to either blank or unblank the beam.

RESOLUTION (GRANULARITY MODES)

Typographical fonts are used for the production of printing plates or microrecords serving many different end-uses. Since the writing speed (character/seconds) and digital-memory size (bytes/character) are dependent on the granularity mode which directly effects the resolution, digitized fonts are produced specifically for the quality required in the selected end-use. Quality requirements can be classified (from highest to lowest) in the order specified in Table I.

TABLE I—Quality Requirements

End Use	*Approx. No. of strokes/inch*	*Approx. No. of bytes/average character in up to 8-point size*
a) Text books (incl. Dictionaries & Encyclopedias)	>1000	200
b) Books (except pulp publications)	≈ 900	180
c) Magazines & Directories (including Catalogs)	≈ 750	150
d) Pulp publications (Pocket Books & Magazines on Newsprint semi-glazed paper)	≈ 600	120
e) Newspapers (produced by off-set printing)	≈ 550	110
f) Newspapers (produced by rotary letterpress)	≈ 500	100
g) Proofing Mode for a) through d)	300	60
h) Proofing Mode for e) and f)	250	50
i) Computer printout (w/o stylized font)	250	50
j) Computer Printout (using stylized font)	175	35

The method of establishing the approximate number of strokes/inch needed to satisfy the various end-applications is primarily empirical. Actually, the printing method (intaglio, offset or letterpress); the type of printing ink (viscosity of base and type of pigment); and the type, surface treatment, and impregnation of the printing paper (wood pulp, rag content, epoxy impregnation, and surface coating and rolling) are as much of a determining factor as the established graphic-arts standards.

An important consideration is producing satisfactory quality with a minimum of strokes/character since this assures of highest writing speed and minimum core storage requirement. The character/second speed follows the relationship:

$$T_c = N_s T_s$$

where T_C is the Character writing time; N_s is the No. of strokes/character; and T_s is the writing time/stroke.

The required N_s is calculated for any application using Table I with the following statistical assumptions:

An average character has a width of ½ its height. For example, an average 10-point character is 5 points wide. For text books (application a) in Table I) we then need this granularity in the 10-point size:

$$N_s \text{ (per inch)} = \frac{\text{Strokes/inch}}{\text{Characters/inch}} = 70$$

The character writing time (T_C) is calculated from the relationship:

$$T_C = K_t N_s V + D_T$$

where K_t is the constant that determines the required spot dwell depending on the spectral energy contained in the spot and the exposure requirements of the photosensitive material (offset-plate, stabilization photo paper, film); V is the Velocity of beam; and D_T is the interstroke delay, including dwell, and return time.

SPOT SIZE

It is obvious that we can generate the character **M** shown in Fig. 3 by using any one of a different number of sweeps. The number of vertical sweeps that are used for the painting of the character and the number of horizontal positions within each sweep at which the beam can be blanked or unblanked determines the resolution which affects the fineness and smoothness of character presentation. The terms *horizontal granularity* and *vertical granularity* express the various modes of fineness of raster. Fig. 4 shows greatly magnified examples of a character written in three granularity modes.

The spot size of the electron beam must be matched to granularity. If the distance between vertical sweeps is 0.001 of an inch, the diameter of the spot should also be 0.001 inch, so that it will butt with the previous and successive sweep to generate a solid black-bodied character. Because of the Gaussian energy distribution of the writing spot, it is actually made to overlap each adjacent spot approximately 20%, which in the example for 1000 sweeps/inch dictates a spot size of 1.2 mils.

DESIGNING CHARACTERS FOR ELECTRONIC GENERATION

Because of the restraint of generating characters within a given resolution grid raster, this digitizing system is not capable of exact copying of existing typefonts. The typographic characters have to be specifically designed for the digitizing method. The differences between VideoFont images and those generated by optomechanical or hot-metal casting methods are small; nevertheless, there are differences. In some instances limitations have occurred which made it necessary to re-design some established typographic fonts to a greater extent than others.[7] In other cases electronic VideoFonts have been acclaimed to be of greater aesthetic quality than those produced by nonelectronic methods.

Fig. 4—Examples of three granularity modes.

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Hyphenation and Justification by Computer

One of the problems in setting type by computer is in justifying each line of type (spacing words and letters within a line so that all full lines in a column of type have even margins on the left and on the right). When a line cannot be justified by varying the spacing, a word break is necessary; the word must be hyphenated at the end of the line and continued on the next. This paper describes the algorithm used to hyphenate words by computer and provides some of the rationale for this algorithm. Accuracy, cost, efficiency, time, and size of computer storage, as they relate to the hyphenation routines, are treated.

While developing specifications for a marriage of the old art of printing with the new science of computers, certain requirements of typography were questioned by the computer programmers. These time-honored rules did not necessarily fit the neat world of computer programming. The most pressing question was why is justification necessary and, if so, why should hyphenation accompany it? The question of justification was answered simply by stating that a line which does not fill a measure marks the end of a paragraph.

Words are elements of a sentence. A sentence is a complete thought, and a paragraph is a group of related thoughts. Therefore, the existence of a justified line implies to the reader that the group of related thoughts has not ended and that more will follow. Conversely the short line indicates the end of a group. Whether or not the reader is consciously aware of the reasons for justification is not important; what matters is that his mind is led effortlessly and naturally from thought to thought and group to group. And, there is no questioning that even right-hand margins greatly improve the appearance of a page. Therefore, if justification of the printed page is accepted, the next question is how does the computer programmer attain this justification?

JUSTIFICATION—GENERAL APPROACHES

There seems to be two ways of attaining justification for a general purpose composition system: *hyphenation* and *monospacing.*

Monospacing

Monospacing requires that letters which are naturally slim be made wider and conversely letters naturally wide be compressed, so as to conform to the selected monospacing norm. This may be mechanically advantageous, but the advantage is gained at the expense of the reader. The crudity of the printed material is accepted by the reader as a necessary evil, but not as desirable. Therefore, in a general purpose composition system, the hyphenation process is necessary to attain justification. While we can always expand the size of a group of characters by such techniques as interletter spacing, changing set sizes, and interword spacing, there is a certain limit below which we cannot contract the line, such as a 10-*en* line when a 13-*en* word is encountered. The term *en* is defined as being one half the width of a capital *M* for a given typeface and point size.

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Hyphenation

In the definition of *hyphenation*—a process of dividing a word into two or more syllables to allow aesthetic justification of a printed line—the intricate relationship between hyphenation and justification can be clearly seen. This definition also states why hyphenation has consumed the larger part of the time and money spent to automate the printing process. Since the present scoring of the hyphenation process is aesthetic, it varies from printer to printer, each with his own ideas of what is important in the hyphenation process.

To give the reader some idea of what is involved in aesthetic hyphenation, the hyphenation rules of style given in the *U. S. Government Printing Office Style Manual* are listed in the appendix of this article. These rules offer the most representative listing of what is required of a good hyphenation routine. Note the recurring stress on aesthetics, notably the desire to reduce the tendency of hyphenated words to break the reader's train of thought.

At the present time, it seems that there are in existence four basically different approaches to machine hyphenation. These approaches are categorized as follows:

1) Based almost entirely on grammatical knowledge of the language;
2) Based almost entirely on empirical observations;
3) Based on storage of enough words with their points of hyphenation to insure accuracy; and
4) Avoid hyphenation as much as possible.

Much work has been done on method 4). However, due to the increasingly lower costs and higher quality of machine hyphenation systems, it is not likely that any typographically acceptable solution will be found in the method of completely avoiding hyphenation.

JUSTIFICATION—COMPUTER APPROACH

Our present composition system incorporates methods 1) and 3). Method 1) is capable of reaching an accuracy of 95% with an acceptable efficiency of hyphenation and storage requirements. Incorporating method 3) with method 1) and using a different level of storage for this method, accuracies greater than 99% have been achieved. Theoretically, this method can be 100% accurate if we are willing to overlook the costs involved in terms of both the storage required to hold the words encountered in general-purpose applications and the time required to access this storage.

It is useful to know the meaning of certain words within the framework of this paper. These terms, and their meaning as used here, are:

Accuracy: the numerical ratio of correct hyphenation to hyphenation performed.

Efficiency: the numerical ratio of hyphenation points found to possible hyphenation points. In the industry, the term frequency is also used for the same measurement.

The algorithm used by the Graphic Systems Division in its present composition system consists of a logical decision-making process applied to the problem of word division. The algorithm does not

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include statistical analysis of word forms, but it does employ an exception dictionary of complete words if the word fails the algorithm. The basic approach to logical word division utilized by this routine is:

1) Obtain and isolate common suffixes, arriving at a "root" word.
2) Divide the root word by using a specific set of rules and their known exceptions.
3) Use group patterns of vowels and consonants to divide the word.

Hyphenation of a word consists of an orderly progression through these parts until all the possible divisions are found.

Isolating Suffixes

The routine starts its search by irradicating (masking) the letters S and T from the end of a word, where S is a plural or possessive and T is a contraction. Apostrophies and consonants beginning the word are also erased. If fewer than four letters remain, the word is not hyphenated.

When masking is completed, the routine starts its search for common two- and three-letter suffixes. The standard rule for division on a three-letter suffix is:

XXX-YYY

where XXX are the three letters of the word preceding the ending, and YYY is the suffix. An example would be the word VANISH, where -ISH is the suffix. However, the occurrence of certain letters preceding an ending constitutes an exception to the standard rule. Considering the ending -ISH, the letters QU preceding ISH lead to a division: -QUISH (VANQUISH). Note that it is not possible to look at just the letter preceding the suffix; considering up to three letters preceding the suffixes, divisions take the forms:

XXX-YYY	POISON-OUS
XX-XYYY	OMI-NOUS
X-XXYYY	COURA-GEOUS
-XXXYYY	MON-STROUS
XX-YY	PROF-IT
X-XYYY	CON-CERN
-XXYYY	UNDER-STOOD
X-YYY	ANY-ONE
-XYYY	ENG-LAND
XYYY	QUIT

Each ending may have a list of exceptions accompanying it in the above order. After the endings have been recognized and the exceptions examined, the words are divided.

Since there are many inconsistencies in the English language, it would be futile to attempt to cover these inconsistencies with a small list of exceptions. For example, the words CON-SCIOUS and LUS-CIOUS both end in OUS preceded by SCI — each has a different hyphenation point. The rules utilized here are: 1) S preceded and followed by a consonant is divided between the preceding consonant and S, and 2) the syllable CIOUS is indivisible.

Root-Word Analysis

If the program fails to determine a division point by syllable analysis, it will examine the root word to see if any of a set of rules is satisfied. A partial list of the rules is:

1) Hard Glottals: A *hard glottal* is defined as B, C, D, F, G, K, P, T, W or Z followed by L or R. Glottals are handled as one consonant; the division point precedes the glottal—EN-GLISH, DE-GREE;
2) Soft Glottals: A *soft glottal* is defined as H preceded by C, P, S, W or T. Soft glottals are also carried as one consonant; the hyphen precedes the glottal —GRA-PHIC, CO-CHAIRMAN;
3) Allophones: S preceded and followed by a consonant. Allophones are divided before the S—MON-STROUS, AB-SCOND;
4) Double Consonants: A root word is divided between double like consonants—BUF-FER, WITH-HOLD; and
5) The letter X: Words are divided after the letter X—EX-PORT, TEX-AS.

Again, exceptions to these rules are considered. For example, the glottal rule is broken when L, R, or GH precede the glottal—COURT-ROOM, LIGHT-HOUSE; while NF, BN, TN, and MN are generally considered to be impossible combinations —SOLEM-NITY.

Consonant-Vowel Test

Occasionally, a search through the above rules and their exceptions will not determine a division point. For these words a consonant-vowel pattern test is made. Starting at the end of a root word, the letters are examined for the consonant-vowel-consonant pattern. If this pattern is recognized, the hyphen precedes the pattern—DEMOC-RACY, -RAC. Because a series of consonants is considered to be a single consonant and a series of vowels is considered to be a single vowel, patterns such as CVVC and CVCCC also represent the basic pattern CVC. If the word has reached this point and no basic pattern has emerged, the word is not hyphenated by this routine, but depending upon the frequency of usage by a particular user, it may be added to the exception dictionary.

When the first hyphenation point in the word has been found, the word is assumed to end just before the division point. The program control is then returned to the beginning to search for any additional hyphenation point. The process is continued until all possible divisions of the word have been made. This process, coupled with our justification, attempts to place as many letters on a line as possible, being consistent with the criterion of *tight* lines.

Exception Dictionary

Words are continually being run through the hyphenation routine to further test the routine, but also to inform the user of words which have to be added or deleted from his exception dictionary. This exception dictionary is currently maintained at 6000 words. The contents of the dictionary will vary depending upon the user of the general purpose composition system. Therefore, it can be seen that our goal is to obtain 100% accuracy on the high-frequency words of the user at the sacrifice of possibly having incorrect hyphenations for low-frequency words. This sacrifice is made to save time and money since each user can arrange his own dictionary to suit his needs. Thus, every user should have an in-text accuracy of better than 99% correct hyphenations.

PERFORMANCE OF HYPHENATION ROUTINES

Having previously detailed the present method being used in our general composition system, we should now justify the reason for using this approach to the hyphenation process. There are five factors used in scoring the performance of hyphenation routines: accuracy, efficiency, time, size, and cost. However, only the first four will be discussed since cost is greatly related to all others.

Accuracy

The accuracy of a hyphenation routine is perhaps the most important factor. The reasons for this are threefold:

1) Since we have established that the reasons for hyphenation are primarily aesthetic, why hyphenate at all if the output is to be incorrect and, therefore, unaesthetic?
2) Incorrect hyphenations are hard to find in text. Therefore, an increase of incorrect hyphenations slows down a proofreader, increasing the cost.
3) Due to the nature of the justification process, physically correcting hyphens can become a very expensive process.

We can see that accuracy is not only an aesthetic but a strongly economic consideration.

Efficiency

It has been long thought that the efficiency of hyphenation (ratio of division points found to the total number of division points available) is an important factor. However, no one seems to be exactly sure of just how efficiency affects the appearance of the printed matter or what range of efficiency is important. The philosophy about the effect of efficiency has been developed that has two basic rules:

1) The probability of attaining the *tightest possible line* is directly related to the probability of finding a division point within the justification range, and
2) The probability of finding a division point within the justification range is directly related to the efficiency of the hyphenation package.

To develop what we define as the justification range, assume the following values:

1) L is a line length in *ens* (for a homogeneous typeface).
2) The range of the interword space in a line is $\alpha \leq W \leq \beta$ where α is minimum interword space in *ens*; W is interword space in *ens*; and β is maximum interword space in *ens*.
3) n is some average number of characters in a word.
4) N is the number of words in a line.

The formula for the number of characters in a line is, if C is the total number of characters in a line (measured in *ens*):

$$C = L - (N-1)W$$

or the line length minus the length taken up in interword spaces. The range of C, not counting the possible chaange in the number of words is:

$$L - (N-1)\beta \leq C \leq L - (N-1)\alpha$$

It is this inequality that we are going to call the justification range. We now use the justification range to show two things:

1) The justification range depends greatly on the length of the line in ens, and
2) The efficiency of in-text hyphenation becomes decreasingly important as the line lengthens.

If we reduce our formula for C to one for N (number of words on a line), we then can use the relationship $N = C/n$, which, although not exact, is a good approximation due to the symmetry of word size distribution. This will produce the relationship:

$$N = \frac{L - (N-1)W}{n}$$

or

$$N + \frac{NW}{n} = \frac{L + W}{n}$$

and finally:

$$N = \frac{L + W}{n + W}$$

giving us the number of words expected on a line of length L and interword space W. N is conditional, ranging from:

$$\frac{L+\beta}{n+\beta} \leq N \leq \frac{L+\alpha}{n+\alpha}$$

Because β, α, and n are fixed parameters for a given sample, it can be seen that N and thus C are directly related to the size of the line, and that the justification range in terms of characters increases with the line length. Therefore, as the average size of the syllable found by the hyphenation routine is not dependent on the line length, it is true that in-text hyphenation efficiency becomes decreasingly important as the line lengthens.

Since the distribution of syllable size in letters is generally symmetric, not finding a division between two syllables has the effect of producing one syllable on the average twice as large as the average syllable. To find the size of the average size of the syllable from the hyphenation routine, let S be the size of syllable and E be the efficiency of hyphenation. Therefore:

$$S_H = ES + 2S(1-E) \text{ or } S_H = (2-E)\,S$$

As the average size of an English language syllable is 3.2 characters, the size of the average syllable found by the hyphenation routine is:

$$S_H = 6.4 - 3.2\,E$$

The above syllable size sets up the most important measurement of the hyphenation routine. The efficiency measurement for a particular line length is determined by the probability that:

$$S_H < \alpha - \beta + N(\beta - \alpha).$$

The above measure is the probability that the hyphenation routine will find a syllable within the justification range. It is this factor that is important. As α and β are parameters to the justification routine, the ability of the justification routine to handle the division-points output by the hyphenation routine affects the efficiency rating of the routine.

Thus, in a general purpose composition system, we have derived a variation of the method of measuring the efficiency of the hyphenation routine. By merging the efficiency of the hyphenation routine with the ability of the justification process to handle these division points, we can now measure the efficiency of the whole justification process to correctly meet the criterion of *tightest possible line* with a minimum amount of errors. For our final output, this is the *only* standard that is of interest to the system user.

An indirect benefit of using this justification method is to bypass the hyphenation routine except as a last resort to justify the line and therefore save valuable computation time.

Time and Size

The time and size of the hyphenation and justification routine are tied very closely by cost to the computer used with the output device. The time must be such that it keeps pace with the output device. On larger computers with multi-programming and much storage space, a large dictionary and exception table of hyphenation rules could be stored. In the general purpose composition system, both of these factors have been kept as compact and modular as possible, so that the system may be run on a variety of computers. This compactness led to a 9900-byte hyphenation routine, and optional 6000-word dictionary, and a 5000-byte justification routine. With this choice, a line can be justified in two milliseconds per character for the output device.

APPENDIX—HYPHENATION RULES

1) The final word of the last full line of a paragraph should not be divided.

2) . . . under no circumstances are words to be divided on a single letter (USU-AL-LY, not U-SU-AL-LY).

3) The following suffixes are not divided:

CEOUS	GEOUS
CIAL	GION
CIENT	GIOUS
CION	SIAL
SIOUS	TIAL
SCIOUS	TION
SION	TIOUS

4) The digraphs AI, CK, DG, GH, GN, NG, OA, PH, SH, TCH, and TH are not split.

5) Do not divide contractions.

6) Avoid a division which would add another hyphen to a hypenated compound (COURT-MARTIAL, not COURT-MAR-TIAL).

7) A one syllable word is not split.

8) The *em* dash is not used to begin a line of type.

9) Abbreviations and symbols are not broken at the end of a line.

10) Figures of less than six digits, decimals. and closely connected combinations of figures and abbreviations should not be broken at the end of a line. If a break in six digits or over is unavoidable, divide on the comma, retain it, and use a hyphen.

11) Divisional and subdivisional paragraph reference signs and figures should not be divided, nor should such references be separated from the text to which they pertain.

12) Chemical formulas—if a break is unavoidable in a formula, division is preferably made after an original hyphen to avoid introduction of a misleading hyphen. If impractical to break on a hyphen, division may be made after an original comma, and no hyphen is added to indicate a runover.

13) Neither periods nor asterisks used as an ellipsis are overrun at the end of a paragraph. If necessary, run over enough preceding lines to provide a short word or part of a word to accompany the ellipsis.

14) Mineral elements—When it is necessary to break mineral constituents, division should be made preferably before a center period and beginning parenthesis; elements within parentheses are not separated. In cases of unavoidable breaks, a hyphen is not added to indicate runover.

15) In words with short prefixes, divide on the prefix—AC, CO, DE, DIS, EX, IN, NON, ON, PRE, PRO, RE, UN. For example, NON-ESSENTIAL is preferred to NONES-SENTIAL.

16) Division of words less than six letters in length should be avoided; two letter divisions, including the carry-over of two letter endings (ED, EL, EN, ER, ES, FY, IC, LY, OR, and TY) should also be avoided. In narrow measure, however, a sounded suffix of two letters may be carried over — only if unavoidable. Therefore, when necessary, it is possible to hyphenate RELAT-ED, but it is never proper to hyphenate CANCEL-ED.

17) If possible (subject to good spacing) it is desirable to preserve as a unit such forms as:

ACETO	FLAVO
ANHYDRO	FLOURO
BENZO	FLUORO
BROMO	GLYCO
CHLORO	HYDROXY
CHROMO	ISO
CINCHO	KETO
CYCLO	METHYL
DEHYDRO	NAPTHO
DIAZO	PHOSPHO
SILICO	POLY
TRIAZO	TETRA

18) Closely related abbreviations and initials in proper names and accompanying titles should not be separated, nor should titles, such as *Rev., Esq., Jr., 2d.,* be separated from surnames.

19) Avoid division of proper names, but, if inescapable, follow the general rules for word division.

20) In dates, do not divide the month and the day, but the year may be carried over.

21) Wordbreaks should be avoided at the ends of more than two consecutive lines.

22) Division of words should be minimized in leaded matter and avoided in double-leaded matter.

23) In centerheads and in display lines, wordbreaks should be avoided.

24) Words of two syllables are split at the end of the first syllable: DIS-PELLED, CON-QUERED; words of three or more syllables, with a choice of division possible, divide preferably on the vowel: PARTICU-LAR, SEPA-RATE.

25) When the addition of -ED, -ER, -EST, or of a similar ending causes the addition of a final consonant, the added consonant is carried over: PIT-TED, ROB-BER, THIN-NEST. However note: BLESS-ED, DWELL-ER, GROSS-EST.

26) Words with doubled consonants are usually divided between these consonants: CLAS-SIC, RUF-FIAN, NECES-SARY. However, again note: CALL-ING, MASS-ING.

27) Words ending in -ING, with stress on the primary syllable, are preferably divided on the base word: APPOINT-ING, COMBAT-ING. However, present participles, such as CONTROL-LING, FORBID-DING, with stress placed on the second syllable, are divided between the doubled consonants.

28) In case of an unavoidable break in a land-description symbol group at the end of a line, use no hyphen, and break after a fraction.

29) Avoid breaking longitude and latitude figures at the end of a line; space out the line instead. In case of an unavoidable break at the end of a line use a hyphen.

30) Solid compound words should preferably be divided between the members: BAR-KEEPER, PROOF-READER.

31) Two consonants preceded and followed by a vowel are divided on the first consonant: ABUN-DANT, ADVAN-TAGE; but ATTEND-ANT, or ACCEPT-ANCE.

32) Generally, words ending in -OR, with a consonant preceding the -OR are divided before the consonant, e.g., ADVI-SOR, SIMULA-TOR; but BAIL-OR, GRANT-OR.

33) The suffixes -ABLE and -IBLE are usually carried over intact; but, when the stem word loses its original form, these suffixes are divided according to pronunciation: COMFORT-ABLE, CORRUPT-IBLE. Note, however, DURA-BLE, COMPREHENSI-BLE.

34) When adjoining vowels are sounded separately, divide between them: CRE-ATION, GENE-ALOGY.

35) If formation of a plural adds a syllable ending in an s sound, the plural ending should not be carried over by itself: HOR-SES, VOI-CES. However, the base word is not broken: CHURCH-ES, CROSS-ES.

36) When the final consonant sound of a word belongs to a syllable ending with a silent vowel, the final consonant or consonants become part of the added suffix: CHUCK-LING, HAN-DLER, but ROLLICK-ING.

37) Words preferably should be divided according to pronunciation; and to avoid mispronunciation, they should be divided so that the part of the word left at the end of the line will suggest the whole word: CAPAC-ITY, not CAPA-CITY; EXTRAOR-DINARY, not EXTRA-ORDINARY.

38) In breaking homonyms, distinction should be given to their relative functions:

PRO-DUCE (*v*)	PROD-UCE (*n*)
REC-OLLECT (*recall*)	RE-COLLECT (*collect again*)
ARITH-METIC (*adj.*)	ARITH-ME-TIC (*n*)

39) Words ending in -METER—In the large group of words ending in -METER, distinction should be made between metric system terms and terms indicating a measuring instrument.

CENTI-METER	DECA-METER, but
BA-ROM-E-TER	MI-CROM-E-TER.

Electronic Halftones

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To derive the greatest advantage from a computer-controlled process in the production of newspapers and books, it is important to replace the current optical method of producing halftone dot-patterns with an electronic method. This article discusses developmental electronic-halftone techniques that use a high-resolution cathode-ray tube (CRT) as the display device.

THE TERM, halftone, as used in the graphic arts industry, refers to an image composed only of black and white elements—of variable fractional area (commonly small dots)—that represent the local integrated reflectance of the continuous-tone illustration, e.g. a photograph, being reproduced.

The halftone shown in Fig. 1 is an electronically produced *newspaper scan* with the rows of dots running at 45 degrees to the horizontal. This type of dot orientation is achieved by displacing alternate rows of dots by a distance equal to one-half the horizontal interdot spacing. The area of the individual dots is a function of the light transmittance of the sampled input picture, and is controlled by spiral-scanning of the CRT beam until the desired dot size is achieved and then blanking the electron beam.

Fig. 2 is a block diagram of the developmental system for producing halftones electronically. Either the 45-degree news scan (Fig. 1) or the *hex* structure comprising the halftone in Fig. 3 can be obtained from the system by using different sampling-raster configurations.

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FORMATION OF THE HALFTONE DOT

As noted, the system employs spiral scanning of the CRT to produce circular halftone dots. The spiral scan is achieved by modulating cosine and sine waves which are added in a deflection-amplifier input-summing network. This cosine-sine relationship produces a lissajous figure of circular shape when plotted orthogonally as a function of some parameter, usually time.

The density loss in the exposed film due to the increased scanning velocity with increased radius should be roughly compensated by writing a higher number of scanned circles per unit radius increment as the dot is scanned. That is, a constant area of the dot per unit time must be scanned, requiring that the radius must increase as the square root of time. In our evaluation the required half-power law was approximated by a simple exponential curve, as shown in Fig. 4. The exponential was made adjustable to obtain the closest match by providing adjustment of the voltage toward which the capacitor charged in a simple RC charging circuit, and adjustment of the series resistance of the RC network. The capacitor voltage can be returned to zero at the end of the dot-unblanking interval or by the variable-pulse width signal itself, which is a function of the light transmittance of the subject.

Uniformity of dot intensity as a function of dot radius was adequate to expose the high-contrast films used for our halftone recordings to a density that was high enough to prevent significant additional density in the regions of dot overlap. The half-power radial modulation requirement can thus be seen to be fairly non-critical.

The modified rate of dot area increase resulting from dot overlap is plotted in Fig. 4, for the theoretical half-power radius function and for an assumed practical RC charging function. Note that the practical function requires black and white stretch of the transfer characteristic to restore a linear area-time function. Other factors affecting optimum gray-scale reproduction are discussed under Gray-Scale Requirements.

Dot Polarity

A close examination of the halftones in Figs. 1 and 3 will show that the circular portions—the dots—are "white," being delineated by the surrounding black printing ink. In the example shown in Fig. 5, the black areas are round dots, more nearly in keeping with photographically screened halftone structures.

The white dot structures of Figs. 1 and 3 were produced by configuring the pulse-width modulation circuitry to produce longer unblanking time when the lighter portions of the positive transparencies are scanned, as described under Video Pulse-width Modulation Considerations. The halftone image of the positive transparencies thus appeared as positives on the CRT faceplate and a photographic reversal process was used to provide photographic positives as the first reproduction film records. The next

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R. J. Klensch

R. L. Hallows

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step was the preparation of high-contrast photocopy negatives of the halftones. These negatives were then used to make the "plates" used to print the pages on which the halftones appear.

The black-dot photograph of Fig. 5 was made by presenting a negative image of the same positive transparency on the CRT by electronic inversion of the pulse-width modulation process. The negative CRT image was photographed onto high-contrast (negative) film. This resulted in a black-dot positive image as the first reproduction film record. As in the case of "white-dot" halftones, an intermediate photographic negative was used to transfer this image to the printing plate. The white-dot process is more analogous to the television process because the video voltage is proportional to the reproduced light level; that is, the signal "creates" the white dots which produce the visual sensation. The white-dot system may be thought of as being additive, whereas the black-dot system can be considered subtractive, because the video signal is proportional to the amount of ink that creates the spaces between the sensation-producing light areas.

The black-dot process would probably be preferred by the segment of the printing industry that uses letterpress printing because of its superior printability by the letterpress process and because of its closer resemblance to usual halftone structure. However, there is a disadvantage inherent in black-dot generation by electrical processes. This disadvantage manifests itself because it is difficult to maintain a uniformly small difference between two large quantities. If we observe that the black-dot process requires large signals to produce adjacent black halftone dots with relatively small white areas, we can see that a small percentage of perturbation in the diameter or position of one black dot with respect to its neighbor will cause a substantial percentage change in the area of included white space. This constitutes a sizable modulation of the represented brightness level.

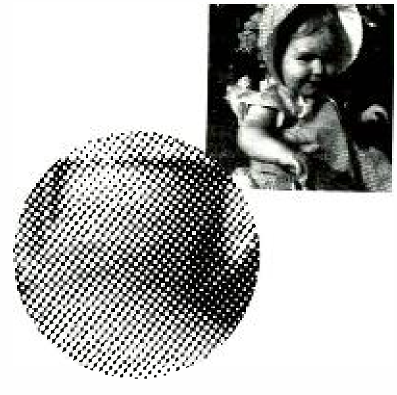

Fig. 1—Electronically reproduced "newspaper scan" 65-line halftone with portion enlarged 5.5X, using "white dot" halftone system.

Fig. 3—Hex-format white-dot structure—110 line screening in original; this reproduction magnified approximately 2.5X.

The type of perturbation likely to appear in an electronic system is hum modulation from the AC line. It can be seen in the black-dot halftone, Fig. 5, as the semi-circular swirl pattern that appears convex-upward over a large portion of the picture. It was found that by locking the halftone generator to the AC line and by counting an integral number of cycles-per-line of halftone dots, the pattern could be immobilized at a minimum spatial frequency to lie along straight rows perpendicular to the horizontal-dot row. Threshold tests indicated that the hum pattern visibility was lowered by a factor of only about 2 by this technique. For these tests, the spiral modulators and all other video and CRT geometry, and focus correcting equipment were temporarily disconnected to eliminate possible ground loops that might introduce hum. Then hum displacement was inserted through a calibrated attenuator into the deflection amplifier input. Dot areas of about 50 percent were achievable for this test, not by spiral scanning, but by defocussing the apertured CRT to form a fairly uniform dot cross section. The 50-percent dot blank-field structure has a threshold visibility for displacement modulation of about 1.0 percent of the 9-mil interdot spacing used in the test. This threshold was extrapolated to be about one-third as large, or 0.33 percent (0.03 mils) for the assumption of a 95 percent dot, the usually permissible maximum, especially with letterpress printing. This observation is fairly consistent with calculations based on the assumption that the brightness threshold, ΔB, is about 1 percent for large contiguous fields having a sharp line of demarcation between them. For the large dot percentages of interest, the allowed dot perturbation ΔS_{max}, is proportional to the brightness threshold, $\Delta B = 0.01$, times the square root of the fractional white area, T_{min}, times the interline spacing, S:

$$\Delta S_{max} = 0.01 \sqrt{T_{min}}\, S$$

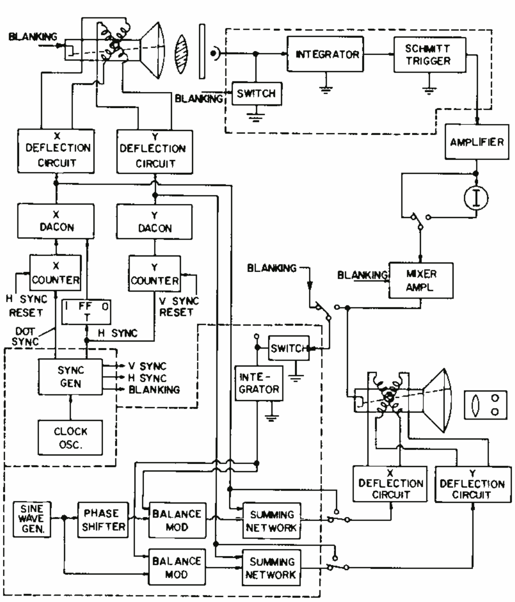

Fig. 2—Block diagram of developmental halftone system for spirally scanned dots.

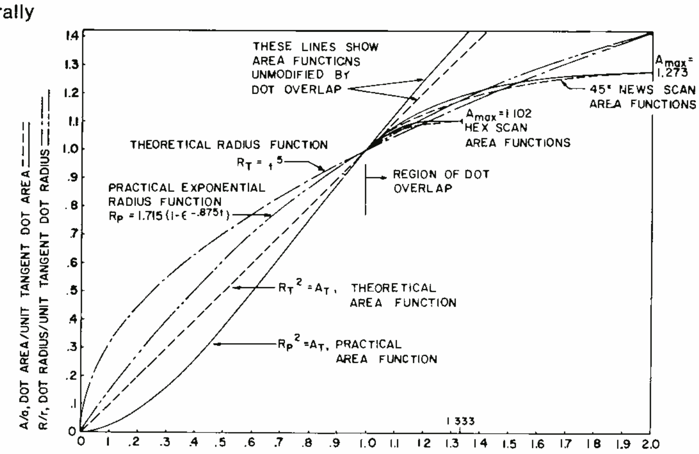

Fig. 4—Radius and area functions for spiral-scanned halftone dots.

This is plotted for a few values of contrast ratio,

$$R_c = \frac{1 - T_{min}}{T_{min}}.$$

in terms of the screened dots per inch and the interdot spacing in Fig. 6.

For the same case of 110-line screening (9-mil interdot spacing) as in the above measurements with a 19:1 contrast ratio, the allowable dot displacement from the normal is about 0.021 mils, or 0.231 percent of the interdot spacing. Since the measured or calculated allowable displacement error amounts to about 2 or 3 parts in one million, the dynamic range and hum-rejection ratio of the deflection circuitry to produce such a 10-inch final picture (regardless of the demagnification on the CRT) must be about 120 dB. This stringent requirement was met in a stripped-down version of the halftone CRT display.

An important observation to make, however, is that the "white-dot" system is, by its nature, orders of magnitude less sensitive to hum disturbance. This is because a hum signal in the deflection system does not modulate the area of the small white dots, but rather just moves them slightly in a black field. Hum pickup in the video pulse-width modulation system is of course to be avoided because it has the same effect on dot area as the video modulating signal.

The various offset processes that are coming into wide acceptance do not have the same difficulty as the letterpress in producing the odd shaped ink areas demanded by the white-dot process. In addition, additional contrast range can be achieved by allowing the dot structure to drop out in the whites and "go solid" in the blacks, by virtue of inherently smoother transitions into these regions in the offset process. The white-dot process, or other novel-printing formats, may thus come to be of increasing interest as the graphic arts industry continues to develop techniques mutually compatible with electronic capabilities.

VIDEO PULSE-WIDTH MODULATION CONSIDERATIONS

Pulse-width unblanking to control the recorded size of the spirally scanned dot has been produced by driving an integrator from the photomultiplier-tube output of the flying spot scanner, and allowing the integrated voltage to activate a Schmitt-trigger circuit. This form of pulse-width modulator uses a constant-current source to fire the Schmitt trigger just before blanking resets the integrator circuit. This is the "black-level" control. The electrical system using the pulse-width modulator is described as the negative-acting type because increased light transmission in the subject produces decreased dot area on the CRT. The first halftone experiments were made with this pulse-width converter and produced surprisingly good results. Analysis showed that a "black stretch", ($\gamma < 1$), characteristic is needed to produce approximately equal unit density changes in the output for unit density changes in the input transparency. The integrator had such a characteristic by virtue of a relatively low voltage with respect to the Schmitt-trigger level, to which the integrator was reset by the dot-blanking pulse. The voltage level to which the integrator was resettable was adjustable over a limited range to provide a limited control of the black-stretch characteristic.

A more versatile pulse-width modulation method was evaluated in which a sawtooth voltage was added to the video signal. In this device the video signal caused the sawtooth voltage to trigger the Schmitt-trigger circuit at varying points on its slope, depending upon the extent to which the video-level raised the sawtooth into the Schmitt threshold. This device made a linear transform of video-voltage to pulse-duration for a linear sawtooth. It had an advantage in that the sense of the pulse-width modulation could be made negative or positive for a given video polarity simply by

Fig. 5—Black dot 105-line "news" dot structure. Face enlargement is approximately 1.8X. Note concave-upward hum bars in actual-size reproduction; enlarged inset is shown for clarity in illustrating the "black dot" structure.

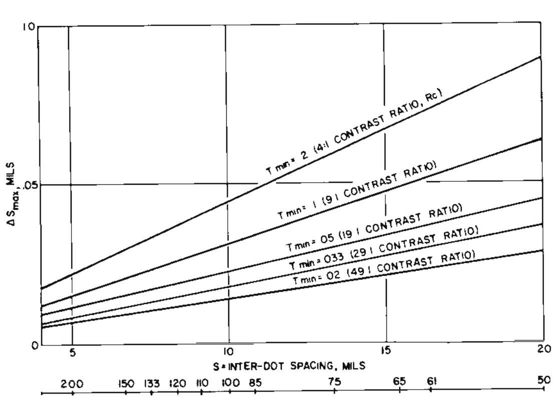

Fig. 6—Permissible displacement, ΔS_{max}, of a halftone dot row in V or H direction for assumed brightness threshold, $\Delta B = 0.01$, as a function of interdot spacing and dots per inch.

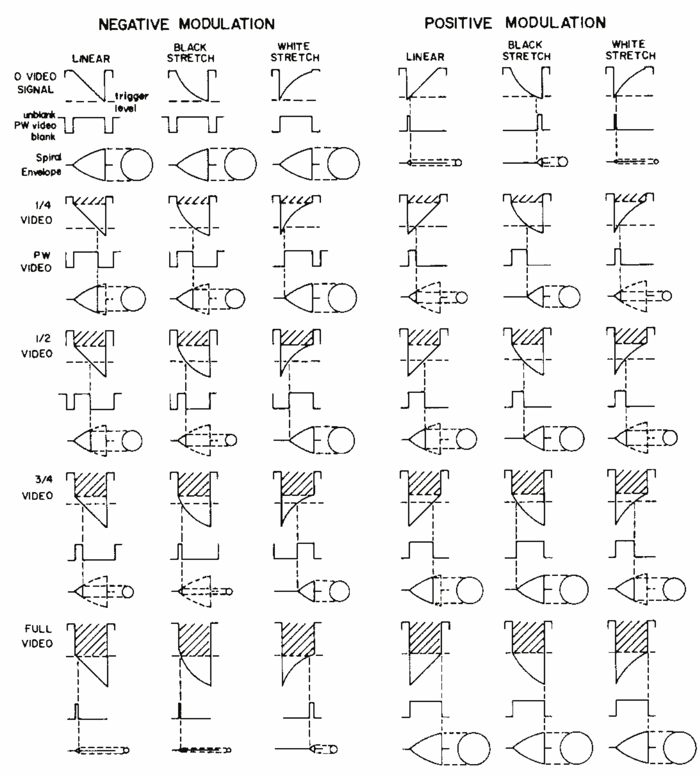

Fig. 7—Illustration of pulse-width modulation concept for producing positive and negative halftones with gray scale compensation.

inverting the sawtooth voltage waveform. The modulation characteristic could be distorted to produce black stretch by using a nonlinear sawtooth, which was produced by using a relatively large portion of the exponential RC charging characteristic. The simpler, integrating pulse-width modulator also has an inherent advantage of improving the electrical signal-to-deviation ratio. This advantage was of no importance in our experiments, however, because of a sufficiently noise-free signal source for both modulators.

GRAY SCALE REQUIREMENTS

In reproducing the gray scale of a photographic negative as a positive image, it is desirable that the transmittance of the reproduction be proportional to some power of the reciprocal of the object transmittance.

The polarities of the electrical and photographic processes that constitute the halftone system can be arranged to produce negative or positive copy from either negative or positive input. The conditions necessary to produce the possible combinations are summarized in Table 1. This table indicates the nature of the halftone dot and the *sense* (black or white stretch) of the electrical distortion of the transfer characteristic needed to give the desired unit-density correspondence in the output copy. The *black-stretch* or *white-stretch* definition must be referred to the addition of differential gain in those respective portions of the photomultiplier-tube video-output signal, since this circuitry has no "knowledge" of the polarity of the output and input film processes which affect whether black stretch or white stretch occurs with respect to the output process. Table 1 also shows the *sense* of the required transfer characteristic referred to the output copy. This is seen in every case to be a black-stretch requirement, indicating that the need for white stretch within the system is only an internal artifice of implementation.

Fig. 7 illustrates the generation of video pulse-width waveforms for the linear black-stretch and white-stretch conditions in producing both positives and negatives, for various degrees of video modulation. The active portion of the spiral-scan modulation envelope is sketched within the unblanking interval, and the corresponding dot size appears adjacent to the modulation envelope.

The required electrical black-stretch waveform for negative modulation is made by using a negative-sawtooth slope with exponential curvature and by starting the spiral scan at the end of the normal dot-blanking period. For electrical white stretch with negative modulation, the exponentially shaped sawtooth is used as it is generated, in its non-inverted form. The spiral scan is started from the residual of the pulse-width modulation waveform by inverting it for input into the spiral scan generator. With positive modulation, the exponential sawtooth for black stretch is used with negative slope with the residual pulse-width-modulation (PWM) mode of operation. Electrical white stretch for positive modulation uses the positive curved-sawtooth slope and the normal, non-residual, PWM mode.

The developmental equipment used in making the dot halftones shown with this article used the superimposed-sawtooth type modulator to produce the PWM video signal. The white-dot examples correspond to Case I-a-1 as listed in Table 1, and the black-dot example to case I-b-2. The theoretically required linear setting of the pulse-width modulator was modified to provide some black stretch. In addition, it was found advantageous to use some black stretch and white stretch from a separate gradation correction amplifier which used diode-break circuits to synthesize greater differential gain in those video signal regions. This can be explained by noting the *S*-shaped response of the practical dot area versus time curve shown in Fig. 4. Control of the transfer characteristic to compensate for the printing process used for this article has not been optimized. Therefore, these figures do not represent the ultimate quality believed possible with electronic methods.

The exponential sawtooth shapes used in providing black- and white-stretch waveforms of this experimental equipment should theoretically be modified to provide logarithmic PWM characteristics. Diode-break circuits could, of course, be preset to provide this condition more accurately in a more advanced model of this halftone generator.

TABLE I—Summary of Operating Conditions for Various Positive and Negative Halftone Processes

Input Subject	*Film Output Process*	*Electrical Sense*	*Nature of Required Transfer Characteristic to Give Constant ΔD per Output Step* — *Referred to PEC Video*	*Referred to Output Copy*	*Process Results* — *Half-tone Dot*	*Hard Copy Display*
Case I, Pos.	a. Pos (reversed)	1 Pos	Linear	Linear	white	Pos
	Pos (reversed)	2 Neg	Black stretch	Black stretch	white	Neg
	b. Photo-neg	1 Pos	White stretch	Black stretch	black	Neg
	Photo-neg	2 Neg	Linear	Linear	black	Pos
Case II, Neg.	a. Pos (reversed)	1 Pos	Linear	Linear	white	Neg
	Pos (reversed)	2 Neg	Black stretch	Black stretch	white	Pos
	b. Photo-neg	1 Pos	White stretch	Black stretch	black	Pos
	Photo-neg	2 Neg	Linear	Linear	black	Neg

VARIABLE LINE-WIDTH HALFTONES

Although, the use of variable size dots can be considered the *standard* means for generating halftones, other systems have been devised and experimentally implemented. In the system described below, a TV-type scan is used and the

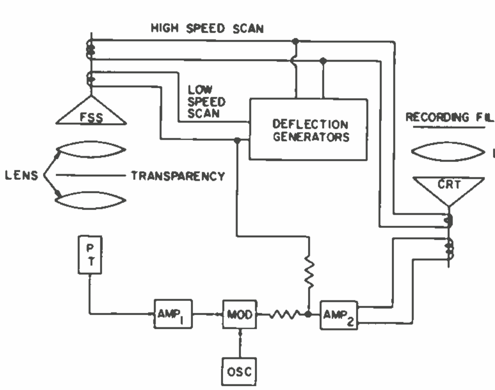

Fig. 8—Simple line-width halftone generator.

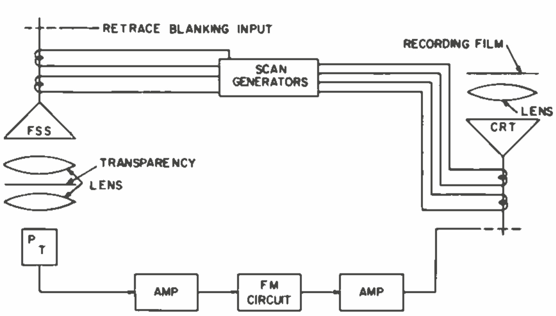

Fig. 9—Simple FM halftone generator.

width of the scan lines is made to be dependent on a video-control signal. Fig. 8 is a simplified block diagram of this system. A flying spot scanner (FSS) scans a continuous-tone transparency in TV fashion and the photomultiplier tube (PT) detects the amount of transmitted light through the required lenses. The phototube output signal is amplified (AMP) and fed to a balanced modulator (MOD), modulating the sine-wave carrier generated by the oscillator (OSC). The modulator output is summed with the low-speed scan, amplified (AMP_2), and feed as a deflection current to the low-speed yoke. The high-speed scan system is not modified. Also, the scanner and readout CRT are synchronously scanned by use of common deflection generators.

There are a number of systems that can be used to generate electronic line-width modulation halftones. Some of these systems and the various constraints and limitations of each were outlined in the preceding paragraphs. Modifications such as curved, rather than straight, width-modulated scan lines were not discussed, but these can indeed yield at least interesting halftones. A major newspaper uses such optically screened halftones for some eye-catching advertising, e.g., concentric line-width-modulated circles in lieu of straight lines.

FM HALFTONE SYSTEMS

The systems described earlier in this paper produce halftones by varying the size of a dot, or line, while keeping the general structure fixed. The FM system described in the following paragraph generates a halftone using small, fixed-sized dots of adjustable spacing. The system is described as an FM system because the spatial dot frequency is made to vary in accordance with the desired optical density.

The standard variable dot-size technique can be called an AM system since the spatial frequency of the dots is constant while their size, or amplitude, varies as a function of optical density. In the FM system a TV-type scan is used to generate the raster and the unblanking waveform determines which spot locations within the raster will be used. As stated above, the dots, when producing an FM halftone, are all the same size. This means that the unblanking waveform must be a fixed width pulse of a rate dependent on the desired optical density. Fig. 9 is a simplified block diagram indicating a possible configuration for such a system.

The flying-spot scanner and readout CRT are driven from synchronized scan or raster generators. A continuous-tone transparency is scanned in TV fashion with the photomultiplier tube gathering the light transmitted through the transparency by means of imaging and collecting optics. The amplified photomultiplier-tube output is fed to an FM circuit that converts the amplitude-varying signal into a period-varying fixed-width pulse train. After amplification and buffering, the pulse train is applied to the control grid of the CRT for unblanking. Sample waveforms at various circuit points in the system are shown in Fig. 10 to further illustrate the above process.

The first waveform represents the video signal on the scan line from the photomultiplier using a step-wedge transparency. The second waveform represents the pulse-train output from the FM circuit as a result of the video waveform above. The third line indicates the dot pattern as seen on the CRT faceplate. Line three is a photograph of the CRT display; the display consists of high optical-density dots surrounded by unexposed or low optical-density film base. In the example, if the video waveform corresponds to light transmitted through the transparency then the picture taken off the CRT faceplate will be a negative of the original transparency. A print of this negative will, of course, yield a positive. It is also possible to change the polarity of the image electrically by inverting and offsetting the gamma-corrected original video signal prior to application to the FM circuit. Therefore, positives or negatives of the original transparency are possible with this system.

The operation speed of this or other systems is limited to various constraints imposed by CRT-brightness capabilities versus spot size and recording-film speed or sensitivity. A reasonable maximum spot velocity on the film is approximately 5 inches per millisecond.[1] The required *on* time for the FM circuit is determined using the following equation:

$$T_{ON} = \frac{\textit{desired spot width} - \textit{act. spot width}}{\textit{spot velocity}}, \qquad (1)$$

where it is assumed that the actual spot width is smaller than the desired spot width and the spot velocity can have a maximum value of 5 in/ms. The *off* time requirement for the FM circuit when producing maximum optical density is given by the equation

$$T_{OFF}\Big|_{D=MAX} = \frac{\textit{actual spot width}}{\textit{spot velocity}}, \qquad (2)$$

and the off time for minimum optical density is given by:

$$T_{OFF}\Big|_{D=MIN} = \frac{\textit{des. spot width} - \textit{act. spot width}}{(\textit{spot vel.})(\log^{-1} \textit{density}_{MIN})-1}$$

$$= \frac{T_{ON}}{(\log^{-1} D_{MIN})-1} \qquad (3)$$

The low optical-density end of the picture can be set by a constraint that gives a maximum dot-to-dot spacing for reasons of objectionable structure discernibility. From the preceding remarks and equations it should be apparent that the density-range capability is determined by the spot width and maximum interdot spacing. The spot shape, for ease of discussion, is assumed to be square, and the spacing between suc-

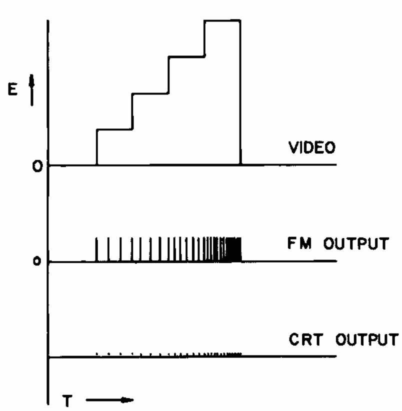

Fig. 10—FM system waveforms.

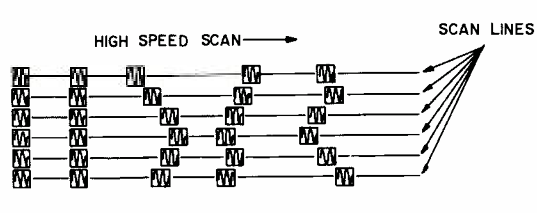

Fig. 11—Possible FM dot pattern.

cessive scan lines is set equal to a spot width.

To illustrate the use of the equations above, an example using typical values will be given. Assume that the readout device produces a square spot 1½ mils on a side and that a square spot 3 mils on a side is desired in order to be compatible with the smallest reliably printable spot in the final inked process. Also, assume a spot of velocity of 0.15 in/ms which yields an *on* time requirement for the FM circuit of 10 μs. (To increase the spot dimension from 1½ to 3 mils in the other direction, such techniques as spot wobble or an asymmetric aperture may be used.) The *off* time for maximum density will then also be 10 μs. If 10 mils (or 100 lines/in) is the maximum allowed inter-dot spacing then the minimum density can be calculated using Eq. 3 with the knowledge that

$$T_{OFF} = \frac{\textit{spot spacing} - \textit{actual spot width}}{\textit{spot velocity}}$$

$$= \frac{8.5\ \text{mils}}{150\ \text{mils/ms}}$$

$$= 56.7\ \mu\text{s}.$$

The required *off*-time variation is therefore 10 μs to 56.7 μs or a ratio of 5.67 to 1. Thus, the density, D, is

$$D = \frac{\log T_{ON} + T_{OFF}}{T_{OFF}},$$

$$\approx 0.07,$$

and is the theoretical minimum density using the assumptions stated above. Also assumed is that the optical density of the spot has a value of one or greater. If the optical density were exactly one, the density figure of 0.07 would be reduced to approximately 0.062 due to the light transmission through the spot itself. The maximum density is, for this example, just equal to the optical density of the spot itself. A paper fully covered with ink can, for example, produce an optical density of 1.4 and consequently a "tone" or density range of 1.4 − 0.07, or 1.33, would be possible.

The FM circuit has a threshold characteristic that allows the tone range to be extended in the highlight areas of the picture. That is, at video levels below the adjustable threshold the FM circuit ceases to oscillate. Since no spots are then produced, the density theoretically goes to zero. A halftone made in that fashion has a continuous density range from about 1.4 down to 0.07 and then a step from 0.07 to approximately zero.

When a field of constant density is produced with the FM system, a structure becomes apparent to the eye. The structure consists of lines running in a direction parallel to the low-speed scan. Fig. 11 illustrates the pattern formed. The first two columns are shown as if the dot rate were synchronized to the high-speed scan rate, while the last three columns indicate a possible pattern if no synchronization exists.

For normal pictures, however, the information content is high. Consequently there are no large areas of constant level, and the picture information obscures the structure by virtue of the constantly changing modulation. It is possible to obscure the structure, even for large areas of constant density, by the addition of random noise to the video-signal input to the FM circuit. The amount of noise added should be inversely proportional to the video-signal level to allow deviations of plus or minus one-half the average interdot spacing for optimum structure obscurity. Although the original structure can be made to vanish in the noise, the unremovable low-frequency noise components tend to produce a slightly blotchy effect. In any case, normal pictures of high-information content are relatively free of interference patterns (Fig. 12).

A still more complex FM system, called the bidirectional FM system, is currently being investigated. In this system, the dot spacing is made to vary not only in the direction of the high-speed scan, but also in the direction orthogonal to it. Fig. 13 shows the pattern obtained from this system for various optical densities. It should be noted that the pattern is always regular and, in the case shown, approximately square.

No noise will be introduced into the bidirectional system because the regular pattern should not be objectionable (ordinary halftones currently used in industry have a regular pattern) and added noise will only tend to introduce a slightly blotchy characteristic as noted previously.

ADVANTAGES OF FM SYSTEMS

One advantage of FM systems is that they lend themselves to incorporation with lasers. Consider a rotating drum wrapped with a sheet of film and, as shown in Fig. 14, a laser mounted on a carriage driven by a lead screw. Scanning is accomplished by rotation and translation.[2] The laser is *on-off* modulated by the FM circuit with a suitable driver. This avoids the laser-deflection problem, and could lead to a direct printing-plate production method, using a laser of sufficient power to generate gravure cavities directly in the final printing plate.[3] This would eliminate the intermediate steps of optical screening and photographic plate making.

Another advantage of the FM system is the absence of the non-linear transfer function that relates the dot size on the printing plate to the dot size on the final inked copy, because, in the FM system, all dots are the same size. It should be noted that both the FM systems and the AM systems are still in the experimental stage and further exploration is required before a final operating model is produced.

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2. Woywood, D. J., "Laser Recording Systems," this issue.
3. Stephens, A. W., "Lasers and Printing Plates," this issue.

Fig. 12—An FM electronically screened halftone.

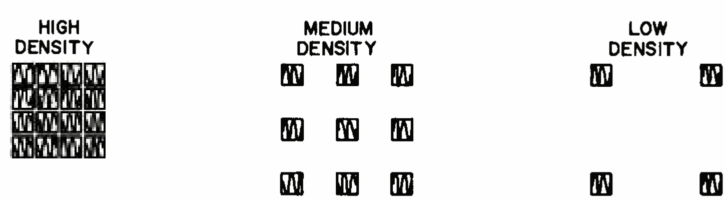

Fig. 13—Various patterns vs. optical density for the bi-directional FM system.

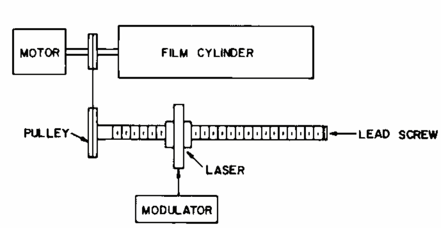

Fig. 14—Possible implementation of FM system using laser as modulated light source.

Videocomp Photorecording

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Essential to the faithful reproduction of the type characters formed by the Videocomp is the efficient functioning of the photorecording system. In this paper the author describes the photorecording processes which involve the cathode-ray tube, lens, and photographic stages.

An IMPORTANT phase of RCA's Videocomp line for the graphic arts industry is the photorecording process. The recording method is a logical extension of companion RCA developments in computers and cathode-ray-tube systems.

PHOTORECORDING COMPONENTS

The photorecording equipment components are located at the top-center and right-side of the Videocomp (Fig. 1); major components include the cathode-ray tube (CRT), the lens, and the photographic sections. Tube, lens, and film relationships are shown schematically in Fig. 2. The photographic film section processes the photosensitive materials and can handle photographic film, stabilization paper, or short-run printing plates. Since emulsion characteristics of these materials are sufficiently similar, they are discussed only in terms of the photographic film.

BASIC OPERATION

When the CRT receives a writing signal, the electron beam scans according to the pattern shown in Fig. 3. To give a clearer picture the vertical strokes have been expanded; in practice, they form an uninterrupted line which makes up some portion of a character. The individual typefaces of characters, letters, or figures are generated on the CRT in type lines and transferred to the film through a fixed lens. At the end of each line the film is advanced one-line height. Fig. 4 shows one of the first messages composed and printed by the Graphic Systems Division on its photocopy unit. Obvious similarities to earlier RCA photorecording equipment exists by the combined use of the CRT, lens, and film. This paper concentrates on the overall compatibility achieved with these components. Two aspects considered are the system efficiency and the quality requirements.

CATHODE RAY TUBE

Essentially the CRT is a device to convert electrical video signals from the computer into light energy on the tube face. This light must be produced with high resolution (small spot size), high intensity, and proper spectral characteristics. Assuming the electron optics can deliver energy adequately to the phosphor faceplate in an area small enough to satisfy the resolution requirements, the phosphor portion of the CRT is of primary concern. The electron beam must accomplish several things when directed toward the faceplate. Generally, the beam must pass through an aluminum layer and penetrate the phosphor layer to a depth where the remaining energy can produce useful radiation. Only a small portion of the original beam energy is converted into usable flux; the remainder is usually dissipated as heat. This conversion process is a measure of phosphor efficiency. Fig. 5 shows the spectral relationship of four phosphors, selected because of the known basic sensitivity of silver halide in the ultraviolet and blue portions of the spectrum. Table I lists the efficiencies of these aluminized phosphor screens.

The aluminum layer performs two functions:

1) Since phosphors are good insulators, it prevents accumulation of a negative charge on the screen surface,
2) The aluminum acts as a reflector to increase the flux output from the tube face.

The reflective layer is usually applied in a thickness proportional to the normal accelerating voltage of a particular tube. For a layer thickness of 0.5 microns, 97% of the electron-beam energy passes into the phosphor layer when the beam has been accelerated through 20 kV. The transmission drops to 93% when the layer is 1-micron thick and the beam voltage is 20 kV.

For the photorecording application under consideration, the requirements for smaller beam diameters are significant. The ultimate in CRT resolution is achieved with evaporated phosphor. However, the amount of usable radiation is considerably reduced. This utilization factor, K, for evaporated screens can be as low as 10%. Alter-

Reprint RE-13-6-14/Final manuscript received January 10, 1968.

Fig. 1—Front view of the Videocomp 70/820.

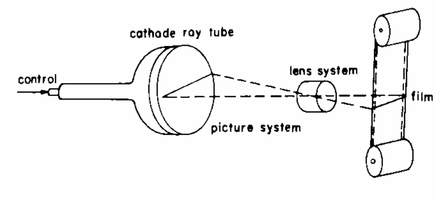

Fig. 2—Photorecording components.

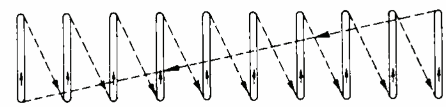

Fig. 3—Electron-beam motion on the cathode-ray tube.

The words you are reading were electronically generated by RCA without physical fonts or matrices. This method is capable of speeds greater than 900 lines per minute.

Fig. 4—Early photocomposition.

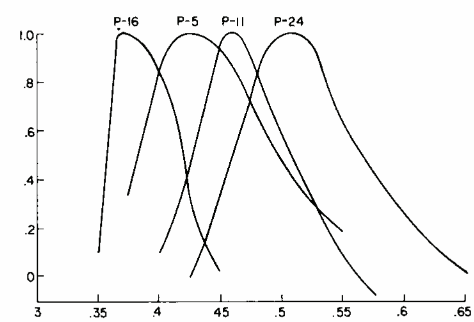

Fig. 5—Typical photorecording phosphors.

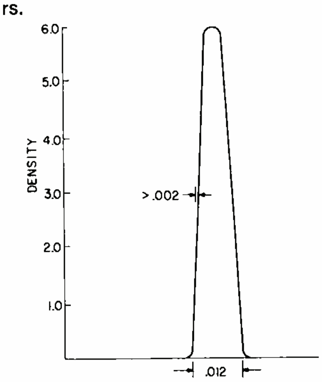

Fig. 6—Microdensitometer trace of lower case "f".

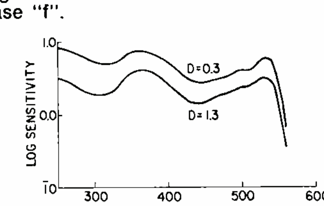

Fig. 7—Spectral sensitivity of Kodak phototype setting film.

TABLE I — Phosphor Efficiencies

Phosphor Screen P-Number	*Fluorescent Color*	*Typical Luminous Equivalent (radiated lumens/radiated watt)*	*Typical Absolute Efficiency η (radiated watts/watt of excitation)*
P-5	Blue	90	0.025
P-11	Blue	140	0.10
P-16	UV-Blue	25	0.049
P-24	Blue-Green	360	0.026

nately, it can be as high as 100% for a coarse aluminized screen which is used where spot size is not critical. Currently most photorecording tubes use a fine-grain, settled aluminized screen with a utilization factor of 50%.

On an absolute or energy basis the P-11 phosphor is the most efficient according to Table I. Even if the output were to be visually observed, this phosphor would produce 14 lumens/watt while the P-24 would produce 9 lumens/watt. In the present photographic application the last column of Table I is more significant. Before a choice of phosphor is made another aspect must be considered, that of spectral compatibility with the photographic film.

PHOTOGRAPHIC FILM

Beiser[1] has made a comparison of the phosphor-to-emulsion transfer efficiencies of phosphors in Fig. 5 with blue sensitive and orthochromatic film. The results of his analysis are shown in Table II.

TABLE II — Phosphor-Emulsion Transfer Efficiency, α

	Phosphor Type			
Film Type	P-16	P-5	P-11	P-24
Blue sensitive	0.95	0.68	0.50	0.15
Ortho	0.93	0.87	0.87	0.81

The Phosphor-emulsion transfer efficiency, α is obtained by evaluating the expression:

$$\alpha = \frac{\int_0^\infty \frac{P_\lambda}{P_{max}} \frac{F_\lambda}{F_{max}} d\lambda}{\int_0^\infty \frac{P_\lambda}{P_{max}} d\lambda}$$

where P_λ/P_{max} is the relative phosphor radiation at wavelength λ, and F_λ/F_{max} is the relative emulsion response at wavelength λ.

Film evaluation tests have been made with blue sensitive, orthochromatic, and panchromatic films. Table III lists films tested with a P-11 phosphor. An important factor in the selection of a suitable film for our type of photorecording is shown in the last column under gamma. Gamma is the ratio of the difference between two densities to the difference between the logarithms of the exposures which produced them:

$$\gamma = \frac{D_1 - D_2}{\log E_1 - \log E_2} \qquad (1)$$

It is measured as the slope of the straight line portion of the D versus log E plot. Since the gamma of a film is influenced by processing techniques, only methods recommended by manufacturers were used.

TABLE III — Tests of P-11 Phosphor Films

Mfg.	*Film*	*Sensitivity*	*γ*
Dupont	1186	Blue	2.2
Kodak	2490	Blue	1.3
Kodak	2492	Ortho	1.4
Kodak	Photo-typesetting	Ortho	4.4
Kodak	Line Shellburst	Pan	1.8
Gavaert	051	Ortho	4.2

The importance of gamma to the printer needs further elaboration. In the graphic arts field, the lithographer is interested in high contrast on his printing plates. When the lithographer uses photographic techniques to produce a printing plate, he demands a sharp transition at the edge of a line or character. The sharp edge then is carried over to the printing plate. In this type of work a class of films has emerged called lithographic or lith films. In general lith films are high-gamma films. Typically their gamma is about 4.0.

The effect of a high gamma can be seen in Fig. 6. This plot is a microdensitometer trace of the lower-case letter "f" in the word "fonts" of Fig. 4. The width of the vertical portion of the character is .012 inches. When the scan produces a density reading of three, the distance from the edge is less than .002 inches.

Of equal value in selecting the proper film is film speed. Nothing has been said concerning the relative speeds of the films listed in Table III. The speed of a photographic film can be taken as inversely proportional to the exposure necessary to produce a certain density in the film. In graphic arts, we are accustomed to high density, and often use a density of 3.0 to measure speed. At this density, phototypesetting film is slightly faster than Linagraph Shellburst. If a lower density is acceptable, the Shellburst film is faster. Here we have experienced the case where exposures producing densities of 1.0 and below on Shellburst give essentially no density on the Phototypesetting Film. The use of high densities and high gammas requires that the Phototypesetting film and P-11 phosphor be used with our equipment.

With a choice of phosphor and film accomplished, the amount of energy required to produce a given density should be determined. The exposure required to produce a given density is usually available from the characteristic curve for a particular emulsion. Unfortunately, the classical methods of photographic sensitometry are based on luminous energy units. This is a result of earlier days of visual photometry and the necessity for calibrating sources in the candle-lumen units. Therefore, film exposure is conventionally plotted in terms of meter-candle-seconds. A meter-candle is the illumination equivalent to one lumen per square meter. For engineering applications, the source of radiation needs to have a flat response across the visible portion of the spectrum, or serious errors can result if luminous units are used. In this paper we will avoid the luminous units by describing flux in the absolute value of watts.

Recently, some film companies have been publishing spectral sensitivity curves for specific emulsions. These curves plot the ordinate as log sensitivity (reciprocal of exposure in ergs/cm^2) against wavelength. Usually these curves are for a stated density above density of base plus fog. Fig. 7 shows the spectral sensitivity of the Kodak Phototypesetting Film, when processed for 5 minutes in a D-11 developer. The characteristic curve for Phototypesetting Film when processed to a gamma

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of 3.7 in a K-30 developer for 4.5 minutes after exposure to simulated P-11 radiation is shown in Fig. 8.

LENS TRANSFER EFFICIENCY

In addition to the characteristics of the phosphor and film, the effect of the lens must be considered. The function of the lens is to transfer the CRT radiation to the film at maximum efficiency. The losses in the lens are of two types:

1) There is the decrease in energy due to reflection and absorption by the glass, and,
2) There are geometrical losses involving the lens aperture and the field angle.

To minimize reflection losses, lenses for specialized applications have an anti-reflection, thin-film coating on each air-glass surface. The coating can be selectively specified to maximize the transmission at a particular wavelength. In the present case the maximum transmission is specified for the peak of the P-11 phosphor, .46 microns. For a lens of eight air-glass surfaces, such as presently in use, the transmission can be 90%.

The other glass loss is that of absorption. The present lens has an axial glass thickness of about 12 cm. A typical absorption for the kinds of glass used in this lens (average index of 1.6) is 2%/cm. This value leads to a transmission of 78%. The combined glass losses would provide a transmission factor, T, of 70%.

To evaluate the geometrical losses consider a conventional camera. The irradiance, H_0, produced by a source considered to be a Lambert radiator is given by:

$$H_0 = TP \sin^2 \emptyset \qquad (2)$$

where T is the transmission factor of the lens; P is the radiant flux; and $\emptyset$ is the half angle of the cone of rays proceeding from the lens to the image. For a well-corrected lens at infinity object distance, $\sin \emptyset$ is equal $D/2f$. Therefore Eq. 2 can be written in terms of the image distance, f, as:

$$H_0 = \frac{TPD^2}{4f^2} \qquad (3)$$

where D is the diameter of the lens aperture; and f is the focal length of the lens. When a lens is used at a finite magnification as in photo-recording, the image distance becomes $f(1+M)$ where the magnification, M, is the ratio of image-to-object size. This means that the angle $\emptyset$ is reduced as the magnification increases, and the image receives less illumination for the same aperture. Therefore, to keep the same exposure value calls for an enlarged aperture or increased exposure time.

The ratio of f/D is the familiar infinity f-number of a lens, and the equation for irradiance on the optical axis may be rewritten as:

$$H_0 = \frac{TP}{4\,(f\text{-number})^2\,(1+M)^2} \qquad (4)$$

Sometimes a more convenient expression of effective f-number, f_e, is used at finite magnification where the effective f-numbers equals the infinity f-number multiplied by $(1+M)$.

For the off-axis case, the fixed angle measured from the optical axis to the corner of the image area defines an angle Θ. The geometrical factors which decrease the irradiance are due to the circular aperture being reduced to an ellipse at the off-axis angle where the area of the aperture is reduced by a factor $\cos \Theta$. The radiation falls on the film at an angle Θ which causes a reduction in irradiance by a second $\cos \Theta$, and then the distance from lens to film off axis is greater than the axial distance by a factor of $\sec \Theta$, leading to a $\cos^2 \Theta$ factor through the inverse square law. These factors multiply to give the ratio of image irradiance at an angle to that on axis of:

$$\frac{H_\theta}{H_0} = \cos^4\Theta \qquad (5)$$

The importance of the $\cos^4\Theta$ factor should not be underestimated when working with wide-angle systems, and especially with high-gamma films. Its effect is implicit in Eq. 1 which shows that a greater change in density will be obtained for the same change in exposure with a high-gamma film than that obtained with a low-gamma film. Obviously, this effect can result in a complete loss of information at the maximum off-angle point when only the on axis case has been analyzed. Fig. 9 is a plot of the $\cos^4$ factor and off-Θ axis angle. This relationship H_θ/H_0 has been termed natural vignetting as opposed to artificial or mechanical vignetting. The latter type arises when for an extra-axial point the entrance pupil is not uniquely defined by the image of the aperture stop in the object space. Thus all apertures, masks, lenses, and mounts must be taken into consideration for they can block part of the rays from the object point. Usually this effect is more predominant, the longer the mechanical construction of the lens. For a specialized lens design, specifications are usually stated so that only the $\cos^4\Theta$ factor is involved. This is the case for the lenses used in the present recording equipment.

Summarizing the discussion on the effect of the lens in the system, a lens efficiency factor, β, can be determined:

$$\beta = \frac{T \cos^4\Theta}{4(f\text{-number})^2\ (1+M)^2} \qquad (6)$$

A typical Videocomp β can be obtained by using values of the present system. The lens operates at a maximum off-axis angle of about 7° and has an effective f-number of 10. Combining these numbers with the transmission of 0.70, produces a lens efficiency factor of about 0.17%.

EXPOSURE RELATIONSHIP

The relationship of the system components can be observed by combining factors contributed by the phosphor, the lens, and the film. The radiant flux of Eq. 4 is the product (in watts) of the beam current and the accelerating potential. If we assume that the phosphor is not driven to saturation, a condition reducing flux output by phosphor heating, then the available power can be used directly in Eq. 4. When this equation is multiplied by the writing time, t, in seconds, the irradiance H becomes the exposure E in energy units. This exposure takes place over some area A in cm². The time t may be the time to write one line, and A may be the length times the effective width of the line; or the time may be expressed as the application time for a single impulse in recording a dot, and A the

Fig. 8—Characteristic curve of phototypesetting film.

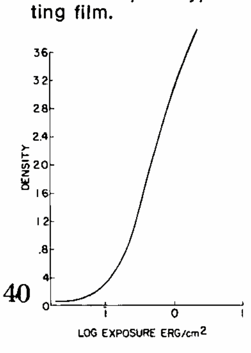


Fig. 9—Relationship between illumination and field angle.

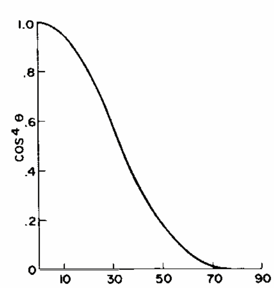


Fig. 10—Modulation transfer function of Kodak phototypesetting film.

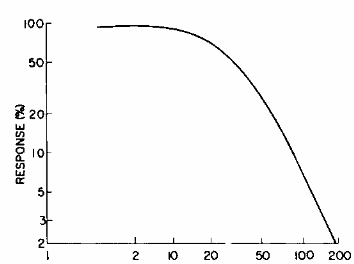
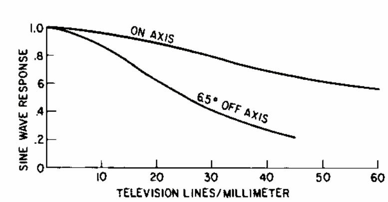


Fig. 11—Modulation transfer function of Videocomp lens.



area of the dot. Alternatively, for a raster scan, the time may be the total frame time, excluding blanking, and the area that of merged lines. If the raster is not merged, then the reduction in active area for the space between the scanning lines must be taken into consideration.

By converting watt-seconds into the required ergs the following expression can be formulated:

$$E = \frac{\alpha\beta\eta KPt}{A} \times 10^7 \text{ ergs/cm}^2 \quad (7)$$

The phosphor rise and decay times do not appear in the above equation because the film is fixed during exposure and integrates the radiant energy for a long exposure period compared to the phosphorescent decay time.

It is informative to consider the system in operation, using the factors developed so far. The tube has a P-11 fine-grain settled aluminized face. It is operated at an anode voltage of 20 kV and a beam current of 1 microampere. The power to the phosphor is $2\text{x}10^{-2}$ watts. Consider for example a writing rate on Phototypesetting Film of 5000 in/s, and it desired to write a 2-mil line 0.1-inch long.

Summarizing the efficiency factors and tabulating their values: $\alpha = 0.87$, $\eta = 0.1$, $K = 0.5$, $P = 0.02$ watts, $\beta = 0.0017$, $t = 2\text{x}10^{-4}$ seconds, and $A = 2\text{x}10^{-4}$ inches $= 1.29\text{x}10^{-3}\text{cm}^2$.

From which, using Eq. 7, the following exposure is obtained:

$$E = 2.3 \text{ ergs/cm}^2$$

The log exposure value is therefore 0.36. Referring to Fig. 8, it can be seen that this exposure will produce a density well above the density speed point of 3.0.

SYSTEM QUALITY

People of the graphic arts industry use a highly subjective method of determining the quality of their finished product. Usually this method consists of an observer examining the output copy with a 10X magnifier and declaring its acceptability or nonacceptability. The lack of objective information is a problem when engineering data must be used to define system specifications. To resolve this problem, Graphic Systems Division has attempted to provide a relationship between the subjective quality assessment and objectively measured quantities. The purpose was to provide standards in the form of modulation transfer functions for the CRT, lens, and film. These modulation transfer functions are directly related to the equivalent passband line number N_e. Use of such a line number has been documented by Schade.[2] It is a departure from the conventional graphic-arts criterion of specifying system components in terms of limiting resolution.

The equivalent passband line number N_e is defined by assuming a flat sinewave response from $N = 0$ to $N = N_e$, such that the area under the normal squared sinewave response curve is equal to the area of a rectangle of unit amplitude whose base extends from 0 to N_e. If N_e is specified in television lines (half cycle) per unit length, then its reciprocal value, $1/N_e$, specifies an equivalent line width or bit size. Another advantage of the N_e concept is the ease of determining the overall N_e of n components by the expression:

$$\frac{1}{N_e^2} = \frac{1}{N_{e1}^2} + \frac{1}{N_{e2}^2} + \ldots + \frac{1}{N_{en}^2} \quad (8)$$

To determine the system modulation transfer function, some high-quality text printing and the USAF 1951 resolution test target were simultaneously contact-printed onto photographic paper. The selected paper had a finish similar to that used in good quality magazines.

Succeeding copies had a transparent spacer between the original negatives and the paper. The spacer reduced the image quality in proportion to spacer thickness. Image quality reduction applied equally to the text material and the resolution chart on eleven photographic prints.

Each print had the resolution target data scanned with a Joyce-Lobel reflection microdensitometer at AED, Hightstown, N.J. Data from this equipment, in the form of squarewave response measurements, were normalized and converted to sinewave response curves. The effect of the spacers could be seen as a loss in high-frequency response for successive prints.

A panel of engineering and graphic arts specialists evaluated the quality of these prints. They were asked to separate the prints into two groups, acceptable or unacceptable; their decision to be based on the text matter only. Their criterion was based on comparable good quality magazine printing. The results of these observations produced an average print value from which sinewave response and a system N_e of 224 television lines/inch was derived.

CRT LINE NUMBER

Assuming a gaussion spot on the cathode ray tube, an N_e value can be determined from: $N_e = 1.6/2d_0$, where d_0 is the diameter at which the relative intensity is $1/_e{}^3$. GSD normally specifies the diameter of the spot at the 65% intensity point, as determined by shrinking raster techniques. For our value then:

$$N_e = 1.6/2\, d_0\, 1.52 \quad (9)$$

where the factor 1/1.52 has been derived by Rogell[4]. The equivalent passband of a 2-mil spot will then be 264 TVL/inch.

FILM LINE NUMBER

The modulation transfer curve of phototypesetting film can be obtained from published data by Eastman Kodak Company. Fig. 10 shows this curve plotted on a logarithmic scale. The N_e of the film is approximately that point on the curve where the response is 70%. At this point, the N_e of the film is 20 cycles/mm or 1016 television lines/inch.

LENS LINE NUMBER

The N_e of a good lens is indicated by the TV line number at which its modulation transfer function response is approximately 65%.[5] Fig. 11 shows the modulation transfer function of the lens used in the 70/820 Videocomp Photocopy Unit. This curve was obtained from the lens tests conducted at DEP Advanced Technology, Camden, N.J. The 65% response at an effective aperture of $f/8$ and an off-axis angle of 6.5° is about 19 TV lines/mm or 473 TV lines/inch.

Using Eq. 8 we can obtain the system equivalent passband. This is the measure of system quality. The calculated value obtained is 225 TV lines/inch, almost exactly that suggested by our observers and the modulation transfer function derivation.

CONCLUSION

The methods discussed above have contributed to the Videocomp development. By establishing the CRT-lens-film relationship in terms of efficiency and quality, a standard has been established for future equipment. The same balance of analytical and empirical methods can be used for further Videocomp development.

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Proofing of Color Separations in the Graphic Arts

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The end product of a composing and plate making department is a master which will be used to make multiple copies. In general, this master is expensive and the steps in the process are difficult to control. Errors such as improper screening, over or under exposure of color separations, and improper plate etching or washing are difficult to spot before the damage is done. The ultimate proof of the quality of the complete composing and plate-making operation is a satisfactory print from the production press; however, this requires completion of the total process. Proofing can be carried out at various stages in the process, one of the most critical being the completion of the transparencies from which color plates are made. There are a number of these proofing systems. Hand development of Electrofax coatings is one of the better, and can provide high quality proofs of the separation transparencies but takes time. Improvement of the development process in terms of automation and better control should make this system superior to those now on the market.

ORIGINAL COLOR ARTWORK to be printed arrives in the composing room in many forms. It may be a freehand drawing or painting, a line drawing, or a transparent or reflection-type photograph in color or black and white. It is analyzed and decisions made on how it is to be presented. These decisions may require cropping, enlarging, highlighting certain areas, reducing or increasing the contrast or any other treatment the editor or art department needs to project the important features of the picture.

PRODUCING COLOR SEPARATIONS

Continuous tone color separations are then made of the original by exposing it on black and white film through color filters. These filters are red, green, and blue giving a record on the film of the amount of red, green, and blue light in the image. A neutral image is also made giving the amount of black which serves to sharpen the reproduction. These transparencies are the first step in preparing printing plates but two further processing steps are needed.

COLOR CORRECTION

First, the printing inks are the subtractive primary colors: magenta, cyan, and yellow. These transmit or reflect two of the positive primaries and absorb the

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S. W. Johnson

Dr. D. A. Ross

SIGURD W. JOHNSON studied physics and music at the Northern Illinois State Teachers College from 1933 to 1936 and continued at the National Institute of Electronics from 1936 to 1938. From 1953 to 1955 he completed additional courses in advanced color and black and white photography at the Philadelphia Museum School of Art. From 1939 to 1945, Mr. Johnson was employed by the Leich Electric Company where he designed and developed custom-built switchboards. In 1945 he joined the RCA Photophone Advanced Development Group where he was engaged in sound recording on color films. In 1946 Mr. Johnson transferred to RCA Camden where he worked on kine recording and magnetic recording and playback equipment, environmental testing, color correction, precision test films, sound ranging equipment, and optical devices. Mr. Johnson also intiated the research project to develop materials and equipment to produce Electrofax prints in color. In 1955 he became the Project Engineer of the Color Electrofax applied research program in Camden. This program resulted in a feasibility model of a color map printing machine. Mr. Johnson joined the RCA Laboratories in 1961 where he is now active on a color Electrofax research program to develop methods and materials for making Electrofax color enlargements from color negatives or transparencies. Mr. Johnson holds 7 U.S. Patents. He is the author of several technical papers and is a member of the Society of Photographic Scientists and Engineers.

DR. D. A. ROSS received the B.Eng. in electrical engineering in 1947 from McGill University. Dr. Ross worked with General Electric X-ray Corporation until 1950 doing application work in the medical and industrial field. He joined the High Voltage Engineering Corporation in 1950 doing design and application work on high energy particle accelerators. From 1953 to 1957, he attended Yale University. He received the M Sc in 1955 and the PhD in 1957 in physics. While at Yale, he did work on radiation effects in biological and chemical systems using high energy electrons and gamma rays. Dr. Ross returned to the High Voltage Engineering Corporation in 1958 and was responsible for radiation applications in medical, industrial and research fields covering areas in nuclear physics, solid state physics and biophysics. Dr. Ross joined RCA Laboratories in 1958 as Head of the Nuclear Reactor Group carrying on research work in the field of solid state physics with the five megawatt nuclear reactor. He is now Head of the Electronic Printing Group of the Data Processing Applied Research Laboratory conducting research in novel methods of copying and printing by electrostatic and electromechanical methods. Dr. Ross is a member of the American Physical Society, Sigma Xi and the American Association for the Advancement of Science.

third. Magenta absorbs green and passes red and blue. Cyan absorbs red and passes blue and green. Yellow absorbs blue and passes red and green. The red light record is a transparency where the opaque areas represent the red image; the clear areas represent the blue and green images, and the transparency is called the cyan printer. Similarly, the blue record transmits the green and red images and is called the yellow printer, and the green record transmits the blue and red images and is called the magenta printer.

If, now, subtractive inks or dyes are deposited in registration in amounts directly proportional to the optical density in the three printers—the magenta image being printed by the magenta printer, the cyan image being printed by the cyan printer, and the yellow image being printed by the yellow printer (with the black image superimposed on the color) —a true reproduction of the original should be expected. This might happen if the filters and printing pigments had sharp cut-offs and matched each other exactly but unfortunately, such is not the case. The magenta ink tends to absorb some of the blue, the cyan some of the green, and the yellow also absorbs some of the green light.

The non-uniform light absorption of the process inks must be corrected if a true color reproduction is to be obtained. For example, where the magenta absorbs some blue light, it is taking over the role of the yellow which is to absorb blue. We must reduce the amount of yellow in areas where there is magenta. This is done by masking where a new yellow printer is made by exposing it to the original yellow printer and a low-level magenta printer. The density of the yellow printer is reduced in areas where the magenta is also to be printed. Similarly, the cyan and yellow printers are corrected by masking to give a true representation of the original colors.

SCREENING

The second step in producing a transparency suitable for plate making is to screen each of the transparencies. This is necessary because the mechanical contact printing process cannot control color density by varying the ink thickness. Instead, the image is broken into elemental dots by exposing a piece of film through a screen constructed so that the highlight areas produce large dots and the low light areas produce small dots. The eye cannot resolve the dots and sees only changes in optical density as the dot size is varied. Care must be taken to ensure that moiré patterns are not produced by interference between the screens and this done by rotating the screens for each color. Fig. 1 illustrates how this is done.

Both of the above steps may be carried out manually by normal photographic techniques or electronically with a color scanner. The end result is a screened set of color corrected transparencies suitable for plate making.

PROOFING

Once the screened separations are completed, the printing plates can be made. Since errors may have been made in processing the transparencies, the plates can be exposed without retouching and the printed image quality determined by an actual press run. Press proofs are then examined to determine whether the plates are satisfactory and, if not, what corrective action such as dot etching can be taken to improve the print. This may be an expensive procedure. A set of four-color copper photo-engraved plates can cost as much as $2500 for a high quality monthly magazine. It would be much more economical if errors in the transparencies could be spotted before making the plates.

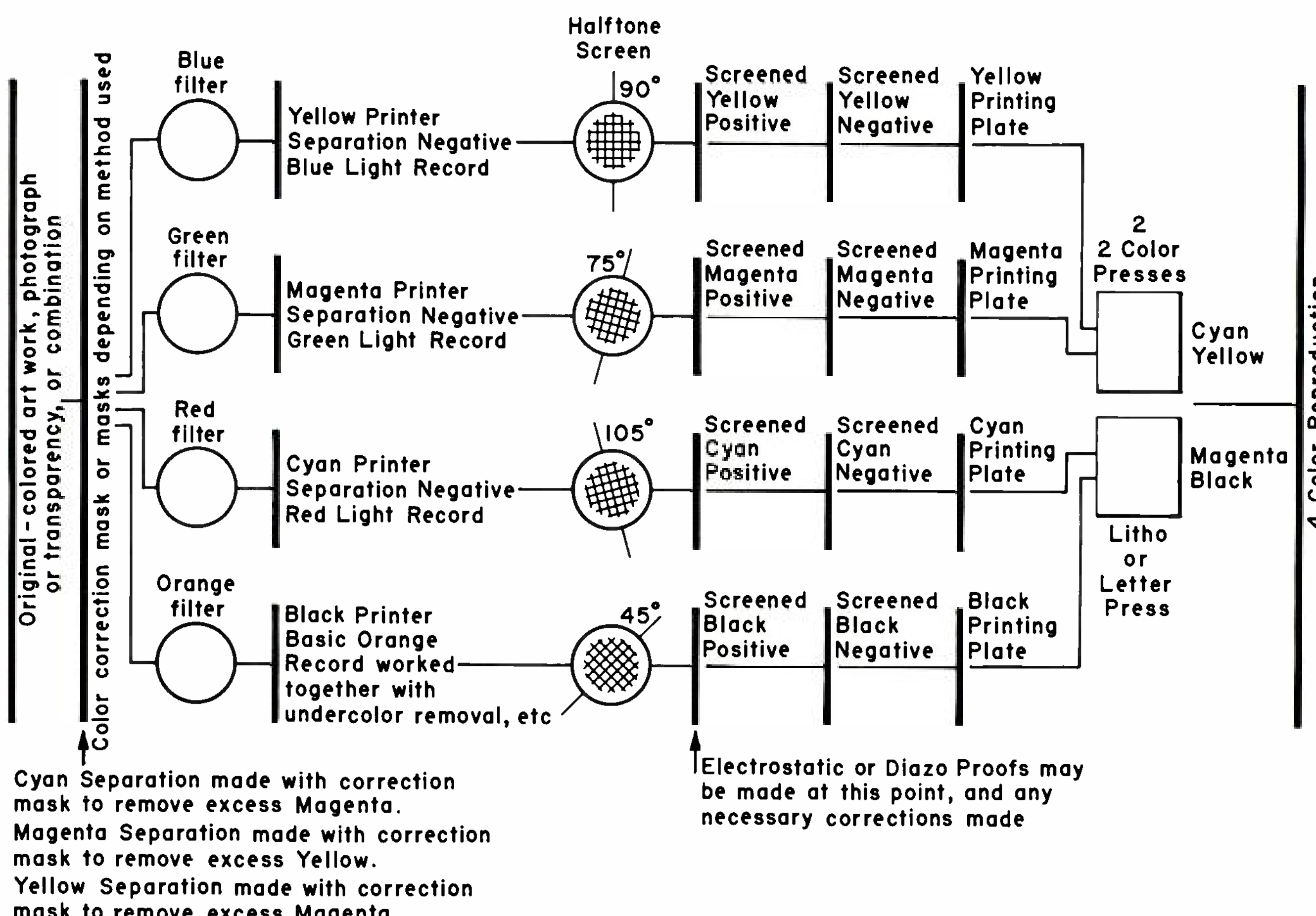


Fig. 1—Color reproduction flow chart.

Diazo Systems

A number of methods may be used for proofing the transparencies before exposing the printing plates. One of the most common is to expose a colored diazo transparency from the appropriate separation. If the diazo dye color matches the primary subtractive colors (cyan, magenta and yellow) they can be overlaid to give an impression of how the final print will look. While simple to expose and develop, the overlays are transparent, and the light reflected from a white sheet under the overlays must pass through the four sheets. In addition, there are reflections between the sheets. A skilled artist is needed to interpret how a finished print will look from observation of the overlays and, if color errors are apparent, how the transparencies should be corrected.

A method of avoiding the interlayer reflection is to use diazo dye layers which can be stripped from their backing and deposited on a reflecting substrate. Although superior to the overlay method, the saturation and color of the dye may not match the printing ink used by that particular shop and there is no simple way to alter the dye. Both of these diazo systems may be negative or positive. They take about 40 minutes for each proof.

Electrolytic System

An electrolytic color proofing system called Electro-color has been demonstrated by the Minnesota Mining and Manufacturing Company. A zinc oxide-binder layer is coated on an aluminized paper base. Light changes the electrical conductivity of the photo-sensitive layer so that imaging will give a conductivity pattern. Electrolytic deposition from a solution of ionic dyes develops the conductivity pattern to produce an image. Multiple imaging is possible so that four color prints can be produced by successively exposing the sheet to the separations. The system is negative working so that negative transparencies must be used.

Electrofax System

Probably the most effective proofing system at the present time is one using the Electrofax principle with the zinc oxide-binder paper and the toners manufactured in Australia. The Electrofax paper is charged and contact exposed from positive transparencies and toned by immersing the paper in a tray of the appropriate toner. The dot pattern is very hard and a wide range of toners with various levels of saturation and hue are available. It takes approximately 30 minutes to make a print. The quality is excellent. In fact, it is a much better reproduction of the transparencies than can be made on a printing press.

One of the main drawbacks to the manual process is the excessive time required to make a print and the need for a semiskilled operator. A wetting step, four toner immersions, and four washes are needed for each print. All of these steps are by tray immersion each of which must be carefully timed. Automation of the process would improve its usefulness.

ELECTROFAX PRINTER

A new toner applicator developed by RCA has made it possible to develop a machine for making Electrofax proofs. A laboratory model is illustrated in Fig. 2. The Electrofax paper is held down by vacuum on plate *A*. The paper is then charged by moving the processing head *B* over the paper. The processing head shown in detail in Fig. 3 uses a single corona wire operating at 9000 volts and pulsed at a rate of 6000 Hz. When charging is complete, the image is exposed either by contact or projection through a transparency. The toner is then applied through the processing head by means of the vacuum system and a solenoid valve. The toner is in a typical high resistivity iso-octane carrier solution and the pigments used in the toner have a printers-ink base. The toner is delivered to the print through slot *C* (Fig. 3) by means of a 24-inch vacuum on slot *D* on each side of the toning slit. The control slots to the atmosphere, slot *E*, on each side of the toner slot control flow and turbulation of the toner. The toner head moves over the print at a rate of about 1 in./sec in the present setup. The entire toning head unit is supported about 0.020-inch over the print. On the return trip of the toner head, clear Freon TF flows over the print to clean the loose toner particles from the background and to rinse the toned image to a thickness there it can be recharged along with the open areas for the next color. All four colors can be applied right side up without moving the print out of registration. A finished print can be made in about four minutes.

At present, the machine uses about 100 ml of toner solution of each color for an 8x10-inch print along with about 150 ml of Freon TF. With suitable plumbing, the toner solution can be reclaimed because the Freon TF rinses out the system each time so the colors do not become contaminated. Thus, the machine can deliver a dry, ready-for-use proof in about four minutes with no mess or lost fluid. For completely free handling, a soluble organic fixing agent can be applied with the last color to "fix" the print so it will not smudge with abrasion, or it can be sprayed with clear lacquer. The cost of the solutions and the Electrofax sheet is in the range of a few cents for an 8x10-inch print.

The saturation of colors that can be obtained at present with this machine does not yet match printing inks. It is believed, however, that further development of materials will make this possible. Such a machine should be a valuable addition to any print shop. It can be operated with any light source (e.g. a typical enlarger) and will furnish a full color proof from a set of separations in less than five minutes for pennies per print.

Fig. 2—Laboratory model electrofax color printer.

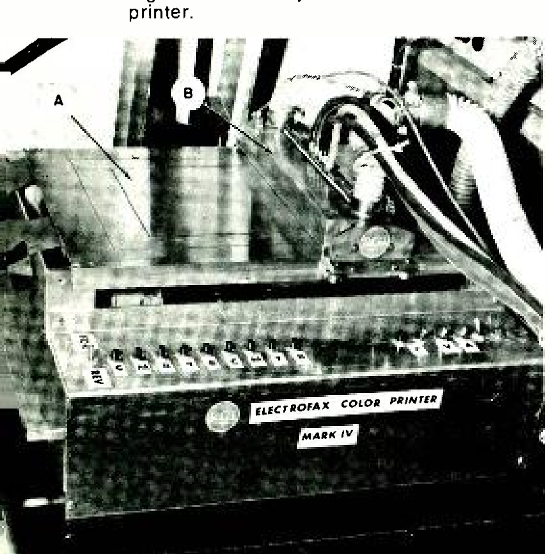
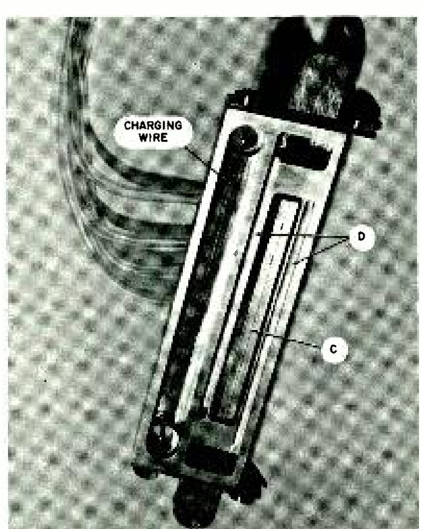


Fig. 3—Color printing processing head.



The Series 1600 Computer—a new solution to an old problem

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While the electronic computer has been with us only about 20 years, some of today's computer problems go back much further than that. Since the beginning of calculating machines as an aid to problem solving, we have always been after increased efficiency. At any one time our most efficient system has been one designed specifically to solve the particular problem at hand. These special purpose machines have always been very expensive and usually late! What we have been striving for is a special-purpose machine at a general-purpose price and a reasonable delivery. The new requirements posed by Graphic Systems Division gave an excellent opportunity for RCA to tackle this problem. This paper will describe the system designed by RCA Information Systems Division to meet the needs of the Graphic Systems Division and other applications within RCA.

MANY TIMES and in many different environments, attempts have been made to design a computer system with the efficiency of a special purpose computer, but with price and delivery of a general purpose machine. Some attempts have fared better than others, but generally speaking, they have always failed. At the beginning of this program to design a special-purpose computer for the Graphic Systems Division, it was necessary to ask the question: "So what is new?" In other words, are there techniques and hardware available to us now that we did not possess a few short years ago? Furthermore, will any new combination of these enable us to more closely approach our efficiency goal? One has only to pick up a Technical Journal to discover that new and fantastic claims are being made for exotic hardware products almost every day. Many of these new inventions are still looking for an effective application, but certainly multifunction integrated chips have found a home in the computer business.

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Three of the Spectra 70 computers now in production make heavy use of integrated circuits. With their use comes further knowledge, and with this knowledge comes further understanding of their power and capability. The Spectra 70/35 and 70/45 computers have also made use of the technique known as microprogramming. In these machines, the instructions and even the algorithms are formed by picking up fixed patterns of bits from a Read Only Memory. By using a specially designed Read Only Memory, and a modest amount of hardware, it is possible for these machines to emulate other computers. The power and versatility of a machine controlled by microprograms has been known for some years. It took the advent of today's effective hardware to make the resulting system competitive when compared with the heretofore accepted standard design techniques.

These two items—the multifunction integrated chips and the microprogramming techniques—gave us powerful new tools to tackle this old problem.

HAROLD MORRIS received the BSEE from Purdue University. During World War II, he was a Combat Bomber Pilot with the Eighth Air Force in England. His Post-war career began with the NACA Research Facilities in Virginia where he worked on missile instrumentation and launch systems, as well as radar, telemetry, and optics. In 1950 he moved to Cape Canaveral as a research member at what was then the Joint Long Range Proving Ground. For the next ten years he held various management positions in range instrumentation and data processing for Radio Corporation of America. In 1960, he transferred to the Electronic Data Processing Division of RCA, and was a member of the original contingent sent to Palm Beach County to establish the EDP Facility. His present position is manager of computer products engineering, which encompasses all of the development and product engineering activities assigned to the Palm Beach Engineering Operation. He is a Director of the Palm Beach County Science Museum and Planetarium, and a member of the Industrial Visiting Committee of the Dept. of Electrical Engineering of the University of Florida.

GRAPHIC SYSTEMS DIVISION

Late in 1965, the new Graphic Systems Division had done sufficient analysis of their potential market to describe in general terms the type of data processing they would require. As with any new effort, this analysis indicated a changing market with emphasis moving as more was learned about the technical problems, and the needs of the potential customers. For the same reason, the time schedule to do the systems design and get hardware in production was very short. This time schedule, for example, would not allow a complete departure from present EDP packaging. In 1966 specific systems were functionally described to control the Photo Copy Unit. These systems known as the 70/832 and 70/833 are the first to use the new processor as a vital part of their capability.

The above requirements indicated the desirability of a jointly sponsored program between the two RCA Divisions. Consideration was also given to other potential requirements within RCA, such as New Business Programs, RCA Communications, and RCA Instructional Systems. What this really means is that the program has been pursued to meet the specific needs of the Graphic Systems Division, and at the same time produce a versatile approach which can be effective in several areas of RCA's business.

SYSTEM APPROACH

Fig. 1 is an attempt to indicate the technical approach taken in this program and how it differs from previous RCA computer systems. Conventional machines are shown to have a set of characteristics described by the circle containing the RCA 501, 301, 3301, and 70/55. The other group of RCA machines employ what is known as elementary operation techniques or microprogramming. Each of these approaches contain certain advantages and disadvantages. The new system, which carries the internal designation of Series 1600 includes features found in both the conventional and the elementary operation machine.

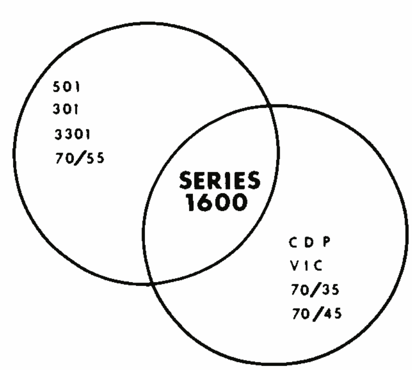


Fig. 1—Technical approach in the development of the Series 1600 system.

Another way to indicate the difference in approach is shown in Fig. 2. In conventional organization, an instruction is sent by the instruction counter (I.C.) to the operations register where it is examined and directly executed by the machine hardware. In the elementary operation approach, this same instruction would go to the operations register and an address would be generated by hardware and sent to a special address register. This would, in turn, enter a specific stored routine and perform the original instruction on a step-by-step basis. The organization of the Series 1600 allows the system designer to directly execute by hardware any of the twenty-nine basic instructions with their various options, or by efficient software, generate an address and perform a MACRO or major instruction by use of the stored routine. This freedom of a program to choose direct hardware execution or a microprogrammed instruction, or to intermix the two provides a technique for most efficient operation when applied to a solution of a specific problem.

As was just mentioned, the system does not have a fixed instruction set as you will find in all previous RCA systems. Rather it employs twenty-nine basic instructions which are used to efficiently move data through the various elements of the machine. These are grouped as register-to-register instructions, memory-to-register instructions, and general instructions which include communications with the outside world. These instructions were carefully selected to provide a mix of power and simplicity to a programmer, and yet not restrict this ability to match the computer to the specific problem. For example, in the conventional fixed-command-set machines, it is not always possible to find the instruction which will most efficiently perform the task you desire. You must, therefore, combine several instructions in a somewhat inefficient way to accomplish the desired function. The Series 1600 can call up a complete basic instruction in one memory cycle. Combinations of these and selected subroutines can be assembled to obtain an efficient solution of the problem. To put it another way, the building blocks provided to the Systems Analyst and Programmers were carefully chosen in an attempt to optimize their size and yet create a sound and efficient structure.

The key to the internal operation of the system is a group of high-speed registers. These registers are created by the new advance in integrated circuits which enables us to obtain a complete 16 bit memory on one silicon chip. We have combined these chips into sixteen 16-bit registers which can also be addressed as thirty-two 8-bit registers. Eight of these 16-bit registers are assigned to each program state. Fig. 3 is a view of these work registers along with their permanent assignments. It should be noted that, in program state one, only register 8 has a permanent assignment as an instruction counter. The remainder of these registers are used by the Systems Analyst. As he views the specific problem he is trying to solve, he can then freely assign these registers as base counters, index registers, temporary storage, etc. In program state two, register 8 has also been assigned as an instruction counter. Registers 6 and 7 are assigned for high speed input/output address and count when required. In other words, if the problem to be solved does not require high speed devices, the programmer is free to use these registers in any way he desires. If high speed operation is required, the internal hardware paths are present to communicate across the input/output interface from these registers. In normal operation, the computer can move from program state one to program state two essentially instantaneously. For example, if the machine was working on its production problem in program state one, and a timer interrupted indicating that it was time for servicing a group of real-time devices, the machine would begin that service in program state two on the very next memory cycle. There are absolutely no overhead functions required. Upon completion of servicing of this group of devices, only one memory cycle is required to return from program state two back to the main routine in state one. In addition to this freedom to move between program states, high speed input/output service can proceed without program interference. Fig. 4 is an example of how this would occur. A high speed device would signal an interrupt request across the interface and at the completion of the current basic instruction in program state one; this high speed device begins stealing memory cycles as required regardless of the program state of the machine. When it completes all data transfers, it automatically calls for termination; meanwhile, the main program has proceeded completely ignorant of its existence. In a manner of speaking, the machine really has three program states: state one, state two, and high-speed service. The flexibility and versatility of these registers has done much towards making the machine approach the efficiency of a single purpose computer in fields as diversified as graphics work, process control, and communications.

Input/output (I/O) operation is indicated in Fig. 5. This is created by three 8-bit I/O registers named *device address* (DAD), *byte out* (BOUT), and *byte in* (BIN). These registers communicate in bus fashion with a group of control electronics. Various systems will require different numbers and types of control electronics. These control electronics (CE) provide the interface between the processor and the device communicating with the processor. For example, the

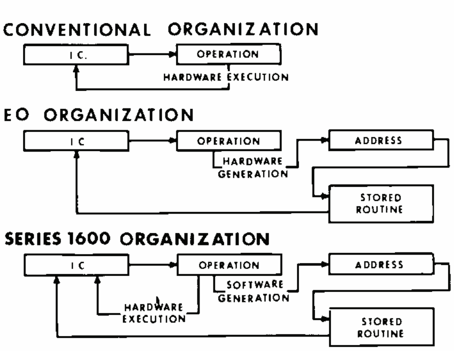


Fig. 2—Comparison of Series 1600 organization with other system organizations.

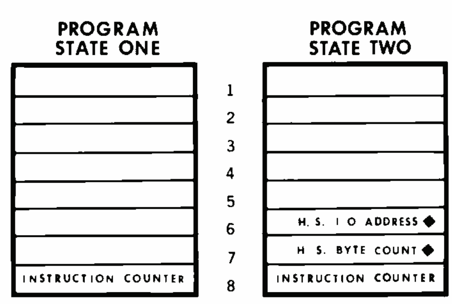


Fig. 3—Eight-bit work registers.

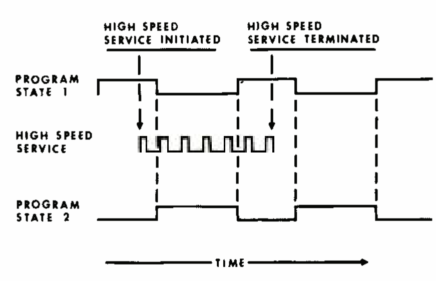


Fig. 4—Two-program operation — each program state (machine) has an independent set of registers.

Graphic Systems application requires a control elecronics to mate with the large and complex Photo Copy Unit and provide it with its necessary input and control. In the same operation, another CE will provide control of a Magnetic Tape Station, while in another configuration, a CE will provide high speed communications with another Spectra 70 computer. In actual operation, the computer will send a device address on the DAD lines. This address will be examined by all the CE's attached to the bus. The CE recognizing its own address will examine the BOUT lines and respond on the BIN lines depending upon the command it received. While this is the normal method of operation, the system designer can use the registers in any number of different modes. The control electronics can be designed to recognize several different addresses as valid and perform appropriate functions as required. This leads to another key point in the optimization of systems performance versus cost.

The processor contains a large group of versatile registers and a full logic capability along with the input/output control just described. This combination enables a system designer to fully use the power of the processor and thereby minimize the amount of electronics necessary in the CE to control the device in question.

As was mentioned previously, time would not permit a complete departure from Spectra 70 packaging. In fact, the speed requirements for the applications thus far reviewed are such that a moderate deviation from the series-2 packaging was entirely adequate. The series-2 packaging is used throughout the Spectra line except for the three largest processors. Series-2 circuits operate at a logic speed of 60-ns pair delay, worst case. The integrated circuit version of this package used in the Series 1600 program runs at 37.5-ns pair delay, worst case. The same physical plug-in size and geometry was chosen so that in any control electronics device, one may choose to use the standard series-2 logic, or the higher speed integrated circuit version, or a mixture of the two even in the same row. The circuits selected for this new family are transistor-transistor logic (TTL) packaged in dual in-line packages. The boards are double-sided with plated through holes.

Fig. 6 gives a comparison of some of the interesting statistics of the Series 1600 and previous RCA computers. It should be noted that with the increasing use of multifunction silicon chips, it becomes more difficult to make an accurate comparison by counting gates. For example, if the internal registers were built from normal logic they would require 1,024 gates, but in this machine they are constructed from 16 chips. Perhaps a more accurate measure would be to refer to the number of chips rather than the number of gates.

The memory selected for this machine is a 2½D memory using thirty 18-mil cores. The system cycle runs at 1.8 microseconds. This cycle is determined by key logic strings rather than memory speed. The 2½D organization has given us a simple but fast and efficient memory particularly at the higher capacities. The complete memory system is housed in a gate mounted in the main rack and can be expanded from 1,024 bytes to 65,536 bytes. This expansion is made in the field by rotating gates from the factory and does not require any change in wiring.

Fig. 7 is a sketch of the maximum version of the Series 1600. The memory is shown in a swinging gate with the four 16-K stacks at the bottom of this gate. The processor is located below the power supply on the right-hand side of the rack. Below this is one row of special electronics to control a program strip reader or other device, and the four rows at the top of the machine on this side contain the complete system power supply. The supply can handle the processor with maximum memory along with nine full rows of assorted control electronic attachments, plus the DC power required to operate two disc drives and two 70/432 tape stations (four tape decks). The left-hand side of this rack is completely empty and available for control electronics to mate the computer with a wide variety of devices. In other words, the Series 1600 provides the space, the power, and the internal interface. The technical department of the using group can select from a growing family of standard control electronics and/or design their own, using building blocks from Information Systems Division. In the front near the top of the left-hand side is a removable maintenance and programming panel. This panel is connected by umbilical cord and can be removed and carried from machine to machine. It can also be placed on the table as a convenient device for the programmer during the checkout of a new program. At the very top on this side are the operator's buttons and the strip reader for entering an operating program, specific control constants, etc.

CONCLUDING REMARKS

The machine in the preceding brief description is the latest in the line of RCA equipments in use in business and industry. It involves some new and innovating techniques and hardware which has furthered our ability to tackle the difficult, if not the impossible, tasks of yesteryear. It is by no means the end, but rather another step in the very beginning of man's ability to devise equipment to assist him in the tasks at hand. There is no question but what the techniques and progress made in his program will assist us in future work just as we have leaned on the experience of the past in developing this system.

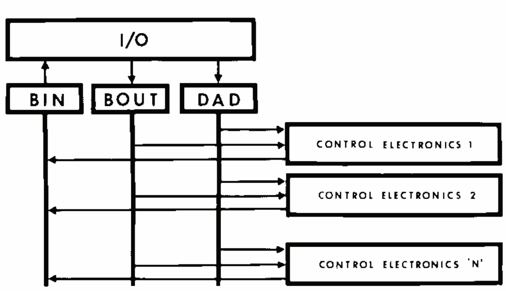


Fig. 5—Input/output operation.

	SERIES 1600	70/15	301
NO PLUG INS	135	314	630
NO GATES	2474 ◆ / 3498	2250	3500
NO. ICP'S	807		
AVERAGE NO GATES PER PLUG IN	18.3 ◆	7 16	5 5
VOLUME CU FT.	1 54	3 46	18 5
POWER WATTS	193	273	1050
CIRCUIT PAIR DELAY	37.5 N S.	60 N S	250 N S

◆ EXCLUDES 256 BIT MEMORY 1024 GATES)

Fig. 6—Circuit and packaging comparison.

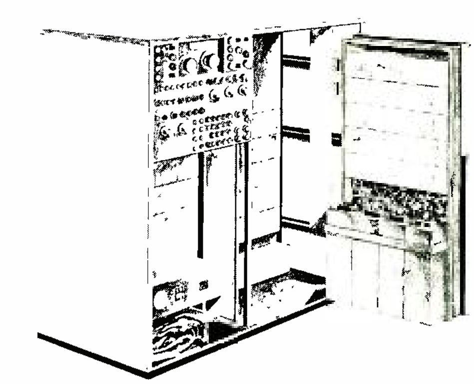


Fig. 7—Sketch of the maximum version of the Series 1600.

The David Sarnoff Outs

The 1968 Individual Awards for

Science and Engineering

Herbert Nelson, of RCA Laboratories, Princeton, N.J., recipient of the 1968 David Sarnoff Outstanding Achievement Award in Science . . . "for conception and application of the solution regrowth technique for making semiconducting devices."


Herbert Nelson

Mr. Nelson, winner of the 1968 David Sarnoff Outstanding Achievement Award in Science, has for a number of years been one of the pioneers in semiconductor fabrication techniques. He has been associated with RCA since 1929. Among his early technical achievements were the development of a hydrogen leak detector for checking vacuum tubes and a new technique for fabrication of a thoriated cathode for television transmitting tubes. With the advent of the transistor era, Mr. Nelson contributed many semiconductor techniques, including the practical incorporation of gallium into alloyed transistors, the development of silicon alloyed transistors, a continuous crystal-growth technique, and development of diffusion and precision lapping techniques. In 1959 he conceived and developed a new method for the fabrication of semiconductor structures: the epitaxial deposition of the desired material from a solution onto a suitable substrate. Because the process, through use of a solvent, occurs at a much lower temperature than most other processes, the technology is much simpler and only relatively simple and inexpensive equipment is needed. Mr. Nelson first applied the technique to the production of large numbers of high speed tunnel diodes for Project Lightning. In 1962, he applied the solution regrowth method to gallium arsenide injection lasers with great success. This method has been adopted as the preferred way to make room temperature injection lasers and is presently being used in the production of both tunnel diodes and lasers by the RCA Electronic Components activity at Somerville.

Dr. Otto H. Schade, Sr., of Special Products Engineering Services, RCA Electronic Components, Harrison, N.J., recipient of the 1968 David Sarnoff Outstanding Achievement Award in Engineering . . . "for the conception of electronic techniques to determine accurately the response of the total television system, including lenses and photographic films."


Dr. Otto H. Schade, Sr.

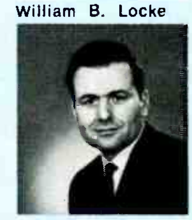
Dr. Schade, winner of the 1968 David Sarnoff Outstanding Achievement Award in Engineering, has made numerous contributions in the field of electron optics. During his more than 36 years with RCA, he has developed a technical competence recognized as outstanding throughout the United States and Europe. He has made important contributions to the application of kinescopes and iconoscopes and has participated actively in the development of image orthicons and cameras. Perhaps the most profound work of his career has concerned the combination of optical and electronic components in the television system. The theories and techniques that emerged from this work not only have been valuable to the unification of system theory but have had revolutionary impact on the individual sciences of lens and film evaluation. The basis for the system concepts was developed during the 1940's. The studies were extended and refined, including the addition of color, through the 1950's, and in the 1960's Dr. Schade has been evaluating camera tubes and electron optics for slow-scan, high-definition television. In 1967 he further developed electronic measuring techniques for the evaluation of image quality in TV images and high resolution film. His technical assistance has been extremely significant in a current Air Force contract on "Advanced Electron Optics" and the camera system for space developed by AED designated as "Earth Resources Observation Satellite" (EROS). The camera's high resolution was made possible by the "return beam vidicon," which he developed.

The 1968


Nicholas J. Amdur


Frank C. Hassett


William B. Locke


Angelo Muzi


Herbert W. Silverman


Earle D. Wyant

anding Achievement Awards

RCA's highest technical honors, the four annual David Sarnoff Outstanding Achievement Awards, have been announced for 1967 by Dr. George H. Brown, Executive Vice President, Research and Engineering. David Sarnoff, RCA Board Chairman, and Dr. Elmer W. Engstrom, Chairman of the Executive Committee of the Board, will present the awards, which consist of a gold medal, a bronze replica citation, and a cash prize for each.

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

Team Awards for Science and Engineering

Messrs. Nicholas J. Amdur, Frank C. Hassett, William B. Locke, Angelo Muzi, Herbert W. Silverman, and **Earle D. Wyant,** all of DEP's Aerospace Systems Division, Burlington, Mass., recipients of the 1968 David Sarnoff Outstanding Team Award in Engineering... "for design, development, and installation of a computer-controlled fully automatic production test system for the on-line electrical test of color kinescopes."

Messrs. Amdur, Hassett, Locke, Muzi, Silverman, and **Wyant,** winners of the 1968 David Sarnoff Outstanding Team Award in Engineering, successfully applied the techniques of test automation to the testing of color TV tubes, at standard production rates, with accuracies and repeatability equal to or greater than those obtained under laboratory conditions. In so doing they demonstrated that skills developed in the performance of defense contracts on Automatic Test Equipment could be applied to an industrial process. One of the contributions of Messrs. Amdur and Silverman was the development of the routing and measuring circuits of nanoampere currents in a factory environment with applied voltages as high as 36,000 volts. Mr. Hassett's combination of design and programming capabilities were essential in simplifying the programming language and in developing the machine-programmer interface. The detailed logic design, developed by Mr. Locke, included a unique system of interrupts which are among the most valuable features of the system. Mr. Muzi solved the mechanical design necessary to allow the equipment to operate in the radio-frequency-interference environment created by high voltage switching transients. Mr. Wyant developed the basic concept of the control system and effectively doubled the rate capacity of the system without materially increasing the equipment complement. This team's accomplishment has laid the groundwork for application of automation to other problems within RCA.


Leslie L. Burns


John J. Carrona


Robert A. Gange


Eugene M. Nagle


Andrew R. Sass


Howard G. Scheible

Messrs. Leslie L. Burns and **Andrew R. Sass,** Data Processing Research, RCA Laboratories, and **John J. Carrona, Robert A. Gange, Eugene M. Nagle,** and **Howard G. Scheible,** RCA Electronic Components' Cryoelectric Devices Laboratory, all of Princeton, N.J., recipients of the 1968 David Sarnoff Outstanding Team Award in Science . . . "for team performance in conceiving cryoelectric memories and developing necessary theoretical understanding and technologies for their realization."

Messrs. Burns, Carrona, Gange, Nagle, Sass, and **Scheible,** winners of the 1968 David Sarnoff Outstanding Team Award in Science, have made important contributions in developing superconductive large-capacity random-access memories and the associated technologies and sophisticated facilities needed to fabricate them. Through their team efforts they have proved such cryoelectric memories to be not only technically feasible, but very economical for use in the next generation of computers. Mr. Burns, one of the co-inventors of the continuous film memory, provided energetic leadership to the project since its beginning in 1958, and was instrumental in gaining Air Force support. Mr. Carrona, head of the Cryoelectric Devices Laboratory since 1965, was responsible for much of the etching technology. Mr. Gange made very substantial scientific contributions including explaining many superconductive effects and suggesting use of a coincident current structured memory. Mr. Sass, the inventor of the current-coincident three-wire system, made very significant and highly original analyses of the speed limitations of Cryotrons and invented an ingenious scheme for reducing write noise. Mr. Nagle contributed much of the design of dewars, fixtures, electronic circuits for testing, and devices needed in making planes. Mr. Scheible was responsible for developing the photo-etch technology essential to fabrication of cryoelectric planes with structural cells.

CRT Display Capabilities

R. J. KLENSCH and E. D. SIMSHAUSER

Research and Advanced Development
Graphic Systems Division, Dayton, N.J.

In a phototypesetting system, the method of generating the image of a character and placing it precisely in the proper position on photographic film is of critical importance — determining ultimate quality, speed, and flexibility of the system. A wide variety of approaches are possible. Because of RCA experience in electronics and the inherent flexibility and speed of electronic systems, the RCA Graphic Systems Division has chosen the computer-driven cathode-ray-tube (kinescope) approach.

With cathode-ray tube systems, choices between electrostatic or electromagnetic deflection, continuous or step scans, and full-face versus single-line scanning must be made. The basic considerations in making these choices are linearity and focus.

DEFLECTION SYSTEMS

There are two general types of kinescopes: one consists of units whose beams are electrostatically focused and deflected; another employs magnetic deflection and focusing. There are combination units employing both electrostatic focus and magnetic deflection.

Magnetic types are capable of the best resolution; electrostatic types have the poorest resolution; and combination types are somewhere in between. The best currently available magnetic units achieve a spot size in the 0.7-mil range on a 9-inch diameter kinescope. The best electrostatic units can achieve a spot size in the 2.0-mil range on a 2.5-inch diameter kinescope. The 9-inch magnetic kinescope can resolve about 12,000 lines across a diameter, whereas the electrostatic unit can only resolve about 750 lines across a diameter.

Electrostatic systems are inferior in resolution because the interference between the focusing and deflecting field cannot be reduced as effectively. In electromagnetic systems, the focusing and deflecting coils are relatively short and can occupy different positions along the electron path. In electrostatic tubes, the deflecting and focusing electrodes are relatively long, and must be much closer to one another. In fact, they are usually side-by-side along part of their lengths so that interference of focus and deflecting fields is relatively high.

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An additional advantage of electromagnetic tubes is that focusing and deflection coils are external to the kinescope. Very precise mechanical alignment can be accomplished while observing the tube in operation—a condition impossible (or at least very difficult) to achieve in an electrostatic tube.

A major problem with electromagnetic tubes is that the deflection is not a linear function of the deflection-yoke drive current. If the deflection field is made uniform across the deflection region (a condition necessary for minimizing spot size) then deflection *angle* is linear with current, but deflection of the spot on the faceplate, which for optical reasons must be flat, is not linear with yoke current. Nevertheless, electromagnetically focused and deflected tubes are almost universally used for phototypesetting because of their superior resolution. Linearity and other problems associated with magnetic deflection, and their correction, are considered below.

Linearity

Kinescopes employing magnetic deflection inherently produce a type of nonlinearity on a flat faceplate called *pincushion distortion.* This nonlinearity derives its name from its appearance. Fig. 1 indicates the presence of pin-cushion distortion on a series of equally-spaced scan lines of equal length.

The source of this problem can be found by an analysis of the electron ballistics for magnetic deflection. Fig. 2 shows the geometric consideration for an electron of charge, $-e$, and velocity V_o orthogonal to magnetic field B. The magnetic field is directed into, and also orthogonal to, the plane of the paper and is present over the distance, lm. L is the perpendicular distance from the center of deflection to the flat faceplate, D is the deflection distance, and θ is the deflection angle. Therefore $\tan \theta_1 = D/L$ and by construction $\theta_2 = \theta_1$ which leads to $\sin \theta = lm/r$.

The solution for r, the radius of curvature of the electron path, is found by the use of two equations that describe the forces acting on an electron moving through a magnetic field. The magnitude of the force in the field is the cross-product between the **B** field and the orthogonal velocity component multiplied by the electronic charge: $\mathbf{f} = e\mathbf{B} \times \mathbf{v}$. Thus, the force acts perpendicular to the electron trajectory, i.e., along the radius, r, and directed toward A in Fig. 2.

The centrifugal force on the electron is given by mv^2/r and when set equal to the magnitude of the eBv force yields $r = mv/eB$. Inserting this into the equation $\sin \theta = lm/r$ yields: $\sin \theta = lmeB/mv$. By trigonometry $\sin \theta = lmeB/mv$ can be written as $\tan \theta = lmeB/\sqrt{(mv)^2 - (lmeB)^2}$ (see Fig. 3). From Fig. 1, however, $\tan \theta = D/L$ and therefore $D = L \tan \theta = LlmeB/\sqrt{(mv)^2 - (lmeB)^2}$ and dividing each term by mv:

$$D = \frac{LlmeB/mv}{\sqrt{1-(lmeB/mv)^2}}$$

For simplicity let $lme/mv = K$, a constant. For a given operating condition this is a valid assumption. Then $D = LKB/\sqrt{1-K^2B^2}$.

The deflection, D, is not linear with **B**, the deflecting field, but has the shape shown in Fig. 4. This is the source of pincushion distortion.

In Fig. 4 is a front view of a flat-face CRT with various deflected spot positions indicated as follows: Y_d is the desired or correct location of a vertically deflected spot; Y_d' is the actual location due to the non-linearity of the equation above and as shown in Fig. 5. X_d and X_d' are similar to Y_d and Y_d', respectively, but are rotated 90°.

The radius vector $\sqrt{2}d$ represents the desired or correct location of a spot deflected when Y_d and X_d fields are simultaneously applied, while d' is the actual spot location. It can be seen that $Y_d' - Y_d = X_d' - X_d = \Delta$ (spot location error) for the deflections considered separately; but, because of the non-linear nature of the error, $d' - \sqrt{2}d$ as measured along the 45° line is greater than $\sqrt{2}\Delta$. Stated simply, the percent error increases with deflection. Fig. 4 and the equation above show that not only are the "corners pulled out," but that there are positional errors over the entire faceplate, except at the non-deflected position in the center.

To determine the required "de-emphasis" of the deflection field to produce a linear spot deflection, the equation $D = LKB/\sqrt{1 - K^2 B^2}$ is solved for B, yielding

$$B = \frac{D/LK}{\sqrt{1 + (D/L)^2}}$$

The above equation (shown graphically in Fig. 6) when converted to its X and Y components, yields the following two equations that give the corrected **B** fields in the X and Y directions for essentially error-free deflection:

$$B_x = \frac{X}{LK\sqrt{1 + (X^2 + Y^2)/L^2}} \quad (1)$$

$$B_y = \frac{Y}{LK\sqrt{1 + (X^2 + Y^2)/L^2}} \quad (2)$$

These equations show their dependence on both X and Y. B_x depends on not only X, but also Y, and B_y is dependent on Y and also X. Therefore, the block diagram of Fig. 7 requires the dashed lines showing the required cross-coupling.

A brief look at Fig. 8 suggests one of the possible techniques for pin-cushion correction; the family of curves gives the required X-axis, **B**-field versus X-axis distance for various values of Y-axis deflection.

A typical method used to generate a nonlinear curve is to construct it from a number of linear approximations which leads to one system as illustrated in Fig. 9. The low impedance voltage sources $e_1, e_2, \cdots, e_n$ used to back bias diodes $d_1, d_2, \cdots, d_n$, determine the level at which the input signal, e_{in}, is shunted

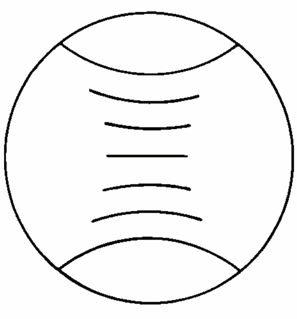


Fig. 1—Pincushion distortion.

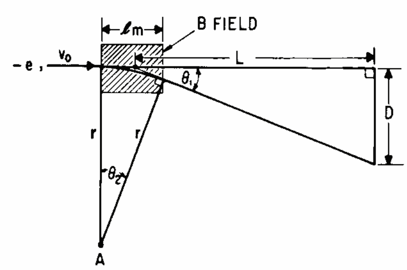
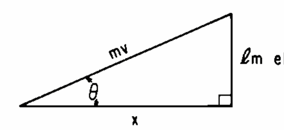


Fig. 2—Geometry for magnetic deflection.



$$\sin\theta = \frac{\ell_m eB}{mv}$$

$$x = \sqrt{(mv)^2 - (\ell_m eB)^2}$$

$$\tan\theta = \frac{\ell_m eB}{\sqrt{(mv)^2 - (\ell_m eB)^2}}$$

Fig. 3—Solution for tanθ given sinθ.

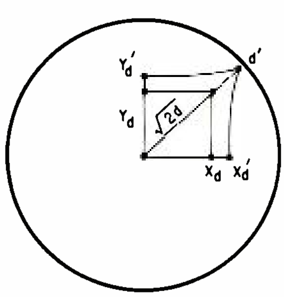


Fig. 4—CRT faceplate showing spot locations.

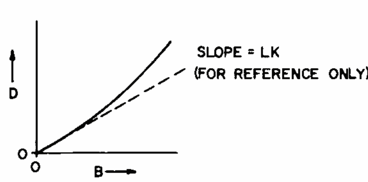


Fig. 5—Deflection D versus B field.

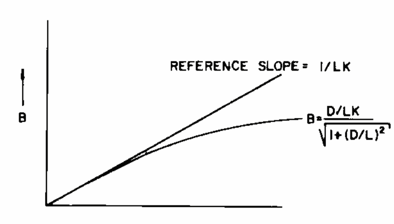


Fig. 6—Required B field—versus distance, D.

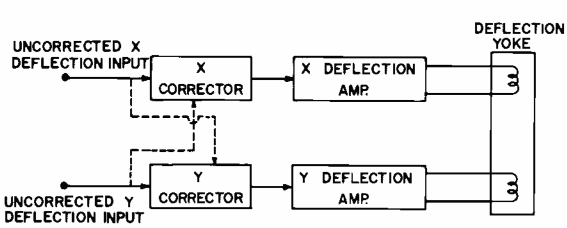


Fig. 7—Corrected deflection system block diagram.

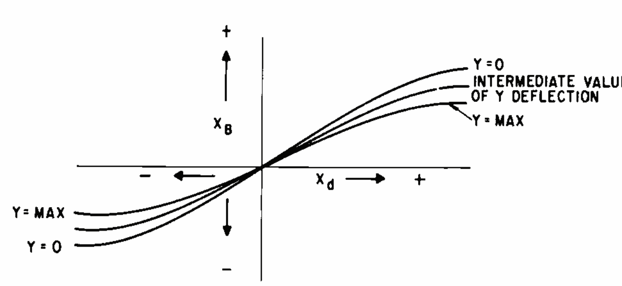


Fig. 8—Corrected B field in X direction versus X distance for values of Y deflection, family of curves.

by resistors $R_1, R_2, \cdots, R_n$, respectively. The slope control resistors $R_1, R_2, \cdots, R_n$ are adjusted (as are voltages $e_1, e_2, \cdots, e_n$) to produce the best approximation to the desired curve. The number of R, d, and e combinations needed is determined by the final accuracy required. It is apparent, therefore, that one of the curves in Fig. 8 could be accurately approximated by this method. If the diode break-control voltages $e_1, e_2, \cdots, e_n$ were then re-adjusted, it would be possible to accurately approximate another one of the curves in Fig. 8. This re-adjustment can be made to occur in some functional relationship to the amount of off-axis or Y deflection. If this functional relationship is properly chosen, then, for any value of Y, the values for $e_1, e_2, \cdots, e_n$ will be adjusted to produce the particular curve in Fig. 8 that allows for optimum correction in the X direction. Correction in the Y direction is accomplished in the same manner.

An alternate approach is possible by expanding the Eqs. 1 and 2 in the following way: The K's in the Eqs. 1 and 2 are constants involving L, K, and those constants derived from the binomial expansion of $[1 + (X^2 + Y^2)/L^2]^{-1/2}$. The accuracy of correction depends on the number of terms used in the expansion. Multipliers, squarers, and adders are the basic building blocks of this system.

To determine the degree of distortion encountered in a given magnetic-deflection system, consider the original deflection equation, $D = L \tan \theta$. This equation can be re-written as $D = L \sin \theta / \cos \theta$ and since $\sin \theta = lmeB/mv = KB$, then $D = LKB/\cos \theta$. Solving for B:

$$B = \frac{D}{LK} \cos \theta \qquad (3)$$

It is apparent that the correction factor is $\cos \theta$. Consequently, for a $\pm$ 20° deflection system the maximum correction factor is approximately 0.94, representing roughly a 6% error at full deflection. A reduction of this figure by an order of magnitude has been accomplished with indications that $\pm$ 0.1% error over the entire faceplate is possible. Using the first three terms of the expansion $[1 + (X^2 + Y^2)/L^2]^{-1/2}$ for the linearity correction, it is theoretically possible to correct to $\pm$ 0.065% for a maximum deflection of about $\pm$ 20 degrees. At this level of accuracy, practical considerations such as stability and accuracy of electronic components, mechanical stability of the CRT/yoke combination, and extraneous deflecting fields play an important role.

Focus

Once the beam strikes the faceplate with great positional accuracy as a result of the linearity corrections described above, the spot on the face of the CRT must be made as small as possible to achieve the best resolution. For best focus, the magnitude of the longitudinal focusing **B** field must be altered as a function of deflection. This is true when the radius of curvature of the CRT faceplate is not equal to the distance from the faceplate to the center of deflection. Usually the radius of curvature is the greater distance, and for flat-face CRT's it is of course, infinite. In this case, therefore, the electron travels a greater distance as the deflection increases, and consequently, optimum focus occurs with less focus current than for the undeflected condition. Fig. 10, the system block diagram, shows the location of the focus coil, and also its input signal requirements. The focus function is broken into two parts: static focus and dynamic

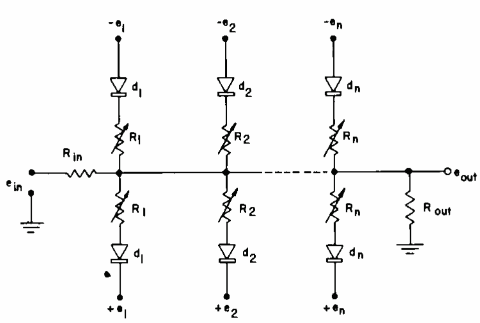


Fig. 9—Pincushion-correction circuit.

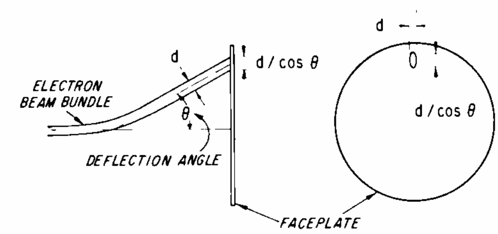


Fig. 11—Side and front views of CRT illustrating a source of spot astigmatism.

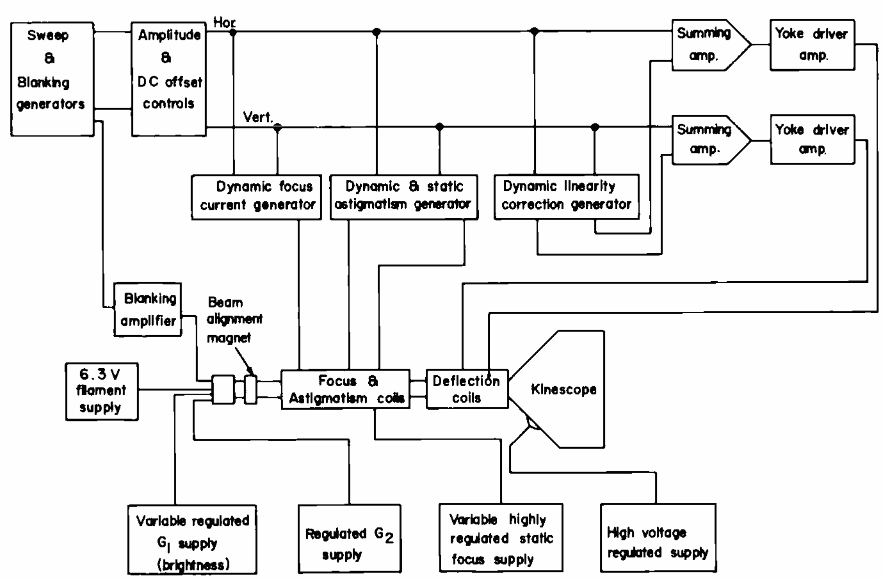


Fig. 10—Typical kinescope test setup, block diagram.

focus. For modest deflection angles, the required change in focus current will be under 10%. Quite frequently a separate coil of low inductance is used for introducing the dynamic focusing signal. This is done primarily to allow high-speed correction currents to be applied through the low coil impedance when rapid changes in deflection occur. The dynamic coil is generally an integral part of the much larger static focus-coil assembly. A well-regulated and variable-current source is the requirement for the static coil. The variable feature is a convenience that allows readjustment for different CRT's and/or operating potential. The proper waveform for dynamic focus correction is approximately $i_c = -ad^2$, where d is the radial deflection, and therefore $d^2 = X^2 + Y^2$. This equation leads directly to the manner in which the correction waveform is generated. The X and the Y deflection waveforms are squared, summed, and fed through a level-control potentiometer to the dynamic focus-coil driver transistor. At this point all the required corrections are accomplished, except for a spot distortion called "astigmatism."

Astigmatism

The lack of roundness of a deflected spot causes a loss of resolution along the major axis of the elliptical spot. Consequently, astigmatism as a function of deflection must be prevented. Plus the pure geometrical cause of astigmatism (shown in Fig. 11), any stray deflection fields reacting with the focus field can also cause spot-shape distortion. To compensate for the distortion a correction axial **B** field is added to the focus field. This field is not uniform. It is used to shape the total axial focusing field to compensate for geometric and deflection-derived distortion. Therefore, as the deflection increases, so does the degree of correction.

The correction is introduced as a current into sets of astigmatism coils mounted adjacent to the focus coils. One set of coils distorts the axial field along the X and Y axes. The other set operates on a set of axes rotated by 45° from the original X and Y. The required current waveform is approximately $i_1 = K_1\ (Y^2 - X^2)$ for the first set of coils, and $i_2 = K_2\ (XY)$ for the second set. These two functions can be generated using squares and adders operating on the X and Y deflecting waveforms. The circuit details will be omitted, but the general location within the system can be seen in the block diagram of Fig. 10.

It is evident at this point that a fair amount of circuitry is required to correct for deficiencies caused by deflection. Now that all these corrections have been described (linearity, focus, and astigmatism) there remain certain other considerations associated with the generation of accurate deflection.

Other Considerations

Hum is a problem, and the usual precautions of ground-loop removal and magnetic shielding around the kinescope should be taken. A more detailed analysis of the hum problem that gives limits of acceptability for various modes of operation is given in another article.[1]

Another distortion that is fairly common in certain deflection amplifiers is axis-crossing distortion. This occurs in zero-bias class-B transistor amplifiers and results in deflection errors in the vicinity of the X and Y axes. These amplifiers should be operated more toward Class A, and thereby trade efficiency for linearity.

The primary deflection signals for typographic material are generally step scans or short linear strokes. If the spot is moved from one location to another by a step function, unblanking should not occur until the spot has settled to within a specified percent of the correct position. Because of finite bandwidths of deflection amplifier and yokes, the settling time is not zero. Some typical values for a yoke of low remanance are 1.5 μs to settle to 1%, and about 10 μs to reach 0.1% of the correct location.

The stability of the various correction circuits described above should be commensurate with the accuracy requirements of these circuits. That is, if .1% deflection accuracy is needed then the stability of the deflection system should be at least that good. Also, the high-voltage power supply regulation in percent, should be approximately twice that of the desired deflection accuracy or better. Fractional percent accuracies in focus are also desirable for maintenance of the high-resolution capabilities of the system, but astigmatism correction is less critical.

CONTINUOUS VERSUS STEP SCAN

Two general modes of scanning are possible on a kinescope. One is the continuous, or TV, type of scan in which the entire tube face is scanned by continuous strokes and the beam is turned *on* where desired. The other may be termed step scan in that the tube face is not scanned in its entirety, but the beam is moved directly to locations where it is to be *on*. The step scan appears to save time which is wasted scanning the blank spaces in the continuous scan method. The problem with the step-scan method is that the beam cannot be deflected instantaneously. A finite settling time, usually about 2 μs, is associated with each step. Thus, if each picture element is written in a step-settle-write sequence to produce a true dot picture, the cumulative settling time of the deflection process may be equal to or greater than the time spent scanning the blank areas by the continuous method. It has been found, however, that a combination of the two methods yields a considerable increase in writing speed. In this combination method, the beam is step scanned to the general vicinity of the character to be written. Then, the actual character is written using a small continuous scan limited to the area of the character. The true step scan has been found useful in the generation of certain types of halftone photographs.[1]

FULL-FACE VERSUS SINGLE-LINE

Several problems, such as obtaining adequate resolution, linearity, and brightness are encountered in kinescopes and considerably limit their use. For minimum film motion and fastest writing, the full face of the tube should be used as much as possible. The ultimate would be to write a full page without moving the film. Tests on various available kinescopes quickly show that one with completely adequate characteristics is not available. Available units either have barely adequate resolution, but grossly inadequate brightness; or adequate brightness with inadequate resolution. Additionally, the pincushion-distortion problem is severe when covering the full face of the tube.

Printing a full page with about a 4/3 height/width ratio "wastes" about 40% of the potential resolution across a diameter of the tube. This suggests sweeping the writing beam along one line horizontally and move the film vertically in order to obtain maximum resolution. This imposes severe film-motion restrictions and necessitates generation of a TV-type of scan by the electronic system. The TV scan, although possible, is much more costly than scanning one character at a time as it is read from memory. A TV-style scan would necessitate storing all the stroke information for all the characters in a given line, and then synthesizing full-line sweeps from this information.

The compromise which has been adopted for text writing, considering the various limitations, is that of a writing "window" which is the height of the largest character to be written. Therefore, it can be nearly the full-tube diameter in width. This arrangement nearly overcomes the problems of wasting resolution and generating TV-style scans, and also greatly reduces pin-cushion distortion problems.

KINESCOPE CHARACTERISTICS

Graphic Systems Division has a continuing study program of the characteristics of various commercial kinescopes. In addition to reviewing literature as it becomes available, formal tests of promising units are conducted.

After a recent series of tests, a 7-inch diameter tube with very high surface brightness and about a 1.1-mil spot was selected for use in a forthcoming series of Graphic 70 photocomposers. After appropriate optical magnification with a lens having an F/11 effective aperture, the tube is capable of writing a 1.7-mil spot at a velocity of 5000 in/s on the film. The tube is a compromise between high surface brightness, generally attainable along with adequate resolution in only the larger tubes, and small size which is desirable for reducing machine size.

A typical test setup is shown in Fig. 10. Space does not permit a detailed explanation of the various functions, but generally deflection amplifiers require errors less than 0.01% to 1% and power supplies should be regulated to about 0.1%. The accuracy required of the correction generators is less stringent because the corrections are small; 2% error is generally tolerable.

When testing kinescopes one quickly discovers that the "ideal" kinescope does not exist, and the problem (as usual) becomes one of selecting the best set of compromises. The "ideal" tube for GSD requirements would be about 5-inches in diameter, have a spot size of about 0.3 mils, and a peak instantaneous surface brightness in the millions of foot-lamberts. In addition, the phosphor should be uniform, so that objectionable phosphor grain or "blotchiness" is not present, and the maximum total deflection angle should be ±20 degrees or less to minimize linearity, astigmatism, and defocussing problems.

Any one of the preceding ideals is attainable, but at the expense of the others. The various characteristics are interrelated as follows:

1) *Brightness and spot size:* The maximum surface brightness increases with phosphor thickness. Because the light diffuses in all directions through the phosphor, the effective spot diameter also increases with thickness. Therefore, high brightness and small spot size tend to be opposing requirements.

2) *Spot size and deflection angles:* As the focus coil is moved closer to the face of the tube, the diameter of the "electron spot" striking the face of the tube decreases. This is analogous to the case of optical lenses where the shorter focal-length lens always produces the smaller image for a given object size and distance. Moving the focus coil close to the face of the tube aids in achieving a small spot. Unfortunately, because the deflection coil must be between the focus coil and the face of the tube, a short focus distance necessitates a large deflection angle for a given scan size which severely increases linearity, astigmatism, and defocussing problems. As a result, small spot size and low deflection angles tend to be opposing requirements.

3) *Brightness and particle size:* In addition to increasing the thickness of the phosphor coating, brightness may be increased by the use of large phosphor particles but this is in opposition to requirements for minimum granularity (dark lines appear at the boundaries between adjacent particles).

MEASUREMENT METHODS

Several methods and devices are used for measuring the performance of kinescopes. Direct observation of the "dot" or raster with a calibrated microscope is the most flexible and most frequently used method at GSD. Analysis (density and line width) of photographic film exposed by the kinescope through an appropriate lens is used in GSD as the final test, since film is the required end product. Another method is the use of slit analyzers to measure spot width and accurate intensity distribution. Finally, light output intensity is measured using light meters.

MECHANICAL CONSIDERATIONS

The mechanical requirements placed on the kinescope-optical systems are stringent. Positioning of critical components such as the focus yoke, kinescope, lens, and film plane must be held to typical tolerances of ±0.001 inches or closer over distances of 2 or 3 feet. Transverse vibration must be held to less than 0.0005 inch on these components. These tolerances must be held over temperature variations of perhaps 30°C. and under conditions of vibration such as are imposed by film handling mechanisms, changing of film cassettes, and vibration of vacuum pumps and blower motors. The system must be mechanically rigid enough to withstand shipment and installation processes without realignment of the kinescope—optical system.

Achieving the necessary mechanical stability is made more difficult by the fragile nature of the kinescope. Additionally, the face of the kinescope and the film plane must be accessible to test and maintenance processes and equipment.

SUMMARY

The high precision kinescope is an excellent device for generating graphics material and is currently in widespread use. This article has presented in summary form the major criteria used in selecting a kinescope and in making it perform properly.

Even though existing kinescopes are very useful, they still need much improvement—particularly in resolution. A resolution improvement of 4/1 would be desirable for graphic purposes. Continuing research at RCA and other companies is expected to improve resolution considerably, but the work is difficult and therefore slow.

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RICHARD J. KLENSCH received the BSEE degree from the University of Illinois in 1951. He did graduate work as an incidental student in the Electrical Engineering Department of Princeton from 1952 to 1958. Mr. Klensch joined RCA Laboratories as a research engineer in 1952, associated with high resolution radar and infrared detection devices. From 1954 to 1956 he served in the army as a radar instructor; returning to the RCA Laboratories in 1956. Subsequently, he did research in the areas of microwave scanning antennas, time division multiplex systems, digital and analog communications, and color television. In 1961, he participated in research leading to an advanced Naval Communications System, continuing this effort until joining Graphic Systems Division in 1966. As part of the Advanced Development Group, at GSD, Mr. Klensch has been investigating new electronic halftone generation techniques and CRT display Systems.

ELVIN D. SIMHAUSER graduated from Kent State University with the BS in Physics in 1951 and joined RCA at that time. After completing the engineering training program, he was assigned to the Special Devices Section where he did development work on sound powered telephones, aircraft and submarine intercom systems, and miscellaneous transducers. After two years in the Army as a computer technician, he returned to RCA (Surface Communications Division) in 1956, working on headset and microphone development for the Air Force. From 1958 to 1963 he worked on several classified communications programs. In 1963 he transferred to the RCA Tucson plant and worked on a variety of small communications devices, including a low power signalling device the JMED, a low power, long distance radio, and a bundle-drop marker radio. In 1966 he transferred to the Graphic Systems Division of RCA and since that time has worked in the Advanced Development Group on kinescope photocomposing systems.

Lasers and Printing Plates

This paper describes some of the current research being conducted by the Graphics Systems Applied Research Laboratory on direct laser preparation of printing plates.

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PRESENT AUTOMATED COMPOSITION of graphic material requires one or more photographic processes between composition and final printing. These photographic processes are costly as well as time consuming. Thus, a direct means for the preparation of printing plates becomes a desirable adjunct of automated graphic composition.

Two possible methods for the direct preparation of printing plates are being investigated: 1) plate preparation by the means of laser exposure of photosensitive materials, and 2) direct laser engraving of printing plates.

TYPES OF PRINTING PLATES

Before considering the possibilities of laser preparation of printing plates, it is of interest to discuss the three most common methods of printing and the characteristics of the plates used in these methods.

Letterpress

Letterpress is the oldest of one of the most commonly used printing methods. The image surface is in relief above the non-image surface. Ink is applied directly to the raised surface and transferred to the paper by pressure.

The depth of the relief depends on the inter-image distance. In pictorial areas (halftones), where the dots are spaced from 5 to 10 mils apart, the relief depth will be only a few mils. In other areas, however, the relief depth may be 30 or 40 mils.

The amount of material removed from the non-image area of an average 18x20-inch newspaper plate is about 35 cm^3. The large amount of material that must be removed severely limits the feasibility of producing letterpress plates by direct laser engraving.

The prime advantage of letterpress is its flexibility. The ease with which plates can be changed on the press has entrenched letterpress as the dominant process in daily newspaper publishing. However, letterpress has the shortest tonal range of the three popular printing methods because the small dots required for the highlight areas of a halftone are mechanically weak and must be omitted.

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Lithography

Lithography is the newest as well as the fastest growing of the three major printing processes. Lithography is based on a physio-chemical phenomenon rather than a mechanical ink transferral process. In lithography, the images are made oil receptive while the non-image area is made water receptive. Oil base ink and water are applied to the printing plate by means of rollers. The ink adheres to the image area and is repulsed from the water coated non-image areas.

The surface of the lithographic printing plate is essentially planographic. Any surface modification is at the most only a few microns in depth. Since the image is essentially a surface effect, it is easily destroyed by abrasion. As a result, lithographic printing is usually accomplished by means of offsetting. A semi-hard rubber roll is brought into direct contact with the lithographic plate. The image area (ink) is then transferred from the printing plate to the paper by means of this offset cylinder.

Offset lithography is ideally suited to high-quality reproduction of medium volume publication runs. It suffers however, from lack of flexibility since, unlike letterpress, the changing of a page on a cylinder requires that the entire plate be changed. Offset lithography cannot reproduce the dark end of the tone scale as faithfully as gravure but is superior to letterpress in the highlight regions. Offset lithography employs photographic composition and plate preparation thus substantially reducing the amount of time required to prepare material for press.

Dry offset is a combination of letterpress and offset lithography. The process uses an offset cylinder for the transferral of the image to the paper. However, unlike offset lithography, dry offset uses a relief plate which is inked directly without the use of water.

Offset plates, both conventional and dry, lend themselves to laser exposure since plate preparation consists of exposure and subsequent development of photosensitive materials. There are also several long-run bimetallic offset plates which are chemically etched by photoresist techniques. The etch depth of these plates is at most only a few microns. Such plates could be prepared by either laser exposure of the photoresists or by direct laser machining.

Gravure

Whereas letterpress prints from a raised surface and offset lithography from a flat surface, gravure printing uses a depressed surface or cavity for image transferral. The image area in gravure is composed of numerous small cavities ranging from 7 to 40 microns in depth and 10 to 140 microns in diameter. These cells or cavities are arranged on the printing cylinder in a grid pattern with a center spacing of approximately 150 microns. A photograph of conventionally etched gravure cavities is shown in Fig. 1.

A. WILLIAM STEPHENS received the BS in Metallurgical Engineering from the University of Arizona in 1962. Following graduation, he entered a half-time Doctoral Study Program while being employed as a Graduate Research Assistant at the University of Arizona. His graduate research was concerned with crystallographic texture and mechanical anisotrophy in metals. Mr. Stephens received the MS in Metallurgical Engineering from the University of Arizona in 1965 and has since completed the requirements for a Doctoral degree from the same institution. In October 1966, Mr. Stephens joined the Technical Staff at RCA Laboratories in the Graphic Systems Applied Research Laboratory. Since joining RCA he has been engaged in applications of laser machining.

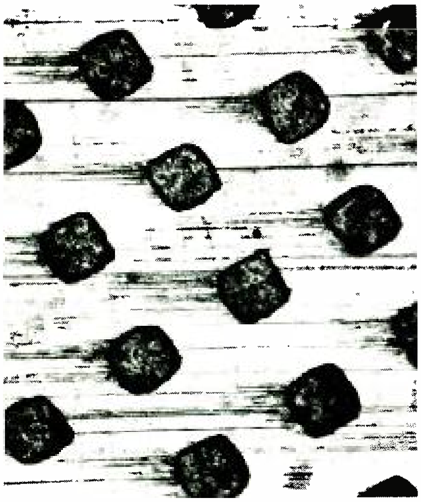

Fig. 1—Photomicrograph of chemically etched gravure cavities. The cavities shown here are 80μ wide by 10μ deep (shown at 100X magnification).

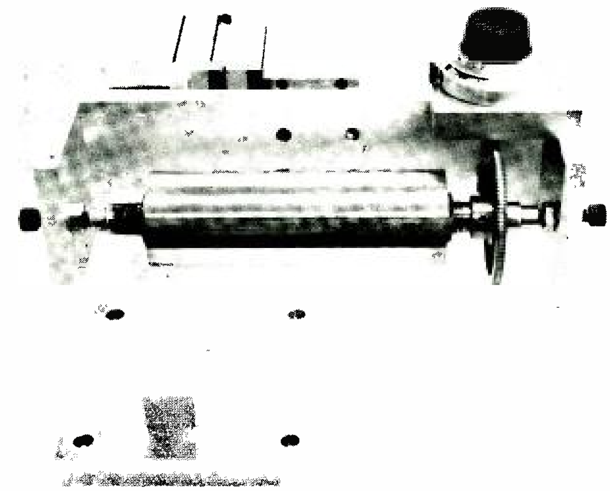

Fig. 2—Copper gravure cylinder and mount.

Rotogravure printing is accomplished by rotating the surface of the cylinder through a bath of ink thus filling all the cavities. The excess ink is then wiped from the surface of the cylinder by a steel blade called a doctor blade. Ink remaining in the numerous recessed cells is then transferred to the paper by a blotting action.

Gravure has the greatest tonal range of the printing processes, but suffers greatly from lack of flexibility. A typical gravure cylinder may be approximately 8-ft long, 14-inches in diameter and will weigh some 2000 pounds. These cylinders must be electroplated, polished, photoengraved, plated with chromium, and mounted on the press. If some change in the composition is required, the entire process must be repeated.

Gravure printing appears to hold promise for direct laser engraving. Since gravure printing is from small cavities, the total volume of material that must be removed is small. The volume of material removed for an average 18x20-inch newspaper page is about one cubic centimeter contrasted to 35 cm^3 for the same size letterpress plate.

CURRENT RESEARCH ON PHOTOSENSITIVE MATERIALS

Dry Offset Plates

There are at present two widely used types of dry offset plates. These are the Dycril (DuPont) and the Kodak Relief Plate. The Dycril plate is a photopolymer which hardens on exposure to ultraviolet light. The Kodak Relief Plate is a multi-layer plate consisting of an acetate layer coated with a silver halide emulsion. The Kodak plate is also sensitized in the ultra-violet.

Experimental work to date shows that the Kodak Relief Plate can be successfully exposed by an ionized neon laser (3320Å line) at an energy density of 0.015 joules/cm^2. The Dycril plate has not as yet been evaluated for sensitivity to the ultra-violet laser lines. However, both the Dycril plate and Kodak Relief Plate have been found insensitive to argon laser lines in the visible region of the spectrum.

Offset Lithography Plates

A survey has been made of twenty-four plates obtained from different manufacturers. Of these plates only four showed any sensitivity to the available gas laser lines. Three paper-type short-run plates were successfully exposed by the 4580Å argon laser line at an energy density of 2 joules/cm^2. One long-run aluminum lithographic plate was found to be successfully exposed by the 4580Å argon laser line at the same energy density of 2 joules/cm^2. None of the other plates showed any sensitivity to the available argon or neon laser lines.

Most of the plate manufacturers seem to feel that their plates could be sensitized to some of the presently available gas laser lines. Several plate manufacturers are currently planning to supply plates spectrally tailored to available gas laser lines.

Gravure

The feasibility of laser exposure of photoresist for gravure engraving is also being studied. This research effort is based on the utilization of the excellent speed and sensitivity of Kodak Ortho Resist (KOR). A small copper gravure cylinder was coated with KOR and contacted with a screened halftone negative. The cylinder was then exposed, in a facsimile manner, with the argon laser (4880Å line) using an energy density of 0.090 joules/cm^2. The cylinder was then developed leaving hardened KOR in the image areas. A thin layer of chromium was then electroplated on the non-image areas and the hardened KOR removed leaving the copper exposed in the image area. The cylinder was then etched in a ferric chloride bath, the chromium acting as a resist to the etch.

Cavities produced in this manner are similar to conventional gravure cavities. Cylinders prepared by the above method have been evaluated on a laboratory proof press and show promise for this technique.

DIRECT LASER ENGRAVING

At present, direct laser engraving is being directed toward gravure printing. The gravure printing process is accomplished by ink transferral from ink wells or cells, thus, this type of printing process is ideally suited to direct laser engraving. It has been known for some time that high energy Q-switched lasers are capable of material removal from metallic surfaces.[1,2,3,4,5] It is generally accepted that the main effect of the laser pulse is due to generation of a heat pulse.[1,2] J. F. Ready has calculated that a 30-nsec giant pulse of 10^9 watt/cm^2 will bring the surface of a metal to the boiling point in less than 1 nsec[2]. The plume of vaporized material, however, develops at a much lower rate—120 nsec for carbon in air.[1] While the mechanisms giving rise

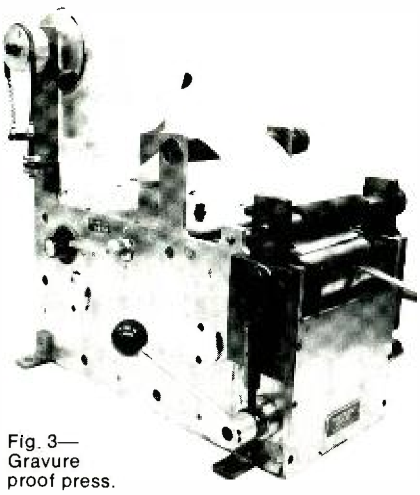

Fig. 3—Gravure proof press.

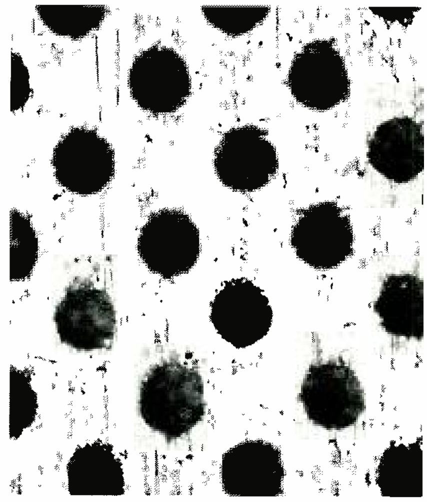

Fig. 5—Photomicrograph of laser engraved cavities at 100X magnification (compare with Fig. 1).

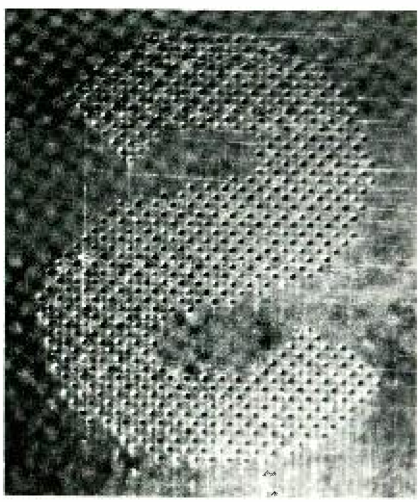

Fig. 4—Photomicrograph of laser engraved gravure cavities. The cavities have average dimensions of 80μ diameter by 50μ depth (12X magnification).

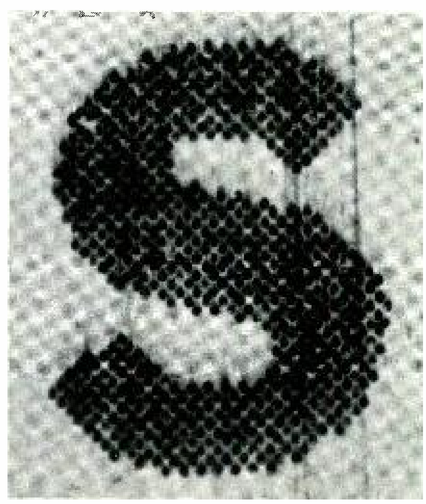

Fig. 6—Photomicrograph of printed results produced from laser engraved gravure cavities (12X magnification).

to this delay are not understood in detail. Ready has proposed the following mechanism. The high energy input of the laser beam causes the atoms to leave the surface with high velocities creating very high reactive back pressures. This high pressure keeps the atoms beneath the surface in a superheated state. Eventually the temperature of the superheated liquid becomes high enough that the heat of vaporization becomes zero and the condensed state transforms into the gaseous state.

Experimental Techniques

The experiments were performed using a Q-switched ruby laser as a radiation source. A ruby rod, ¼-in. diameter by 3-in. long, was Q-switched by a rotating prism. The number of transverse modes was limited by placing a mode selector in the laser cavity. This mode selector consisted of two confocal lenses with a small aperture at the common focal point. The laser beam was focused on the target through a 10X microscope objective. Pulse shape and energy were monitored by means of an RCA-7102 photomultiplier which had been calibrated against a Westinghouse RN-1 "rat's nest" bolometer. The target material was a copper cylinder which fits a laboratory gravure press (see Figs. 2 and 3). The cylinder was mounted on micropositioners so that it could be accurately translated in front of the laser beam. A letter *S* was machined in the gravure cylinder by indexing the cylinder for each laser pulse. The ruby laser was operated at a repetition rate of 1 pulse/min.

Results

The laser engraved cavities are shown in Figs. 4 and 5 at two different magnifications. The cavities produced have average dimensions of 80 microns diameter by 50 microns in depth and were produced by a 0.050-joule laser pulse. These figures give a value of 2 x 10^5 joules/cm^3 as the energy required for the direct laser machining of copper gravure cylinders.

The laser engraved gravure cylinder was subsequently mounted in the gravure proof press and the printability of the gravure cells evaluated. A magnified view of the printed results is shown in Fig. 6. While the laser machined gravure cells do not produce high quality print, the results of these preliminary experiments are most encouraging.

SUMMARY

While the actual direct preparation of printing plates by computer-controlled laser radiation is still some time in the future, the results obtained to date indicate that it is, nevertheless, still a distinct possibility.

The use of photosensitive materials seems more certain of success since the powers required are nominal when compared with those required for direct laser engraving.

Present plans are for the utilization of a facsimile scan with hope for a future method of random-access X-Y positioning of laser beams at high speed.

It should be pointed out that the experiments to date, on direct laser engraving, are only for preliminary evaluation of its feasibility. The repetition rates available with optically-pumped solid-state lasers are much too low to be practical for the commercial preparation of printing plates. It is hoped that a high-power Q-switched CO_2 laser system will soon be available for use in direct laser engraving at high repetition rates.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the work of J. J. Walsh, GSD, on the laser exposure of commercial printing plates, and the work of Dr. D. L. Ross and C. F. Ruopp, RCA Laboratories, on the preparation of gravure cylinders by laser exposure of photoresist.

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Laser Recording Systems

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The laser has been widely accepted as an energy source, with an energy density and wideband modulation capability much greater than other sources. Although recording was not one of the first applications of lasers, it became apparent to RCA in 1963 that a modulated laser beam used to expose high-resolution photographic film could increase recording bandwidth and information density over that available with other techniques. The potential of laser recording for increasing resolution and writing speed was also evident. Since that time RCA has developed two recorders which capitalize on the potentials of lasers.

In laser recording, input signals intensity modulate a laser beam, which is then scanned in a two-dimensional pattern on silver-halide film, resulting in a permanent record after photographic developing. The major difference between the two types of laser recording described in this article is the use of the recordings after developing. The "signal recorder" records signals on film for playback, whereas the "image recorder" records on film for separate visual use without playback.

During playback in the signal recorder, the film is scanned in the same pattern used during recording: the signal recovered from the film is converted into a time-varying voltage duplicating the form of the original input to the recorder. In an image recorder, the film is examined visually and optically processed; the film may also be rescanned in a format different from the original recording. In a signal recorder, the adjacent scan lines are definitely separated but in an image recorder the scan lines merge.

HIGH-RESOLUTION IMAGE RECORDING

Recent developments advancing the state of the art in image sensor technology have resulted in the achievement of image resolutions exceeding the capabilities of conventional image recorders. Image sensors having a total resolving power of 5000 elements per picture width are now in use and additional growth is expected. An image recorder capable of reproducing images from such a sensor at high information rates and with minimal degradation can be implemented using laser recording techniques.

IMAGE RECORDER REQUIREMENTS

To detail the general requirements for an image recorder, it is first necessary to evaluate the present capabilities and near-term growth potential for the sensors which will provide the signals to be recorded. Fig. 1 shows a system which would make use of a high-resolution image sensor and a laser image recorder.

Typical image sensors might include high-resolution TV camera tubes, infrared and other scanned detectors, side-looking radars, and laser ground scanners. All of these sensors have been developed to the point where they can achieve resolutions of 5000 elements per scan or more. Bandwidths of some of these sensors are as high as 100 MHz.

One of the most common methods of recording images using the signals from image sensors has been to image a cathode-ray tube display of the signals onto film with a high-resolution optical system. This recording has been done both with raster scan of the cathode ray tube and with line scan of the cathode ray tube. In the latter case, motion of the recording film provides the other direction of scan. Cathode ray tube image recorders have been employed in systems which, however, exhibit lower resolution than that being discussed here. Due to the state of the art of cathode-ray tube development and the need for an imaging optical system of exceptionally high resolution over the entire field, this type of system is limited in its resolution capabilities. Specifically, the achievement of sufficient response at 5000 elements per picture width is not deemed feasible with this type of system. The use of a matrix of such tubes and optical systems may satisfy the total resolution requirement. However, there are associated problems in registration and matching which will cause undesirable segmentation of the image. Therefore, the cathode-ray tube matrix approach has not been seriously considered for this application.

The bandwidth or writing rate capability of a cathode ray tube system depends somewhat upon the resolution desired. Bandwidths exceeding 5 MHz, while maintaining resolution on the order of 2500 to 3000 elements per scan, represent the presently achievable limits.

Three other approaches can provide higher resolution than the cathode ray tube system: electron-beam recording, drum facsimile scanner recording, and laser-beam recording. The feature common to these three techniques which enables the achievement of high resolution is that none of them requires imaging optics with extended field coverage.

Electron-beam recording is limited due to electron optics field coverage requirements; however, with proper design, the 5000-element resolution can be achieved. For general use, the vacuum requirements have been considered to be an operational inconvenience. Additionally, the achievement of the desired scanning linearity and stability is considered marginal, as is the growth potential.

Drum facsimile image recorders have demonstrated impressive resolution capabilities in terms of the number of picture elements per picture width. In these systems the optics must provide a single recording spot of the desired dimensions and profile, and construction of the image raster is accomplished through film motion. The film drum configuration, however, is not compatible with high writing rates. Also, the modulation capability of present recorders is not consistent with multi-megahertz bandwidth requirements.

The laser-beam image recorder has the total picture resolution capability of the drum facsimile system and additionally can be configured to satisfy all of the other listed requirements. One direction of scan is accomplished by film motion; however, the other dimension of scanning which must be performed more rapidly, is accomplished by swinging the cone of light which forms the recording spot. Through the use of laser techniques, high-rate recording and wide-bandwidth modulation can be accomplished.

A laser image recorder uses coherent optical techniques to produce a modulated, rapidly scanning, recording spot of light. The recording spot produces a permanent record of processed input signals on silver-halide film. The major functions which must be implemented are:

1) Establishment of a basic recording energy source;
2) Modulation of this energy source by the signals to be recorded;
3) Focusing of the modulated energy source into a high energy density recording spot; and

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4) Scanning of a recording medium by this recording spot.

The signal flow relationship between these functions and the implementation of these functions by using wideband laser-beam recording techniques are shown in Figs. 2 and 3.

The laser is used as an energy source because it is extremely bright and is compatible with wideband intensity modulation requirements. Its energy is amenable to being collected and formed into a recording spot with diffraction-limited performance at high efficiency. This energy source is intensity modulated by electro-optic techniques. Wideband modulation techniques using electro-optic crystals intensity modulate the external laser source by application of a signal voltage.

The recording spot is formed with conventional refractive components. In the general case, the intensity-modulated laser beam is enlarged to fill the aperture of an imaging lens. The laser beam must be enlarged because the desired aperture of the imaging lens is generally much larger than the diameter of the laser beam. The beam is enlarged by optical components capable of diffraction-limited performance.

The recording film is scanned both by moving the recording spot across the film and by transporting the film past the scanning station. In a wideband laser-beam recorder, a rotating mirror assembly scans the recording medium.

RCA LASER-BEAM IMAGE RECORDER

The RCA Laser-Beam Image Recorder was developed to provide hard copy images from an RCA-developed TV camera tube which has extremely high resolution. This TV sensor has demonstrated the performance shown in Table I and has near-term potential for an increase in resolution of 50% or greater. Since the sensor is read out with a 6000-line raster and the electrical bandwidth of the system is 5 MHz, approximately 5 seconds are required to transmit the information contained in a single image. To preserve the impressive performance of the image sensor for the entire system, only minimal degradation due to image recording is tolerable.

TABLE I—High-Resolution Sensor Performance

Resolving power: 5000 elements/picture width

Large area dynamic range: 300 to 1

Electrical bandwidth: 5 MHz

The image recorder requirements established to be consistent with total system

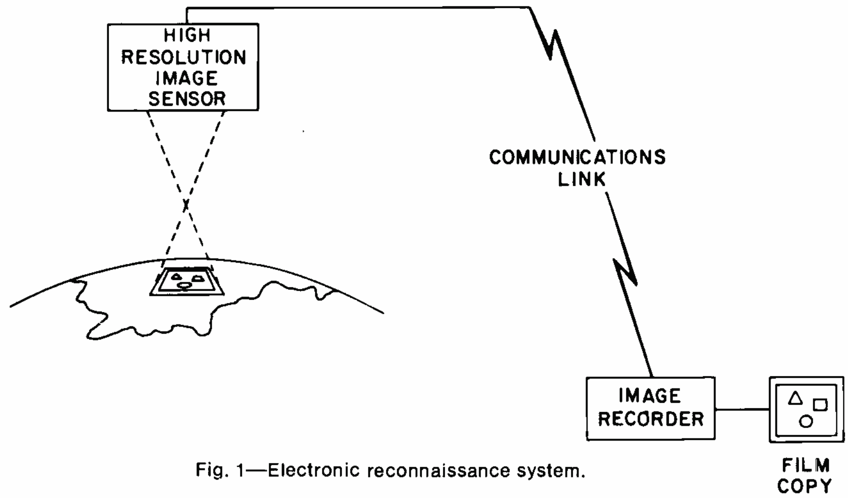

Fig. 1—Electronic reconnaissance system.

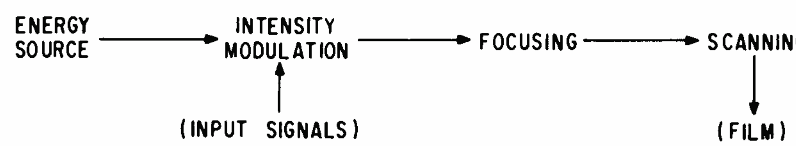

Fig. 2—Basic laser beam recording functions.

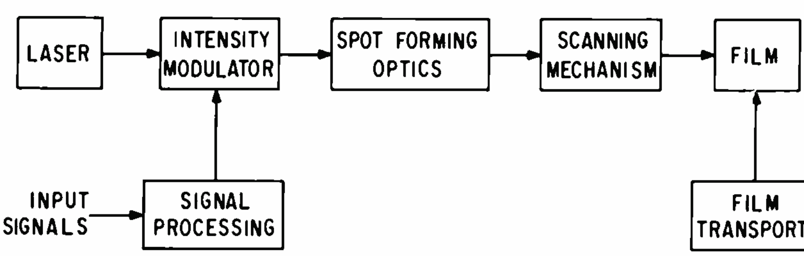

Fig. 3—Basic components of laser beam recorder.

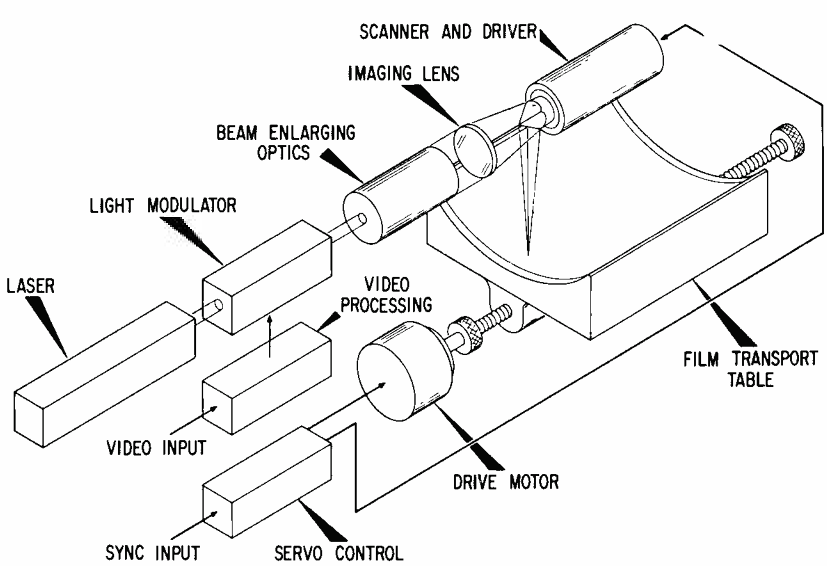

Fig. 4—Laser beam image recorder.

performance are given in Table II. An image recorder system meeting these requirements should also provide for the growth potential available in present image sensors.

TABLE II—Image Recording Requirements

Scan lines: 6000
Scan rate: 1200 lines/second
Video bandwidth: DC to 5 MHz ± 0.5 dB
Image format: Square
Resolution: 75% square-wave response at 6000 TV lines per picture width
Gray Scale: 13—$\sqrt{2}$ steps
Linearity: Less than 0.1% deviation

In addition, an image recorder should provide gamma correction, intensity control, and the other operational features conventionally used. These are the specifications used in the design of the RCA Laser-Beam Image Recorder.

Fig. 4 illustrates the relationships of the major components of the RCA Laser-Beam Image Recorder (LBIR). The continuous-wave He-Ne gas laser has nominal output power of 15 mW of 0.6328 μm wavelength radiation. The beam is approximately 1-mm in diameter to the $1/e^2$ intensity points and has a divergence of 1 milliradian.

The light modulator accepts the laser beam and modulates its intensity in response to the camera video signals. This modulator uses electro-optic crystals to rotate the polarization of the linearly polarized laser beam as a direct function of the applied signal voltage. Polarization modulation is converted into intensity modulation by a polarization analyzer attached to the modulator. The contrast ratio of the modulator exceeds 100 to 1 for a change in signal of 210 volts.

The beam-enlargement optics increase the diameter of the intensity-modulated laser beam until the beam fills the desired aperture of the imaging lens, which in this case is approximately a 50X enlargement. The imaging lens has a focal length of 200 mm, and the convergent cone of light leaving it is intercepted by a pyramidal scanning mirror. Scanning is accomplished by rotating a four-faced beryllium mirror at a speed of 300 r/sec in precision air bearings with a direct-drive servo motor. The converging cone of light repetitively swings through 90° of arc, and a 9-inch active scan is produced on the film, which is curved to conform to the focal path. The film is held to a curved film transport table, which is also supported by air bearings. The film table is coupled to a precision ball screw directly driven by a DC servo motor to provide for smooth and precise film transport.

Servo control systems synchronize scanning and film transport to image sensor signals. Video signal processing provides gamma correction and light modulator drive.

The laser-beam image recorder console as it was designed for laboratory use is shown in Fig. 5. The equipment is completely light-tight and is suitable for operation in a normally lighted laboratory environment.

High-resolution images which can be selected to be positive or negative are produced as transparencies on Double-X Aerographic film with normal processing. Alternatively, hard-copy positive images are produced on stabilization processed paper which can be viewed in 15 seconds.

This equipment has demonstrated the great potential of lasers for providing image recording resolution greater than that achievable with other sources.

LASER SIGNAL RECORDING

The signal recording application of lasers requires the implementation of the previously mentioned components and techniques and in addition requires additional optical components, electronics, and control systems to aid in the playback of signals.

For reproduction of laser recorded signals, the chemically processed film can be replaced in the equipment used for recording and again scanned with the laser beam. However, with the laser-beam intensity modulator deactivated, a constant-intensity beam is intensity modulated by the varying film density along a recording track on the film. The laser energy which is transmitted by the film is collected with an optical system which directs the energy to a photodetector. The photodetector converts the intensity modulation of the laser beam into an electrical signal, which is the desired laser reproducer output.

The relationship of the laser signal recorder components for recording and reproducing signals is shown in Fig. 6. This configuration results in the recorded film format represented in Fig. 7. This format is similar to the magnetic tape format which is characteristic of rotary-head transverse-scan magnetic-tape recorders. The significant differences between the typical magnetic tape and the laser recorded film are the dimensions of the recorded tracks and the writing rates used for recording. Recorded track widths in a commercial video tape recording system are typically on the order of 125 μm, while those used in laser wide-bandwidth signal recorders are usually less than 25 μm. The wavelengths of the recorded signals (the dimension corresponding to one cycle of the signal) are of similar dimensions in both magnetic and laser signal recorders.

The bandwidth capabilities of a signal recorder are thus strongly influenced by the relative scanning velocity which can be achieved. Scanning velocity relates the recorded signal wavelength to

DENNIS J. WOYWOOD graduated with honors from the Milwaukee School of Engineering in 1960 with the BS in electrical engineering. He received the alumni award for outstanding achievement. He received the MSE (EE) from the University of Pennsylvania in 1964. Since joining RCA in 1960, Mr. Woywood has worked with solid-state VHF power amplifiers, electronically variable delay lines for automatic time-correction systems, advanced recording systems and electro-optic systems. He was promoted to leader of the electro-optics group in 1963. Under his direction, additional models of RCA's ideographic composing machine were designed and constructed, and an automatic exposure control system for night cameras using image intensifier tubes was designed. He was responsible for company-funded programs to demonstrate 100-MHz continuous recording. These programs resulted in the development of a unique optical modulator having greater than 100-MHz capabilities. Component fabrication and their mechanical integration into a 100-MHz recorder system have been completed. He recently completed the design of RCA's Laser-Beam Image Recorder, and is continuing to work with laser signal and image recorders. Mr. Woywood is a member of the IEEE and an associate member of Sigma Xi.

Fig. 5—Laser beam image recorder, with protective covers.

the frequency of the signal being recorded. Thus the conversion factor from the time domain to the space domain is scanning velocity. A laser recorder can achieve a scanning velocity which is 10 times that achievable with magnetic recorders. This feature, in conjunction with the available energy to record at these higher rates and the capability for wide-bandwidth modulation of this energy, enables more than a 10 times increase in signal recording bandwidths over those available from the most advanced magnetic signal recorders.

The signal recorder, when considered in block diagram form, must perform the same functions as are performed in the laser image recorder. In image recorders, there is usually a lost time period associated with image sensor retrace in each scan period. The signal recorder is designed to eliminate dead time. This places additional restrictions on the scanner design of a laser signal recorder. A rotating polygon type of scanner (Fig. 6) provides higher scanning rates than an equivalent pyramidal mirror and also allows continuous signal coverage with no loss in recording time associated with the scanning operation.

The playback optical system collects the laser energy transmitted through the film and directs it to a photodetector. The use of a laser ensures that sufficient energy is available to provide detection with a high signal-to-noise ratio.

The signal-to-noise ratio of the recovered signals is significantly affected by film granularity. In general, the finest grained silver-halide films obtainable are used in laser recording systems to maximize the signal-to-noise ratio. Since the exposure sensitivity of films is inversely proportional to the film signal-to-noise ratio, the high power available from the laser source is used when recording at high rates.

The relationships of some of the laser signal recorder components and the system performance to be expected are best discussed in terms of a specific example, a 100-megahertz laser signal recorder breadboard built at RCA.

100-MHz LASER SIGNAL RECORDER

The RCA 100-MHz laser signal recorder is shown in Fig. 8. This system is capable of continuously recording 100-MHz signals for 10 minutes. The recorder consists of a 100-mW argon laser, an RCA-developed electro-optic modulator, optics, a rotating mirror scanner, and a precision film transport.

A nominal 10-μm recording spot is used. In the film format (Fig. 7) scan lines are 38 μm apart. A 50-mm scan line length on 70-mm wide film is used; thus 5000 resolution elements are contained in each scan line. A line scan rate of 40,000 scans/sec. is compatible with recording 100-MHz bandwidth information. The film is transported at 60 in./sec. past the scanning station.

An RCA model LD2100 argon laser is used as the basic energy source. An argon laser has important advantages due to its shorter wavelength (allows the formation of a smaller recording spot and a reduction in modulation power) in the source cavity length. The shorter cavity prevents interference of recorded signals with beats due to laser longitudinal mode spacing.

The output of the laser is intensity modulated by a specially developed electro-optic modulator which requires a drive signal of 50 volts peak to peak. The modulator is capable of operating over a 150-MHz bandwidth and includes solid-state driver amplifiers.

Off-the-shelf optical components were incorporated in the system. The imaging lens used to form the recording spot has a focal length of 125 millimeters, and an 18-faced beryllium polygon mirror is used for scanning. To achieve the desired scan rate of 40,000 lines/sec., the rotational speed is 133,000 r/min.

The recording medium used in the RCA 100-MHz signal recorder is silver-halide photographic film, Eastman Kodak type 3404, which gives a signal-to-noise ratio exceeding 30 dB. The silver-halide films are the only suitable media available for recording at 100-MHz rates. Other potential recording materials require excessive energy to record at these rates. Three thousand feet of film can be accommodated, providing ten minutes of continuous recording.

Playback optics are also off-the-shelf components, and an off-the-shelf photomultiplier, RCA type 7764, is used to convert the intensity modulation of the laser energy into the desired electrical signal. This phototube has been used with bandwidths as high as 600 MHz with success.

THE FUTURE OF LASER RECORDING

The equipments described in this article demonstrated the feasibility and usefulness of laser recording techniques. The high performance achieved verified the analytic design methods, and accurate, confident predictions can be made regarding future recorders.

Although only operation in conjunction with a real-time image sensor was discussed for the laser image recorder, other inputs can be considered. These images can either be the computer corrected and combined images from sensors or they can be artwork generated from programming instructions. This application is an attractive use for laser image recording techniques even in low bandwidth cases where the laser allows the use of other recording materials which show potential advantages for more rapid access and increased packing density at the expense of decreased sensitivity.

Laser signal recording techniques have the potential for increasing signal recording bandwidths even higher than the 100-MHz achievements of today. The increases in bandwidth of today's electronic signal processing systems have been occurring rapidly. Sophisticated instrumentation systems need signal recorders with bandwidths exceeding 100-MHz, which laser recording techniques can satisfy.

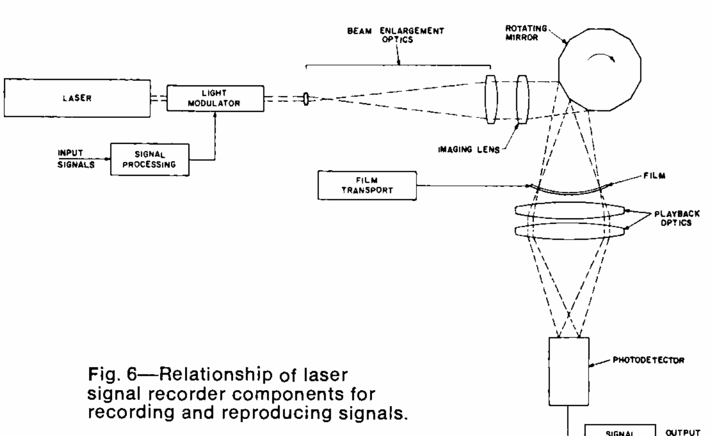

Fig. 6—Relationship of laser signal recorder components for recording and reproducing signals.

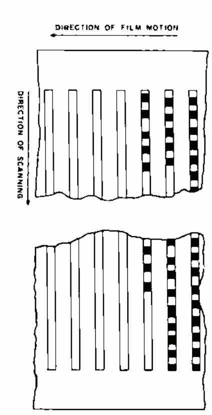

Fig. 7—Recording format.

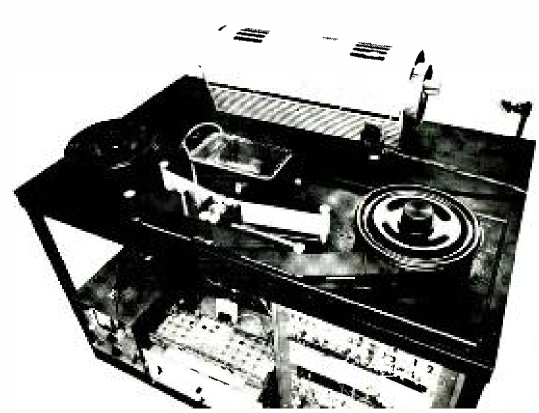
Fig. 8—100-MHz laser signal recorder.

Multicopy Printing from Electrofax Masters

H. C. GILLESPIE
Electronic Printing Group
RCA Laboratories, Princeton, N. J.

Until recently, printing on Electrofax paper has been restricted to producing a single copy on the Electrofax paper itself, except where Electrofax has been used on an offset master in a printing press. However, the toner image can now be transferred to plain paper without destroying the electrostatic image and a sufficient number of such transfers can be made to be of interest in the computer print-out and office duplicating fields. Reversal and direct positive images have been transferred to a variety of papers. The factors affecting the amount of toner transferred, and the life of the electrostatic image (which determines the number of copies that can be made) are discussed. Two examples are described: multiple copy computer print-out from a thin window or fiber optics CRT, and duplication of page size copy by optical means.

CONTACT EXPOSURE of Electrofax paper at the face plate of a thin-window cathode ray tube (TWCRT)[1] makes beam writing speeds over 100.000 in./sec. possible. This method of producing hard copy has much to commend it as a print-out means for computers. These writing speeds translate EDP-quality printed characters into 5000 160-column lines per minute. In addition, it is an inherently more reliable process since it uses no highly stressed mechanical parts as in impact printers. The inability to produce multiple copies has, however, prevented the adoption of the method for computer output printing, where up to six copies on a variety of papers may be required. This obstacle has recently been overcome by the development of means for transferring the image from an Electrofax surface to a wide range of papers.

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ELECTROFAX PRINTING

Before discussing the transfer process, it is necessary to describe the Electrofax method of printing, as it is executed in conjunction with TWCRT exposure. Office copiers of the electrostatic type have made us familiar with the Electrofax principle of operation, consisting of the attraction of pigmented particles to a charge pattern that has been produced by exposure of a charged photoconductive surface to an optical image of the material being copied. This is *direct positive imaging:* the particles are acted on by electric fields near the charged image areas and respond by moving toward those areas because they carry a charge of opposite sign.

In exposure from a TWCRT, it is not feasible to generate a charge pattern in which the charged areas correspond to the characters being printed. The characters are written by a spot moving in a scan pattern of some sort, and it is impractically difficult to control spot size and position so precisely that no underexposed areas are left between the scan lines. Therefore, the writing must be done with the characters displayed as a bright image on the TWCRT, resulting in a charge pattern on the Electrofax after exposure where the background carries the charge and the image area has none. Use of the same toning materials as are used in office copiers to develop this image would, of course, lead to a negatve image—white on a black background instead of the desired black on white. By using particles of the same sign as the charge on the paper, it is possible, however, to develop a positive image, consisting of black characters on a white background. In fact, the development of this so-called reversal image proves to be superior to the more conventional direct positive imaging as well as better suited to the transfer process we will describe.

REVERSAL IMAGE TRANSFER

To explain how a reversal image is produced, Fig. 1 has been drawn to picture the situation that exists when a dry powder developer is brought into contact with the charge pattern that constitutes the latent electrostatic image. The developer is formed into a "magnetic brush" by the alignment of the iron particles *C* in the field of a magnet *M*. These particles are called the carrier because of the adherence between them and the toner particles *T* permitting the toner particles to be carried to the surface to be developed by the iron particles. Surface conditions of the carrier and toner particles are such, in this reversal developer, that negative charges collect on the toner particles and positive on the carrier particles. The charges are equal, hence net charge is zero, but a positive charge can be measured on the carrier particles if they are separated, as with a blast of air.

To the right of the dashed line in the Figure, the surface retains its negative charge; on the left, the charge has been dissipated by light. Near the boundary, negative charge is either induced by or transferred from the charge on the layer, to the particles on the left of the boundary. This establishes a field between the carrier iron and the surface of the layer strong enough to deposit some of the particles in the discharged image area. This action develops adequate image density near the boundary only. A reinforcement, in the form of charge transferred from the magnet, which has been given a negative bias, extends the development to areas remote from the boundary.

For development to take place in this manner, a degree of conductivity must exist between the carrier iron particles. not only to transfer charge from the magnet, but to prevent the accumulation of positive charge resulting from the separation of toner particles from them and from an inductive effect accompanying the passage of the brush across the negatively charged background areas. Stainless steel, for example, is not suitable because the oxide film on the particles prevents particle-to-particle contact and control of the charge on the particles is lost.

The image so developed consists of two to five layers of toner particles in the image area. These can be transferred to a paper surface by the same action that takes place in the image development, except in reverse. This may be seen by reference to Fig. 2. A source of bias voltage applies a field across the developed Electrofax sheet, in contact with the paper *P* to which the toner *T* is to be transferred. The toner particles have retained their negative charges, so are held to the surface of the paper where a positive charge has collected. On separation of the paper from the Electrofax master, toner particles adhere to the paper and are carried off by it. They are then fixed to form a permanent positive image of the information written by the TWCRT.

MULTIPLE COPY PRINTING

The charge pattern is somewhat weakened by the development step, because of charge conducted by the carrier iron to ground through various leakage paths, and by the transfer step, where positive charge from the bias source neutralizes some of the negative charge on the Electrofax surface. However, enough remains (about 85%) for six cycles of development and transfer to be carried out to produce six copies on any sort of paper from onion skin to card stock.

IMPLEMENTATION

A machine, shown in Fig. 3, was built to test this method of multiple copy printing. Three stations only were provided; later tests on smaller equipment have established that more than three copies could be made.

Fig. 4 is a portion of a reproduction of copy produced on this machine. This is the third copy made from an Electrofax master that had been used ten times. Six-point type is clearly reproduced. It should be pointed out that this machine tested only the feasibility of repeated development and transfer. The exposure station is not a TWCRT. An exposure station using a TWCRT to print 8-inch wide copy is being built to confirm earlier results and to study the problems of digitally controlled printing.

The application most frequently considered for GSD is the printing of proof copy where three or four copies of editorial material are needed. With such a proof printer available, the main photocopy generator may be relieved of the subsidiary task of making proofs.

REFERENCE

[1] R. G. Olden, "High-Speed Printing on Electrofax," *RCA Review* Vol. XXII, No. 3 (Sept. 1961)

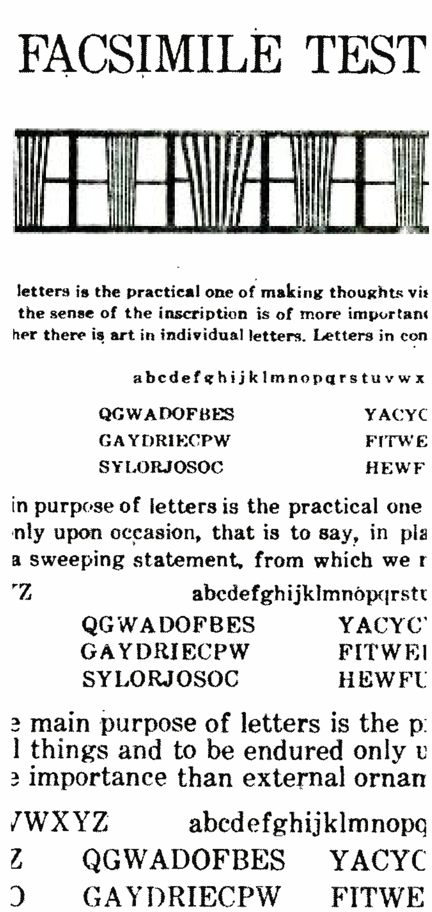
FACSIMILE TEST

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Fig. 4—Reproduction copy from the three-station printer.

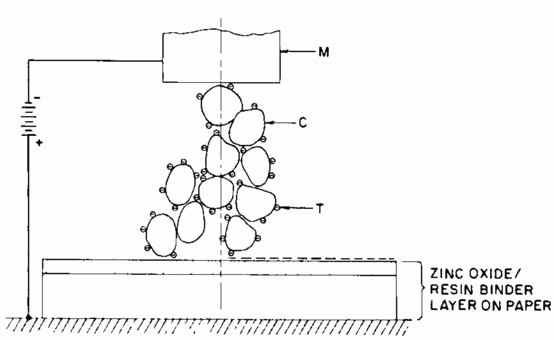

Fig. 1—Development mechanism-reversal electrofax toning.

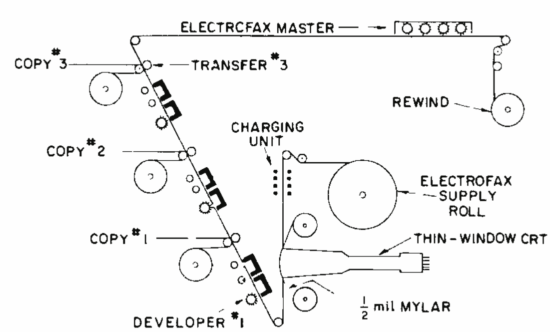

Fig. 3—Schematic of three-station printer.

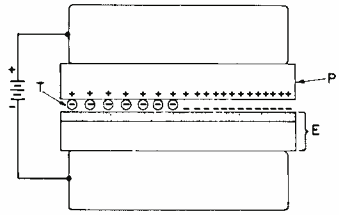

Fig. 2—Conditions for transfer of electrofax® powder image to output paper.

Facsimile in the Graphic Arts—a review

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Data Processing Applied Research Laboratory
Princeton, N. J.

The increasing need for speed in the transmission of graphics from the artist or photographer to the publisher's composing and editing room and to the printer has taxed existing communication systems to their limit. This is particularly true with the trend toward satellite printing plants. New and higher speed facsimile systems are needed. Systems now in use or proposed will produce transparencies or hard copy which can be used later to produce the printing master. Electrofax has the speed and the capability of combining these two functions and it is conceivable that the received copy may be used directly for printing. The pros and cons of Electrofax and other systems are discussed and the limits of each are pointed out.

COMPUTERS AND ELECTRONIC PHOTOCOMPOSING EQUIPMENT are revolutionizing present editorial and composition practices. Editorial information arrives at the composing room in manuscript form via messenger or the mails or electronically via telephone lines or radio. In the composing room, the information is entered into a computer where it is rearranged and proofed until satisfactory. The proof copy may be approved locally or sent to a customer for approval, via mail if there is enough time, or electronically if there are time deadlines.

After approvals, the computer will photocompose a master from which printing plates can be made. The film master may be hand carried or sent through the mails to the printing plant, or the proofed information may be sent electronically to the printing plant when the photocomposition of the master is carried out near the presses. Fig. 1 is a block diagram of the steps described above.

Since the composing room provides essential communication between the many parts of a printing operation, one of its most important functions is the electronic input and output of information. Any major efforts to automate the printing and publishing industry must include an efficient electronic communication system capable of handling high quality facsimile.

CURRENT PRACTICE

Text material which is typed remotely arrives in the composing room as a set of digital codes, each code representing a symbol. A teletype receiver will reproduce the copy, the font being determined by the keys being used. The receiver may also direct the bit stream to a computer where it may be entered immediately for processing or stored in a memory such as punched paper tape, magnetic tape, or punched cards. It will later be programmed by the computer to compose the material in the correct font, font size, column width, etc., and will be justified and hyphenated for final reproduction.

If graphic information is sent electronically by facsimile, it is received as continuous tone reflection or transparent copy. Photographic processing is then used to make a screened master transparency. Proofs are made from the transparency for editorial or customer approval after which the transparency is used to make the printing plate. The editorial or customer approval of the proof copy is generally by visual inspection of the proof sent through the mails or delivered by messenger. There are cases where electronic transmission of the proofs is desirable but, today, facilities are not always available with resolution adequate for good reproduction of a screened image.

When the text material has been composed by the computer and the screened graphics stripped in, the master transparency is ready to send to the printer who will make a printing plate from it. If the printing plant is distant from the composing room, the master must be physically carried to the printing plant or sent electronically.

There has been an increasing trend to satellite or remote printing plants during the last decade. The editorial function is normally located in a metropolitan area which has become too expensive for the printing facility. Many newspapers have adopted these satellite plants and more will do so. Communication between the composing and editorial room and

DR. D. A. ROSS received the B.Eng in electrical engineering in 1947 from McGill University. Dr. Ross worked with General Electric X-ray Corporation until 1950 doing application work in the medical and industrial field. He joined the High Voltage Engineering Corporation in 1950 doing design and application work on high energy particle accelerators. From 1953 to 1957, he attended Yale University. He received the M Sc in 1955 and the PhD in 1957 in physics. While at Yale, he did work on radiation effects in biological and chemical systems using high energy electrons and gamma rays. Dr. Ross returned to the High Voltage Engineering Corporation in 1958 and was responsible for radiation applications in medical, industrial and research fields covering areas in nuclear physics, solid state physics and biophysics. Dr. Ross joined RCA Laboratories in 1958 as Head of the Nuclear Reactor Group carrying on research work in the field of solid state physics with the five megawatt nuclear reactor. He is now Head of the Electronic Printing Group of the Data Processing Applied Research Laboratory conducting research in novel methods of copying and printing by electrostatic and electromechanical methods. Dr. Ross is a member of the American Physical Society, Sigma Xi and the American Association for the Advancement of Science.

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the printing plant will become an extremely serious problem. Technological innovation is needed to improve the communication between the editor, composer, advertising customer, and the printer with particular emphasis on facsimile systems.

FACSIMILE HISTORY

Basically, facsimile means a formal mapping of each element on the original to each element of the output sheet. In all commercially available systems, this replication is carried out synchronously in real time. Thus, both a spatial relationship and a time relationship must be obeyed. Unlike audio or telegraphic information, this time relationship must be exact. Phase delay or noise will alter the picture drastically, whereas audio signals will still be intelligible and a missing letter or two will not destroy the intelligibility of a written message.

In 1842, Alexander Bain was granted the original patent on a facsimile system. A pendulum at the transmitter swung against conducting letters or symbols set in an insulating block of wood. At the receiving end, a pendulum passed the transmitted current through a current sensitive recording paper. If the pendulums swung in synchronism, an exact replica of the conducting pattern was produced on the paper at the receiver. In 1848, Bakewell substituted the flat plate for a rotary cylinder and in 1860, Bonelli used multiple styli to increase transmission speed. These systems, analogous to telegraphic systems, remained unimproved until the advent of electromagnetic information transmission and the increase of available bandwidth.

Further development of facsimile came with the development and construction of commercial radio transmitting and receiving equipment and in 1924, RCA actually sent a facsimile picture from New York City to New Brunswick, New Jersey, by wire; to Brentwood, England, by wireless and to London and thence to Carnarvon, Wales, by wire from where it was retransmitted to River Head, Long Island, and to New York City where it was reproduced on a facsimile receiver. While crude, the picture was recognizable and was a milestone in graphic information transmission.

Since that time, facsimile has grown slowly. Helix/bar carbon paper printers were developed for weather map reception in the middle 1930's. In the late 1930's, broadcast facsimile was developed as the newspaper in the home using carbon-paper recorders. In the 1940's, the wet electrolytic process was refined and tested for radio facsimile in the home and by the government for weather map use. Modifications of both these systems and silver halide rapid processing continued in 1950's. The first commercial electrophotographic facsimile system was introduced by Xerox in the middle 1960's.

The facsimile market volume in 1966 has been estimated to be about 18 million dollars with a projected growth rate of about 10 percent annually. The major domestic manufacturers of this equipment are Alden Electronic, Telautograph, Stewart-Warner, Westrex (a division of Litton Industries), Western

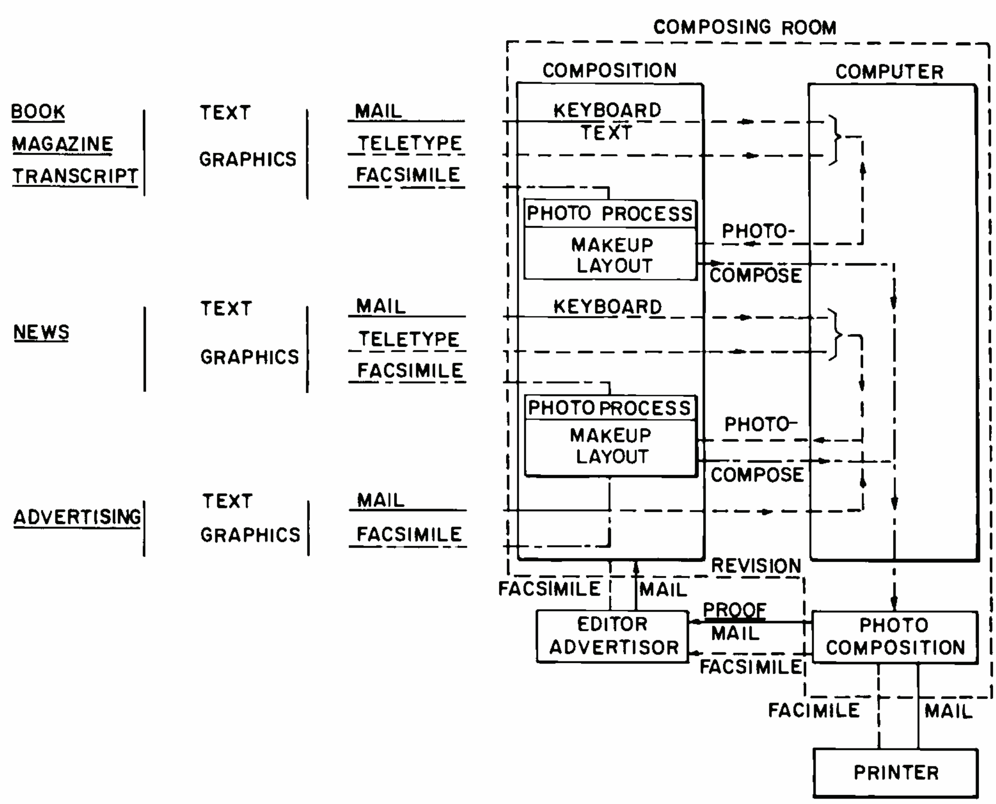

Fig. 1—Intermediate steps between production of text or graphics and printing.

Union, and Xerox. Foreign manufacturers include Muirhead (England), Rudolph Hell (Germany) and Nippon Electric (Japan). Of these, Westrex, Muirhead, Hell, and Nippon have concentrated on newspaper and graphic arts facsimile with wideband transmission systems and silver halide printout.

NEWSPAPER FACSIMILE

Facsimile transmission of a newspaper-page master has been tried many times and is used commercially by a number of publishers.

In 1956, the *New York Times* transmitted a master for their San Francisco edition from New York to the West Coast at a rate of 2 minutes/page and a resolution of 200 lines/inch. Five-point characters could be resolved as well as 50-line screened material. The resolution was too low for advertising copy but could be used for rough graphics in the news section. This system was discontinued towards the end of 1956 because of the high cost of transmission and the quality obtainable at this scanning rate.

The *Wall Street Journal* has been active in this field and, for several years, have been sending full page facsimile from their San Francisco office to their printing plant in Riverside, California, using Westrex PRESSFAX equipment. They use a television microwave link during off hours and achieve 1000-line/inch resolution. They are conducting a comparison between facsimile and the transmission of text material using teletypewriters followed by page composition at the printing plant.

The *Liverpool Daily Post* and *Echo* recently transmitted color separations from an original reflection color photograph on Muirhead equipment. The colors were separated by standard red, green, and blue filters. Each separation took 15 minutes to transmit. At the receiving terminal, the continuous-tone transparencies were screened at 75 lines/inch and used directly to make the plates. No color correction was used. While the proofs showed some color errors, the image was adequate for their use. This system has been in operation over the past year and has been successful for rapid news color photographs.

The *Daily Mail* routinely sends screened copy from London to printing plants in Manchester and Edinborough over a 48-kHz line at a resolution of 500 lines/inch. Transmission takes about 20 min/page. Moiré patterns have not been troublesome at this resolution. This equipment is made by Muirhead and is similar to that supplied to Scandinavia where full sized newspaper pages are being transmitted from Stockholm to Gothenberg and Malmo. The output on these systems is a negative transparency suitable for plate-making.

All of these applications are high priority and the cost of the transmission line can be justified. If these systems were not available, the publishers would have to use air or sea transportation which could fail in inclement weather. In such a case, the newspaper would not be published at the remote printing plant.

FACSIMILE PRINTOUT

It is of interest to briefly describe some of the printing methods which can be used for facsimile output printing.

Non-Optical: electrochemical

One of the most common facsimile recording media makes use of current passing through a specially coated electrolytic paper. Each electron captured in the coating will cause a dye molecule to change its optical absorption. One form of contacting the paper is a conducting helix rotating under the paper and an electronically actuated conducting bar on top. Supplying an electrical pulse to the bar will cause a current to flow through the paper at the helix/bar intersection developing a spot. Alternatively, a series of points may be pulsed to drive a current through the paper to a conducting roller but requires more complex control electronics than the helix/bar system. Since only one molecule is effected by the passage of the electron, there is no gain in the system. Approximately 10^{16} electrons/cm^2 are required for development.

To achieve high printing speeds, the paper must be reasonably conductive. This can be accomplished by wetting the paper but leads to problems of moisture-content control and dimensional stability. High printing speed is limited by the rotational speed of the helix and the current density that can be handled by the paper. An experimental machine built at RCA Laboratories required 100 μsec/picture element and a current density of the order of 20 amps/cm.^{2} Beyond these current densities, the paper fibres ruptured.[1] Resolution was also limited by the spreading of the electron stream from the point of contact. Although electrolytic systems are widely used commercially, they are limited in speed and flexibility and the quality of print is not as high as conventional contact printing with pigment or dye type inks.

Non-Optical: thermal

Low speed facsimile systems have used a double coated paper with a thin white layer over a black substrate. A heated stylus or a series of electronically heated points melt or evaporate the white coating leaving a black spot which forms the image. While the system is limited to writing speeds of about 7 in/s with recording energies of the order of 10^7 ergs/sec and the paper is expensive, it is simple and requires no processing. Its major use is in telephone-connected local facsimile systems.

A novel thermally-activated character printer has recently been described by the Texas Instruments Co. and the National Cash Register Co. where the heating elements are formed by integrated circuit techniques and the paper uses microencapsulated inks which develop a black image when the capsule is thermally ruptured. While simple to process, the unit is presently limited to matrix characters.

Non-Optical: electrostatic

Electrostatic printers have been built which use separate electrodes or pin tubes to charge insulating coatings on paper substrates. The charged areas are subsequently developed by conventional electrophotographic liquid or powder toners. The writing speed is limited mainly by the switching speed of the electrodes. Multiple copies can be produced by transfer or duplicating techniques. It is difficult to develop a gray scale and the resolution is limited by the packing density of the electrodes and the spread of corona. The major application of these systems are magazine address labeling, matrix printing for computer output, and general teletype use. The switching and character generation schemes are complex and their use has been limited to these special applications.

Optical: wet chemical

Silver halide emulsions have been used for many years for facsimile output. They are extremely sensitive requiring only 10^9 to 10^{10} photons/cm^2 for exposure. They usually require chemical processing in some form. Special liquid development systems are used on some commercial facsimile machines and will produce a finished print in 10 to 20 seconds. Dry silver-halide coatings are available which can be developed by ultraviolet radiation but require wet processing to fix the image.

The means for exposure vary from mirror deflection systems, rotating drum/light spot systems, cathode ray tube/lens combinations and fibre optic or thin window cathode ray tube systems. The latter are probably the fastest. The Honeywell "Visicorder" system, Model

1806, which has recently been announced, can write at a rate of 4×10^6 in/s using a fibre optic tube.

Most newspaper facsimile systems mount the film on a rotating drum and scan with a moving modulated light beam. Resolutions of up to 1000 lines/inch can be obtained but linear writing speed is limited by the intensity of the light source. The film in many cases is a transparency from which printing plates can be made directly. While widely used for facsimile printout, silver halide coatings are expensive and require some chemical processing.

Optical: dry chemical or photochromic

Recording paper coatings have been developed which will become light absorbing on exposure to a particular wavelength of light. In some cases, the image can also be erased with radiation of a different wavelength permitting reuse of the imaging medium. The advantages of these systems are the elimination of separate processing to develop the image. Usually, some form of fixing is required if a permanent image is desired.

One such system where a direct image can be produced by irradiation only is DuPont's PRP 265 which can be exposed with light below 360 nanometers (nm) in wavelength and fixed by illuminating with light above 400 nm. The image will usually continue to develop with room or sunlight exposure unless the fixing process is carried out. The resolution capabilities are high since the coating material is essentially molecular.

The disadvantage of photochromics is their slow speed. Exposures of the order of 10^{16} photons/cm^2 are necessary. DuPont's PRP 265 experimental paper requires about 10^5 ergs/cm^2 for a reflection optical density of 1.4.[2]

Diazo coatings are widely used for engineering drawing reproduction and may be used for facsimile with the same exposure requirements as the DuPont photochromic paper. They require auxiliary development by ammonia vapor or heat but do not require fixing.

Photochromic or photochemical materials can be used for medium speed optical exposure but are limited by the availability of high intensity light sources.

Optical: electrophotographic

Electrophotographic facsimile systems as exemplified by Xerox's LDX and Electrofax have optical speeds about 100 times slower than medium-speed silver halide emulsions. The images can be developed without wet processing and provide archival quality high resolution copy. The high speed results from the gain mechanism inherent in the toning process. About 10^{12} photons/cm^2 will discharge the image area permitting development to saturation reflection optical density.

The exposure systems used with electrophotographic facsimile systems are mirror/light beam deflection systems, cathode ray tube/lens systems and fibre optic or thin window cathode ray tubes.

Xerox's LDX system uses a cathode ray tube imaged onto a selenium drum by a lens. From the quoted document speed and resolution (8½x11-inch document every 7 seconds at 135 lines/inch) and the bandwidth (240 kHz) a picture element can be exposed in about 4 μs. The exposure needed, assuming 2.5 eV/photon and 10^{12} photons/cm^2 is about 4 ergs/cm^2 or 3 x 10^{-5} watts/7.4 mil picture element. The writing speed is 1840 in/s, somewhat faster than the photochromic paper but with much lower light intensity. The reason for the slow speed is the light loss in the lens system.

Much more efficient light sources are available in the form of fibre optic or thin window cathode ray tubes. Thin window tubes have been operated at RCA Laboratories at 20 kV with beam currents of up to 500 μA with a 5- to 10-mil spot. Window thicknesses of 2 to 5 mils have been successfully used in these tubes. It is estimated that 1% of the incident electron beam power reaches the image plane as light. The resolution or spot diameter is limited by the distance between the recording medium and phosphor—the window thickness—since the light is emitted isotropically from the spot where the electron beam impinges.

It should be noted that to make efficient use of fibre optic or thin window CRTs, the light sensitive medium should be in intimate contact with the light emitting surface. Separation will reduce resolution and optical speed drastically. A flexible substrate is almost essential for practical use of these light sources.

For a spot diameter of 7 mils, an incident electron beam power of 10 W (20 kV, 500 μA) and a 1% light conversion efficiency, the light power available is about 0.1 watt/picture element. Since the exposure requirements for electrostatic recording media is only 4 ergs/cm^2, the time per picture element is about 10^{-7} seconds. This is equivalent to a beam writing speed of about 10^5 in/s. Speeds of this order of magnitude have been achieved experimentally using direct or reversal liquid or powder toners.

Optimum System

Facsimile links for graphic information transmission serve two basic uses. For local editorial proofing and layout, the quality requirements are low. For final customer and editorial approval and for transmission from the composing room to the printer, the quality must be high.

For low quality proofing electrophotographic, silver halide or electrolytic systems can be used. Electrophotographic systems can give layout copy and permit page makeup by suitably programming the text and graphic material in the computer. While the electrofax system can give resolutions of over 1000 lines/inch if the optical system is adequate, the light intensity available from a lens/high resolution CRT system is generally too low. If 100-line/inch resolution is adequate, thin window or fibre optic cathode ray tubes can be used to expose Electrofax paper at electron beam writing rates of over 100,000 in/s.

For high-speed high-resolution facsimile, silver halide systems can be exposed at speeds of several thousand inches per second from high resolution cathode ray tubes giving up to 500-line/inch resolution. If transparencies are used printing plates can be made directly.

The electrolytic system is generally used for telephone linked facsimile producing low resolution continuous tone on specially coated paper. Units of this type are used extensively for newspaper graphic transmission. The picture is then cropped and normal photographic procedures used to obtain a screened transparency for plate-making.

While a number of other facsimile printout systems have been proposed and are being studied, the above three appear to be the most practical now and in the near term future for the areas described above.

CONCLUSION

Facsimile systems for graphic information transmission are available today in limited quantity and of questionable resolution for high quality images. Materials and processes which might improve the printout operation are being developed in allied fields such as office copying and duplicating. These developments may overcome some of the existing problems in present day terminal equipment such as the cost of supplies and the complexity of processing the exposed master.

Because of the need for facsimile services in the graphic arts, it is felt that the market will continue to grow. Any breakthroughs in more efficient use of the communication channels or a more efficient output medium will drastically accelerate this growth.

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The Engineer-Author and RCA

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RCA encourages qualified personnel to write papers for publication and presentation. This article outlines RCA's policy on papers, describes the services available to RCA authors, and gives a brief list of publications interested in good technical RCA papers.

EVERY ENGINEER OR SCIENTIST has the opportunity of gaining professional prestige for himself and for his company by communicating what he has learned. There can be no question of the value of effective writing in taking advantage of this opportunity.

That RCA engineers accept the challenge of writing to meet this responsibility is attested to by the 1200 papers or more published or presented each year. This total represents approximately one paper for every five engineers and scientists, and includes those authors who, typically, write five or six papers each year. The publication of high-quality technical articles helps to identify the author as an expert in his field.

RCA's POLICY

Corporate policy instruction 10211 reads, in part, as follows:

"The Radio Corporation of America encourages the writing of papers by qualified personnel for publication and presentation. Such papers help establish the author in his profession and contribute to the good will of the technical community toward RCA. It is important that such papers be timely, well written, sound from a technical point of view, and that they conform with all company policies."

To ensure that papers meet the requirements established by RCA policy, all papers written by RCA engineers must be reviewed and approved for policy, legal, patent, security and commercial requirements prior to publication or presentation.

Reprint RE-13-6-21/ Final manuscript received March 26, 1968.

E. M. GEVERD received the BSEE from Drexel Institute of Technology and has more than nine years of experience in the field of engineering writing, including several years as the documentation coordinator for RCA on the TIROS and TOS satellite programs. During three years of service in the U.S. Army, Mr. Geverd was an electronics instructor on the Nike Ajax ground guidance system. Mr. Geverd was named to the post of Administrator, Technical Publications in June 1967. He is the editor of RCA's TREND and is responsible for the planning and editing, and the supervision of production and distribution of the magazine. He also has the responsibility for expanding the use of RCA technical articles in external publications.

ASSISTANCE TO AUTHORS

A number of good writing guides are available at RCA to aid engineers in the preparation of papers and articles. Some of these are referenced at the end of this article. In addition, each major activity has a Technical Publications Administrator who is responsible for administering the technical papers approval procedure. Most of these men, listed on the inside back cover of each issue of the RCA ENGINEER, have considerable experience in the publications field and can assist authors of technical papers. They can help select topics, and can suggest appropriate journals or magazines for technical papers. In some cases, TPA's can also help in organizing, preparing illustrations, and expediting necessary approvals.

WHO SHOULD WRITE

Every engineer or scientist who can add to the knowledge of his profession should consider writing as a means of communicating some of this knowledge to his colleagues. Professional journals and trade magazines are always interested in worthwhile technical papers whether they relate to research, circuit applications, systems concepts, test methods, or surveys.

What is a *worthwhile* article? Briefly, it is one that will enhance the knowledge of others in your field. Examples of subjects for worthwhile articles include the unique or unusual application of standard equipment; the use and advantages of new equipment; the discovered behavior of equipment under severe conditions—such as the space environment; the testing of equipment; an analysis of the basic design requirements and the development of the system to meet those requirements; or a survey of the advances in a particular phase of engineering.

WHERE TO PUBLISH

At least one journal, or magazine, is interested in publishing articles on each phase of technical activity at RCA. Once you have decided to write an article, a good first step is to determine what journal will have the greatest interest in publishing your paper. This is an area where your TPA or your supervisor can help. Not only can the TPA help you make a selection based on his own knowledge, but he can consult with his fellow TPA's to determine the best journal for your article. He will also be able to advise you on the format and submittal requirements of your selected journal.

Broadly speaking, there are two basic types of publications interested in your article: trade magazines and professional journals.

Trade magazines are very competitive and often solicit articles. You can be sure that several trade magazines will be interested in reviewing the articles you write. Most trade magazines pay authors to encourage them to publish. The payment is small—primarily an honorarium; it can rarely be adequate compensation for the time devoted to an engineering article . . . and cannot be considered a primary incentive for writing. This incentive must come from your desire to contribute your knowledge to your chosen field and to gain professional recognition for your work.

The requirements for submitting material for publication vary from magazine to magazine and journal to journal. It is important that you obtain a journal style guide or contact the editor of your selected publication to determine the submittal requirements. Usually trade magazines will want an original and one copy of the text of your article, and one set of good quality glossy prints of any photographs that you are using to illustrate your article. Line drawings, schematic diagrams, etc., should be neat and legible. There is no need to provide final line art, however, since most trade journals will redo the art to their requirements.

In many cases, professional journals will want an original and three copies of your double-spaced typed manuscript, plus an original and three copies of all illustrations. Line art usually must be inked and must be prepared according to the journal's specifications, which are available upon request. A point worth noting is that professional journals usually require a 100 to 200 word abstract in addition to your basic paper.

DO NOT OVERLOOK RCA PUBLICATIONS

RCA publishes a number of very good technical magazines; do not overlook them when you are selecting a home for your article.

The RCA ENGINEER is an internal publication interested in a broad range of high-quality technical papers. This magazine offers several advantages to technical authors within RCA. First, it provides the engineer or scientist with a suitable publication medium for showing his capabilities to the overall RCA technical community. Second, it serves as a valuable communications tool for transferring technical knowledge from engineer to engineer and division to division. Third, it provides an outlet for high-quality papers that would be of interest to too limited an audience for publication in an external journal (for example, articles relating to the development of RCA products).

The *RCA Review* usually restricts itself to research or development papers of primary documentary significance. Unlike the RCA ENGINEER, the *RCA Review* is distributed, by subscription, both internally and externally.

TREND (*T*he *R*esearch and *E*ngineering *N*ews *D*igest) specializes in news about people, projects, and facilities in research and engineering activities of RCA, as well as business information of interest to its readers who are primarily engineers, scientists, and their supervisors, and in communications among and between engineers and managers. Unlike the RCA ENGINEER and the *RCA Review*, TREND does not publish detailed technical papers. Rather, it provides a means of communicating concepts and capabilities. Short articles relating to "how we do it" or "new capabilities that we have" are welcome in TREND if they can help other divisions or engineers to solve problems that they face; articles on new contracts or contract additions are also welcomed. Such articles are of interest throughout the corporation, and they allow your activity to come into the lime-light. TREND articles normally run between 200 and 400 words, and may include by-lines.

DUAL PUBLICATION

When your article is printed in a magazine or journal, it becomes the property of that publication and cannot be printed elsewhere without specific approval. Even with approval, you will find that other major magazines are not interested in printing verbatim articles that have appeared elsewhere.

However, if there is a wide interest in a subject on which you have written an article, you can rewrite it with a different emphasis or with a different level of readership in mind without too much additional effort—and, thereby, make your paper acceptable for publication in a second or even third magazine.

A most noteworthy exception to the "not-interested-if-printed-elsewhere" attitude involves the RCA ENGINEER. Many outside journals and magazines are both willing and anxious to publish articles that have appeared or are scheduled to appear in the RCA ENGINEER. In fact, a Corporate-wide program is now underway to review RCA ENGINEER articles with the purpose of placing them in external magazines, subject of course to appropriate approvals obtained through the TPA.

Another exception results from the close-working relationship between TREND and the RCA ENGINEER. Articles written on the "capsule-concept" or general technical-interest level for TREND can later be printed in detail in the RCA ENGINEER. Thus, the author is able to take advantage of both the quick turn-around time provided by TREND and the detailed technical presentations available in the RCA ENGINEER.

SOME PUBLICATIONS OF INTEREST

A few of the many technical magazines and journals are tabulated here for your information. The TPA or Editorial Representative for your activity has a much longer list that includes the name of the editor and the address for each publication.

Name	*Issued*	*Circulation*
General		
EDN	Monthly	52,000
Electronic Design	Bi-weekly	47,300
Electro-Technology	Monthly	50,500
Electronics	Bi-weekly	65,600
Microwave Journal	Monthly	36,000
Military		
Army	Monthly	76,500
Data	Monthly	8,000
Signal	Monthly	12,000
Computers		
Computers and Automation	Monthly	22,300
Computer Design	Monthly	7,000
Data Processing	Monthly	36,000
Professional Journals		
Proceedings of IEEE	Monthly	34,000
IEEE Spectrum	Monthly	121,000
Journal of the American Institute of Aeronautics and Astronautics	Monthly	9,000
The Physical Review	Weekly	11,000
Physics Today	Monthly	45,000
Journal of the Association of Computing Machinery	Quarterly	15,500
Journal of the Optical Society of America	Monthly	7,300
Journal of the Acoustical Society of America	Monthly	6,500
Journal of the Chemical and Engineering Data	Monthly	4,000
Other		
Astronautics and Aeronautics	Monthly	39,000
Microwaves	Monthly	23,500
Medical Electronics News	Bi-monthly	43,000
Materials Engineering	Monthly	34,000
Instrumentation Technology	Monthly	20,000
Graphic Science	Monthly	18,200
Environmental EQ Quarterly	Quarterly	11,000
Radio Electronics	Monthly	100,000
Electronic Packaging and Production	Monthly	19,500
Popular Electronics	Monthly	414,000
QST	Monthly	
RCA Publications		
RCA ENGINEER	Bi-monthly	9,500
RCA Review	Quarterly	7,500
TREND	Monthly	13,500
Electronic Age	Quarterly	35,000
Broadcast News	Quarterly	15,000

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Analog and Digital Integrated Circuits for Sine and Cosine Generation

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Sine and cosine generation is important in aerospace control systems technology for coordinate transformation. Environment, size, and weight considerations define the importance of developing a small, accurate, and reliable system for this purpose. Because of recent achievements in integrated circuit technology, a review of the analog and digital techniques is in order. More detailed descriptions of these techniques are contained in the references at the end of this paper.

In present technology, electromechanical resolvers, which depend upon the rotation of a magnetic field, are widely accepted as the state-of-the-art devices. To improve upon these, the designer is looking to all-electronic resolvers, and up until now electronic analog resolvers have provided the most promising avenue for improvement. Digital differential analyzer (DDA) integrators, however, are now available on two Metal Oxide Silicon (MOS) integrated circuit chips, drastically reducing the cost and hardware to a level comparable to the analog implementation. With this major breakthrough it appears that a digital technique may replace the analog for sine/cosine generation.

After building a first generation analog sine/cosine generator and a DDA generator, both using integrated circuits, a comparison reveals that the digital technique still may not replace the analog except for certain applications.

ANALOG TECHNIQUE

A simplified analog sine and cosine generator was built using RCA CA-3008 operational amplifiers. To implement the technique requires the use of two integrators and an inverter connected in a feedback loop to provide the oscillation. The oscillator is controlled by a ramp generator and comparator to provide the time interval proportional to the input signal. This time interval controls this amount of oscillation of the loop. The major difficulty encountered with this scheme is obtaining the proper relationship between the ramp time constant and the frequency of the oscillator. Fig. 1 is a functional diagram of an analog sine/cosine generator.

DIGITAL TECHNIQUE

The digital approach (as shown in Fig. 2) is a direct analogy to the analog. Two DDA integrators and an inherent inversion (provided by proper interconnection) accomplish the oscillation. The timing is accomplished with a digital counter providing the necessary number of input pulses for a given input signal. A DDA sine/cosine generator is a special application of the digital filter technique where a low-pass digital filter provides the integration function.

The state-of-the-art implementation of the digital technique was built using the General Instrument MEM 5021 DDA adder element along with the MEM 3016-2 dual 16-bit shift register. The adder element and dual shift register combine to form one DDA integrator.

This adder element is described as a metal thick-oxide semiconductor (MTOS) integrated circuit. It is a result of a process which provides for the oxide at metallization crossover points to be made thick to reduce shorting through pinholes, and the oxide in the gate areas is made thin allowing the device to work properly. This improved process has increased the speed and reduced the size of the integrated circuit as well as improved the yield. This improvement in yield allows for more and more complicated devices to be built on a single chip. This adder element contains 230 devices on a 72x86 mil area, while an equivalent bipolar type would require 66 logic chips.

In addition, MOS devices are now available with Zener protection against damage due to static charge. It is no longer a requirement that the person working with MOS devices (and his soldering equipment) be grounded. For these reasons then, the possibility of replacing the analog implementation with the DDA must be reviewed.

COMPARISON

Speed and Accuracy

The rather crude analog sine/cosine generator which was built could generate sinusoidal functions to within 2% of the maximum value of the sinusoid. This could have been improved by increasing the dynamic range and choosing more precise component values. The frequency generated allowed the answer to be available within one millisecond after the oscillation was started.

The major error resulted from the inaccuracy of the resistor and capacitor values in the oscillator, ramp, and comparison circuits. These component errors resulted in an error in timing the ramp with respect to the oscillator frequency.

Another contributor of error is the operational amplifier offset which is due to a mismatching of the operational amplifier differential input transistors. Finite open-loop gain contributes an error by preventing the idealized integration function from being performed. Improved design and fabrication of integrated circuit operational amplifiers are constantly improving on these limitations.

Even with a very crude analog sine/cosine generator a fair amount of accu-

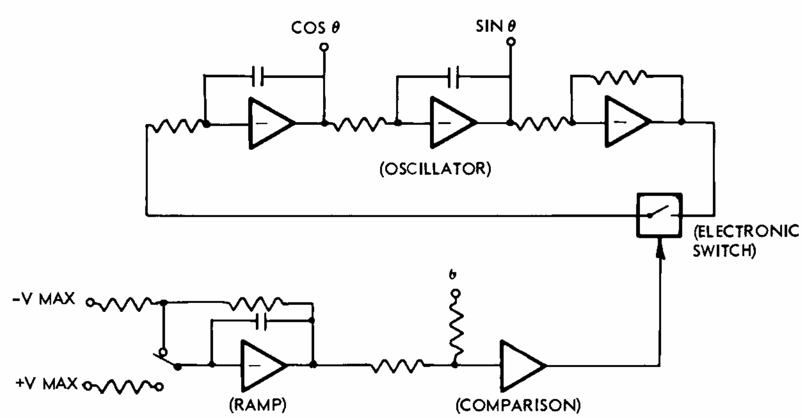

Fig. 1—Analog sine/cosine generator.

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racy was obtained with little effort. This would indicate that a much better system could be built. The present state-of-the-art analog sine/cosine generators claim an accuracy of about 0.1% and can be built using about 17 off-the-shelf integrated circuits in a two-cubic-inch package.

The digital sine/cosine generator can be as accurate as desired. This however, is misleading because an increase in accuracy is only available at the cost of the speed of the solution. Figure 3 shows a speed versus accuracy tradeoff for the first cycle of oscillation. For 2% accuracy (or about 6 bits) it takes approximately 3 milliseconds for one cycle to be generated. To obtain an accuracy of 0.1% (or about 10 bits) requires about 70 milliseconds to generate one cycle. Since the accuracy of the analog implementation is not as speed dependent, 0.1% still appears to be feasible in the one-millisecond range. In applications then, where greater accuracy is required, the digital system can supply it.

Another error source of the DDA sine/cosine generator is quantization noise which results from the additive properties of roundoff and truncation error. This error increases exponentially but becomes significant only after many cycles. This error was observed to be 5 bits of a 15-bit word after about 50 cycles of oscillation corresponding to about 0.1% error. The effect is to increase the magnitude of the sinusoidal function being generated as the number of iterations increases. This error will become prohibitive if many cycles are necessary.

System Considerations

Detecting and describing the output signal is an important consideration from the standpoint of accuracy and, of course, output requirements. In the analog system mentioned as the state of the art, the output is of the form of a modulation of a pulse width. The output voltage level desired is used to generate a new ramp which provides the time interval to modulate the output pulse.

The input signal of the analog implementation is in the form of a DC voltage level, whereas the DDA sine/cosine generator requires a pulse train. The number of pulses required for one complete cycle is $(2\pi)2^n$ where n is the word length excluding the sign bit. For 10-bit accuracy, 6,431 input pulses are required and can be provided from a 13-bit binary counter; 6,431 × 11 or 70,741 clock pulses are required, and at a clock frequency of 1 MHz this takes about 70 milliseconds as stated previously.

Reliability

Due to the nature of the analog system, the operation, and therefore the accuracy, are more directly dependent on the parameters of the individual components. Temperature variations and degradation of components over a long period of time would cause inaccuracies in the system if no adjustments are made for this. Highly regulated power supplies are necessary in order to reduce errors from supply variations.

On the other hand, digital MOS circuits have not existed long enough to completely prove themselves dependable. With the digital system, however, the 2- or 3-volt noise immunity of the circuit requires no adjustments since it is stable over time and temperature and supply variation.

CONCLUSION

The analog system then is faster but has limited accuracy, whereas the digital implementation is as accurate as necessary but at the expense of speed. Since the limitation of accuracy of the analog system is not prohibitive in most coordinate transformation systems, it still appears to be the most acceptable method, except where greater accuracy is required. Speed of solution is an important consideration and the digital system at present cannot provide it.

It is expected that in the future the cost of DDA integrators will be lower and the clock rates higher. Even now some shift registers are being operated at 5 MHz. Clock rates are expected to climb to around 15 MHz which would allow a 10-bit solution to be reached in about 15 milliseconds. Even at present, where a high degree of accuracy is desired, the DDA technique is a very acceptable alternative to the analog method with its small size and comparable price.

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JAMES R. GARVEY received the BSEE from Northeastern University in 1966. Since joining RCA in 1966 on the rotational plan, Mr. Garvey has worked primarily on circuit design problems including multiplier and orthogonal filter implementation and a DDA coordinate transformation scheme. He is presently a member of Advanced Systems and Technology of ASD and is involved in adapting several video circuits for suitable hybrid fabrication. Mr. Garvey is a member of Eta Kappa Nu.

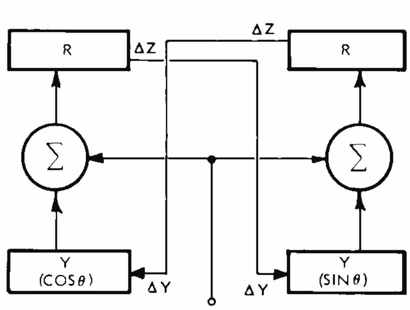


Fig. 2—DDA sine/cosine generator.

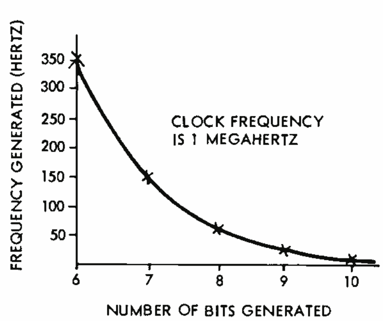
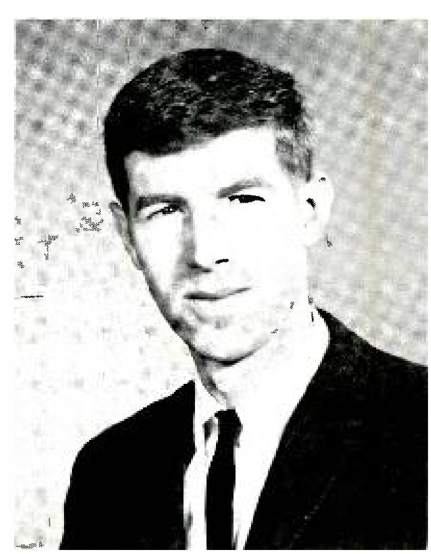


Fig. 3—DDA speed/accuracy tradeoff.



A New Concept in the Design of Low-Frequency Isolators for Industrial and Satellite Applications

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Low-frequency isolators have been in common use in industry for some time to damp vibrations of delicate devices to prevent damage to them. With the recent growth and expansion of space programs, more sophisticated isolators are needed to protect delicate electronic equipment from mechanical vibrations encountered during missile lift-off and other operations. This paper describes a new concept in the design of low-frequency isolators.

ISOLATORS usually consist of springs that support the isolated mass and dampers that dissipate some of the vibrational energy. The configuration, the materials used, and the performance characteristics of the isolators vary from one manufacturer to another, but the principles of operation and purpose of all isolators are the same.

The new concept in the design of low-frequency isolators commonly results in the forms shown in Fig. 1. The completely enclosed, viscous-damped low-frequency isolators shown consist of two identical metal bellows fitted together end-to-end with a common orifice between them; the space within the bellows is filled with a low-viscosity fluid. Spring action is provided by the metal of the bellows, and damping by the fluid flow. The degree of damping can be selected by adjustment of the diameter of the orifice and/or the viscosity of the fluid.

At least two isolators, constructed as shown in Fig. 1a and 1b, are required to isolate a system from its vibrational environment. The necessity for two isolators stems from the requirement that the possibility of twisting motion be eliminated. Other possible low-frequency isolator designs are shown in Fig. 2. The choice of design depends on the intended application.

In the double-bellows design shown in Fig. 1, compression of bellows B causes the extension of bellows A; the volume of fluid lost by one bellows is gained by the other and the total volume within the isolator does not change. During the compression of bellows B, input energy is dissipated in forcing fluid through the common orifice into bellows A. This action produces viscous damping. The choice of fluid depends on the intended application. In the single-bellows design (not applicable to satellite equipment applications), the bellows are the springs and the air acts as the damping fluid. Fig. 2c illustrates this type of isolator.

The bellows can be assembled by many different techniques including welding, brazing, soldering, and epoxying; the bellows isolators shown in this paper were brazed.

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THEORY OF OPERATION

For isolation of vibration-sensitive elements from their surroundings, the isolator-system resonant frequency must be considerably lower than the resonant frequency of the isolated element. In this manner, the isolated device is subjected to considerably reduced accelerations and is said to be isolated from the input. The specific choice of isolator type depends on the environment in which it will be used, namely, the maximum allowable amplitude of motion, the space available for installation, the mass to be isolated, the desired frequency of isolation, and the experimentally determined life-span of the isolator.

The transmissibility and relative displacement characteristics of a system

RICHARD R. HANDEL received the BSME from Stevens Institute of Technology in 1942. Since graduation, his entire career with RCA has been devoted to camera and display tube development and manufacture. His experience includes development of the S10 photosurface; ½-inch and 1-inch vidicons; 2-inch; 3-inch and 4½-inch image orthicons; isocons; graphicons; and radichons. He is presently a senior engineer in the product development portion in the image orthicon manufacturing section. Mr. Handel is a registered mechanical engineer in Pennsylvania.

R. A. MINET worked for RCA for five years in Camera Tube Design Engineering. He is currently administrator of Laboratory Liaison for Electronic Components, Central district. He holds a patent on RCA Isocon and has written two technical papers: "Analysis and Design of Alignment Coils for Magnetically Focussed Electronic Optical Systems" and "Generalized Trajectory Task for RCA 601 Computer Electronic Optic System."

JANIS G. ZIEDONIS received the BS in Mathematics and Physics from Muhlenberg College in Allentown, Pa. in 1959. Following graduation, he joined the environmental engineering department at the Electron Tube Division. He worked on electron tubes for space applications where he contributed to the design and development of vidicons and image orthicon tubes. He developed tube ruggedization techniques that were used on a wide range of conversion tubes including the all-ceramic vidicon and the 2- and 3-inch image orthicons. On a special project for Jet Propulsion Laboratories, Mr. Ziedonis analyzed the impact phenomena on the Ranger satellite cameras during their impact on the moon. This was accomplished by reviewing and analyzing the last 800 microseconds of the telemetry data, and performing experiments that simulated the last received video signals. Recently, Mr. Ziedonis transferred to RCA, Medical Electronics, Advanced Development Group, where he is responsible for the development and design of ultrasonic transducers for medical applications. He is a member of Sigma Pi Sigma, American Association of Physics Teachers, and American Institute of Ultrasonics in Medicine.

R. R. Handel

R. A. Minet

J. G. Ziedonis

with a single degree of freedom but with different fractions of critical damping are shown in Figs. 3 and 4. System transmissibility, T, is computed by means of the equation

$$T = \sqrt{\frac{1 + \left(2 \frac{C}{C_c} \frac{\omega}{\omega_n}\right)^2}{\left(1 - \frac{\omega^2}{\omega_n^2}\right)^2 + \left(2 \frac{C}{C_c} \frac{\omega}{\omega_n}\right)^2}},$$

where C is the damping coefficient of the system (lb-s/in), C/C_c is the fraction of critical damping, ω $(= 2\pi f)$ is the angular input frequency (rad/s), and ω_n is the angular frequency of the system (rad/s). The relative displacement X_R is given by

$$X_R = \frac{M\ddot{a}}{\sqrt{(K - M\omega^2)^2 + C^2\omega^2}},$$

where M is the mass to be isolated (lb-s^2/in), $\ddot{a}$ is the acceleration of the isolated system (in/s^2), and K is the spring constant, or linear stiffness of the spring (lb/in).

Figs. 3 and 4 demonstrate several important features for isolator design and for protection of the item to be mounted on the isolator. In both Figs., the introduction of damping has the important effect of reducing the amplitude at resonance and the secondary effect of reducing resonant frequency. This in turn produces 1) lower stresses on the spring element and 2) lower acceleration on the isolated member.

The spring constant, K, per bellows convolution can be calculated using the equation

$$K = \frac{3.33\, E\, (\text{OD} + \text{ID})\, t^3}{(\text{OD} - \text{ID} - t)^3}, \qquad (1)$$

where E is the modulus of elasticity of the bellows (psi), OD and ID are its outer and inner diameters (inches), and t is its wall thickness (inches). The total spring constant, K_t, for a complete bellows containing a number of convolutions, N, is given by

$$K_t = K/N. \qquad (2)$$

The following equation provides a good approximation of the orifice area, A_o, needed for maximum damping for a given bellows configuration when the fluid viscosity in the bellows is close to one centipoise:

$$A_o = \frac{1}{12}\sqrt{\frac{W_o A_p^3 S}{W}}, \qquad (3)$$

where W_o is the weight of a cubic foot of fluid (pounds), A_p is the effective piston area of the bellows (square inches), S is the increment of bellows stroke (feet), and W is the weight of the moving mass (pounds). It is suggested, however, that several experiments be performed to optimize this parameter.

Additional useful equations for calculating bellows isolator characteristics are shown below.[1]

$$\text{Bellows Maximum Stroke} = \frac{(\text{OD} - \text{ID} - t)^2\, N \times 10^{-3}}{t}.$$

$$\text{Bellows Pressure Rating} = \frac{9.4 \times 10^6 t^2}{(\text{OD} - \text{ID} - t)}.$$

$$\text{Maximum Supportable Load} = \frac{3.33 \times 10^{?2}\, (\text{OD} + \text{ID})\, t^2}{(\text{OD} - \text{ID} - t)}.$$

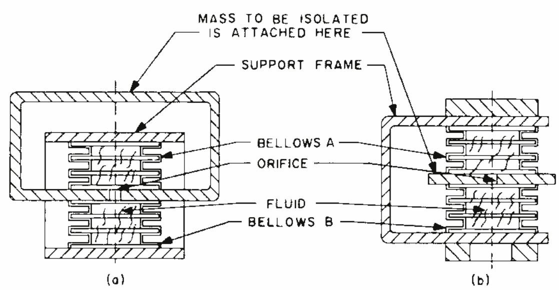


Fig. 1—Typical low-frequency, viscous-damped, bellows isolators.

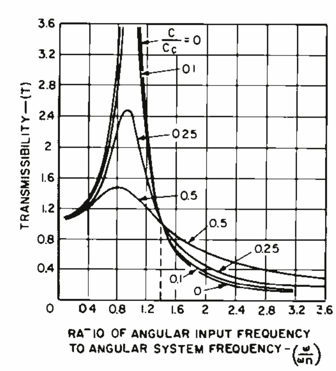
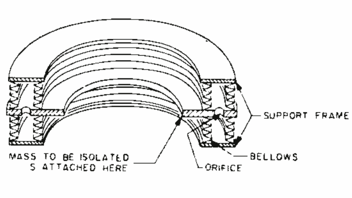


Fig. 3—Transmissibility characteristics as a function of damping factor.



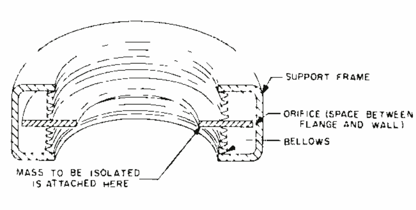
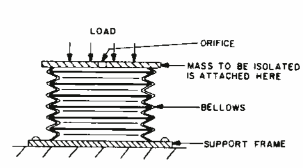


Fig. 2—Other possible low-frequency isolator designs: (a) doughnut-type, fluid-filled, double-bellows isolator; (b) single-bellows isolator; and (c) air-filled, single-bellows isolator.



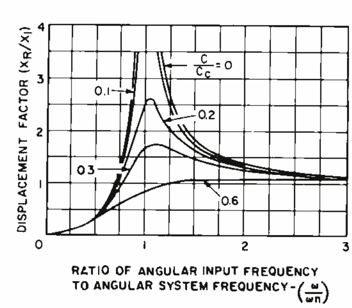


Fig. 4—Relative displacement characteristics as a function of damping factor.

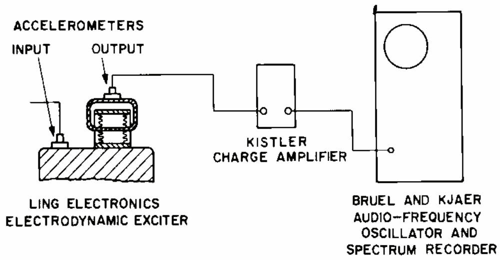


Fig. 5—Arrangement of test equipment for bellows evaluation.

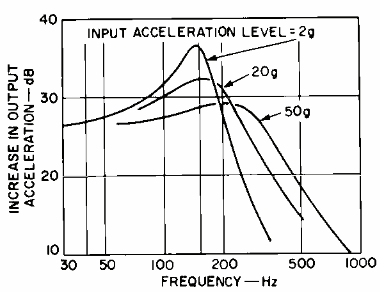


Fig. 6—Vibration response of an isolator at various levels of vibration.

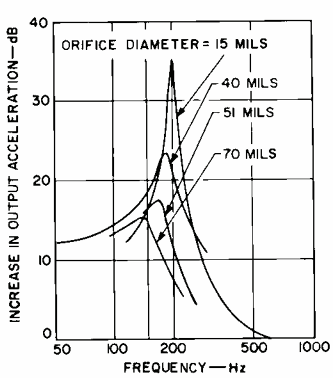


Fig. 7—Vibration response of a single-bellows isolator at various orifice diameters but constant acceleration level.

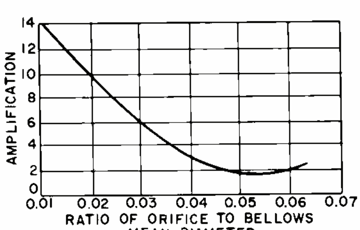


Fig. 8—Vibration amplification in a single-bellows isolator at a constant acceleration level at various orifice diameters.

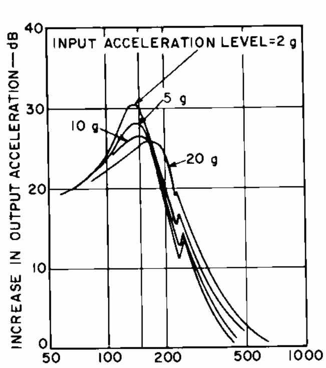


Fig. 9—Vibration response of an isolator with a fixed orifice at various acceleration levels.

EXPERIMENTAL EVALUATION OF THE NEW ISOLATOR CONCEPT

The new isolators were evaluated through the use of an electrodynamic vibrator that produces sinusoidal vibrations in the frequency range from 5 to 500 Hz. The arrangement of equipment used in the evaluation is shown in Fig. 5.

During the vibration test, the input-acceleration level was held constant over the frequency range, and output acceleration was plotted by means of a Bruel and Kjaer recorder.

Fig. 6 shows the response, at three input-acceleration levels, of a water-filled double-bellows isolator with a bellows of 0.25-inch outside diameter and an orifice of 0.028-inch diameter. The increase in output acceleration, a result of bellows resonance, is given in dB. The output acceleration in g's at bellows resonance can be determined directly from the change in dB. The output acceleration, the response of the output accelerometer at bellows resonance for the three input-acceleration levels used, is shown in the following tabulation:

Input Acceleration Level	Output Acceleration Level	
(Peak amplitude in g)	(Change in dB)	(Amplitude in g)
2	9.5	6
20	5	36
50	2.2	60

This tabulation indicates that 1) the amplitude of motion of the system at resonance is a function of the amplitude of the input vibration, 2) critical damping for the resonant system is approached at an input-acceleration level of 50 g's peak, and 3) the bellows isolator is a nonlinear system.

Improved damping coefficients can be obtained at lower acceleration levels by changing the diameter of the orifice and by careful selection of damping fluid. It should be kept in mind that temperature has a great effect on the viscosity of the damping fluid; therefore, the choice of fluid can be made only after a thorough study of the intended application.

When comparing the actual response curves in Fig. 6 with the theoretical transmissibility and relative deflection curves in Figs. 3 and 4, it should be noted that the data for Fig. 6 was developed by varying the amplitude of vibration, not the orifice diameter. As a result the curve patterns in Figs. 3 and 4 are the reverse of those in Fig. 6. When the amplitude of vibration is held constant and the orifice diameter (damping factor) is changed, experimental transmissibility data follow the theoretical transmissibility curves closely.

For the single-ended air-damped isolator shown in Fig. 2c, the diameter of the orifice needed for desired damping at a particular resonant frequency must be determined for each application. Typical data obtained with a single-bellows isolator at room temperature and normal atmospheric conditions are shown in Fig. 7. The isolator used in obtaining the curves was equipped with a variable orifice and a bellows with a mean diameter of 1.250 inches. The peak input-vibration level for the test was 5 g's.

When the orifice diameter was changed and the vibration level held constant, the amplification factor of the single-bellows system at resonance was changed, as shown in Fig. 8.

When the acceleration level in the same bellows was increased at a fixed orifice diameter of 0.070 inch, the resonant frequency increased and the amplification factor at the resonance point decreased, as shown in Fig. 9.

CONCLUSIONS

A number of experiments have been performed using low-frequency isolators with completely enclosed bellows. On the basis of the data obtained, the following conclusions can be stated:

1) The low-frequency bellows isolators described in this paper constitute completely enclosed spring-damper systems that can be used for industrial applications or on satellite equipment.
2) The orientation of the isolators with respect to the earth in no way affects the performance of the isolator.
3) When several isolators are used to support a single device and are subjected to lateral vibration, they behave as a rigid system at the axial resonance point. This condition practically eliminates rocking motion from the system.
4) When the application of the bellows isolator calls for operation throughout a wide temperature range, consideration must be given to the required volume expansion and viscosity of the fluid used. Fluids such as Dow Corning No. 200 undergo large volume expansion under conditions of high temperature. Unless the bellows are designed to expand proportionately, permanent damage to the isolator can occur.
5) The materials selected for the bellows must be capable of withstanding processing and application temperatures without annealing. Assembly by brazing requires that the bellows be able to withstand higher temperatures than when some other method (e.g., epoxying) is used. However, brazed constructions are generally more useful in high-vacuum and/or high-temperature applications.

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2. Harris, C. M., Crede, C. E., *Shock and Vibration Handbook*, Vol. I, McGraw-Hill Book Company, Inc., New York, 1961.
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Video Recorder Reproducer for Space Exploration

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The recording of video data is most frequently accomplished by transverse scan recorders. In recent years, a series of manufacturers have introduced television recorders which take advantage of the simple geometry of the helical scan technique to provide a comparatively low cost equipment. In a television recorder recently delivered to NASA by RCA, the simple geometry of the helical scan technique was utilized to provide an extremely compact recorder. The basic difference in the application of the helical scan technique for the low cost vs the compact unit rests in the size of the recording wheel. In the configuration for NASA, the wheel was made as small as practical so that a compact transport could be obtained. With this configuration, the signal perturbations at the switch are in the area of viewing, but the magnitude of the perturbations are significantly reduced by the short length of the recorded track. In addtion to the compact size of the transport, the recorder electronics have been designed to incorporate integrated circuits wherever practical. These two efforts have yielded a 29-lb recorder/reproducer which can record and reproduce either a 4MHz bandwidth for 1/2 hour or a 0.5MHz bandwidth for 4 hours.

THIS TELEVISION recorder/reproducer evolved from RCA's experience in designing instrumentation for spacecraft—Apollo, Gemini, TIROS and Nimbus—and long experience in recording techniques. The major criteria for space vehicle instrumentation of small size, light weight, and low power drain are embodied in this recorder, which was first built by RCA under contract to NASA's Manned Space-Craft Center. The recorder measures half a cubic foot, weighs 30 pounds, and dissipates 60 watts when operating to record at 4MHz and 48 watts when recording at 0.5MHz. A versatile tool for space exploration, the unit incorporates record and reproduce capability at two discrete operating speeds. It can accommodate over 30 minutes of recording at standard television rates and reproduce the recording either directly or time expanded by 8 to 1. Alternately it can record the 10 frames/sec Apollo television for over 4 hours and reproduce either directly or time compressed by 8 to 1. With the dual capability, the unit can accommodate either the rapid dump required during earth orbit or the limited bandwidth link imposed by the lunar orbit.

Attainment of this extended capability in a small package with low power consumption has been achieved through a combination of three elements:

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1) Electronics, which employ integrated circuits to the maximum consistent with good design;
2) The negator spring reeling system, which has been proven as a reliable, power-saving system in RCA's TIROS, Nimbus, and Gemini Recorders; and
3) The ultraminiature helical-scan recording station which affords inherently precise time stability.

The helical-scan recording station is the key to the recording system. This device forms a helical path for the tape around a high speed rotating head-wheel. The helical path causes the tape to be scanned by the head-wheel diagonally from edge to edge. The recorded tape format resulting from this action consists of a series of 0.005-inch wide tracks at an angle of 45° with respect to the tape edges. The 45° angle of the helically recorded tracks is established by the specific geometry of the recorder elements. The tape is wrapped approximately 190° around the wheel and continuous recording is effected through two diametrically opposed recording heads in the high speed rotating head-wheel. The specific scanning and tape speeds for the recorder are listed below with other features of the recording system:

Size	10x14x6.1 inches
Weight	30 lbs (maximum)
Bandwidths	DC to 4MHz DC to 0.5MHz
Record Time	½ hr @ 4MHz 4 hrs @ 0.5MHz
Head-to-Tape Speed	1120 in./sec @ 4MHz 140 in./sec @ 0.5MHz 10 in./sec @ 4MHz
Tape Speed	1.25 in./sec @ 0.5MHz 40 in./sec @ rewind
Signal-to-Noise Ratio (peak-to-peak to rms)	38 dB
Input Voltage	+28±4VDC
Power Dissipation	60 watts @ 4MHz 48 watts @ 0.5MHz
Time Stability	2 parts in 10^4 @ 4MHz 1 part in 10^3 @ 0.5MHz

The recorder/reproducer consists of three major subsystems—the tape transport, the motor drives and controls, and the video electronics—which will be discussed in the paragraphs that follow:

TAPE TRANSPORT

The tape transport (Fig. 1) includes the tape reeling system, the tape (or capstan) drive system, the helical scanning assembly, the erase head, the longitudinal record/reproduce heads, and an assortment of tape guides.

Tape Reeling

The tape reeling technique employed is the negator spring system which has proven so successful in RCA's line of narrowband spacecraft recorders.[1] The specific advantages of this reeling technique in the wideband recording system are the low power consumption and the uniform and repeatable tension which contributes significantly to the time stability of the unit.

F. DONALD KELL joined RCA in 1955 on cooperative assignment from Drexel Institute of Technology. In this capacity he performed electro-mechanical design for the Surface Communications, Missile and Surface Radar and Applied Research Sections. After receiving his under-graduate degree in 1957, Mr. Kell rejoined the engineering staff of Applied Research and continued his education in the graduate night school at the U. of P. With Applied Research, Mr. Kell engaged in electro-mechanical design on a variety of programs. He designed the first air lubricated headwheel assembly for the commercial video recorders and directed the development of a family of helical scan, wideband recorders which are used in the tracking ships on the Eastern and Western Missile Test Ranges. Mr. Kell participated in the development of the two wideband satellite recorders built by RCA. He was responsible for the tape transport development in the system which is now part of an operational space program and was responsible for the total program which led to the advanced spacecraft unit planned for future use in Apollo Applications. His contribution to these and other programs are evidenced by the 16 patent applications which have resulted from his work. In 1964, Mr. Kell was promoted from Engineering Leader, Applied Research to Manager, Design and Development, Recording and TV Equipment. In this capacity, he continues activity in the broad field of data recording.

Drive System

The primary power element in the tape or capstan drive is a hysteresis synchronous motor. Since three different tape speeds are required in the present system, two different pole configurations are employed and are contained in the same motor assembly. A two-pole configuration is employed for high speed record and playback and for rewind. In the high speed record or playback mode, the two-pole motor is driven from a two-phase, 100-Hz square-wave source. In rewind, the two-pole motor is driven from a two-phase, 400-Hz source. The 4-to-1 difference in drive frequency, of course, yields the 4-to-1 speed-up during rewind. The motor configuration for low speed record or playback is a 16-pole motor driven from a two-phase, 100-Hz square-wave source. The 100-Hz drives are controlled by an internal timing standard during record; but, during playback, the nominal 100 Hz is derived from a voltage controlled oscillator in the capstan servo so that the nominal 100 Hz is, in practice, frequency modulated to accommodate alignment of the video heads with the recorded tracks.

The common motor shaft is coupled to the capstan output shaft through a two-stage, mylar belt/pulley reduction. This mylar belt/pulley transmission system is again a technique which has been proven in RCA's narrow-band spacecraft recorders and is employed in this system for its superior low flutter properties. The output member of the capstan drive is a urethane coated shaft which forms a closed-loop drive around the helical scanning station. The closed-loop drive results because tape is metered into and away from the helical scanning station. This type of drive acts as a low pass filter on tension variations which occur external to the closed loop. This filtering action, of course, provides immunity from the effect of supply tension variations on time base stability. The influence of tension on time-base stability is discussed in more detail in the following section.

Helical Scanning Station

The helical scanning station incorporates a high speed rotating head-wheel which develops the high head-to-tape speed necessary for wideband recording. The scanning station also brings the tape into contact with the head-wheel for about 190° of the wheel rotation. Continuous recording is accomplished by employing two diametrically opposed recording heads in the wheel. With this configuration, at least one head is always in contact with the tape. The recorded tracks are diagonally arranged on the tape at an angle nearly equal to the helix angle. Spacing between consecutively recorded tracks, of course, is established and controlled by the tape motion.

Two facets of the scanning station design establish, to a large degree, the level of time-base accuracy that can be attained in the recorder. The more critical facet is the immunity of the station to time-base distortion due to tape length changes. Dependence on tape length changes is peculiar to rotary head recorders because the information is recorded as a series of disjointed tracks. To obtain an accurate recombination of the disjointed information during playback, the length of the tracks during playback must accurately duplicate the length which existed during record. If this condition is not met, a sharp discontinuity in the phase of the playback signal will occur at the instant the playback signals from the two heads are recombined.

Three design features of the recorder combine to minimize this source of time-base distortion. Two of the features—the reeling system and the closed loop tape drive—maintain accurate tape length through inherently smooth tape tensioning. The other feature minimizes the time-base discontinuity simply by minimizing the absolute changes in tape length which can occur during the interval between the recombining switches. This is directly accomplished through the extremely small head-wheel diameter (0.73 inch) which minimizes the length of the disjointed tracks.

The second facet of the scanning station design which significantly influences time-base accuracy is the speed constancy of the head-wheel. In the present design the head-wheel is driven by a hysteresis synchronous motor through a mylar belt/pulley reduction. This motor, like the capstan motor, employs different head-to-tape speeds.

In all modes of operation, the motor is driven from an accurate frequency source which provides a speed accuracy well beyond that required for standard black and white television rates.

MOTOR DRIVES AND CONTROLS

The primary frequency standard in the present recorder is a 3200-Hz tuning fork.

This standard is counted down to develop the two-phase, 100-Hz and two-phase, 400-Hz references which control the motor drivers in most operating conditions. The motor drivers are basically switching circuits that convert the input DC to the two-phase, square wave drives required by the motors. Conversion of power is normally controlled by the two-phase references derived from the 3200-Hz tuning fork.

The one exception to this practice centers on the operating mode of the capstan during playback. In this mode the capstan servo maintains the alignment of the video heads with the recorded tracks.

Operation of the servo depends on a recorded clock track. In the record mode, a once-around pulse is derived from a tone-wheel fixed to the head-wheel shaft. The pulse is recorded on a longitudinal track (control track) on one edge of the tape. This provides a reference of the relative head-wheel and tape positions that existed during record. During playback, the longitudinally recorded pulse is reproduced and compared in phase with the tone-wheel signal. Comparison indicates the relative head-wheel and tape positions that exist during playback. Thus the comparison serves as the basic error signal for the capstan servo. Correction for phase errors between the two signals is accomplished by applying the error signal to a voltage controlled oscillator. The VCO replaces the 1600-Hz reference in the two-phase capstan motor drive reference. Hence, as the error signal modulates the output frequency of the VCO, the drive frequency to the motor is proportionately changed and the motor remains synchronous with the drive frequency and speeds up or slows down until proper tracking is obtained.

VIDEO ELECTRONICS

The video electronics (Fig. 2) employed in the present system are functionally equivalent to those used in broadcast television recorders. The incoming video signal is encoded on an FM carrier which has an undeviated frequency of about 4.8 MHz for the 4-MHz bandwidth and 600 kHz for the 500-kHz bandwidth. The full amplitude video signal deviates the carrier to approximately 7.2 MHz and 900 kHz respectively. The FM signal is applied to record amplifiers that, in turn, drive the two video heads. Coupling of the signals into and out of the heads is performed by a rotary transformer with a 1:1 turns ratio.

During playback the two head-output signals are processed initially as two independent channels. Each output signal is applied to a preamplifier located adjacent to the rotary transformer. The signal is further amplified in the playback amplifiers and equalization is applied to restore the sideband energy to a more balanced form than is received directly from the tape. At this point the signals are recombined into a single FM channel through a 2x1 switch. Application next of 40 dB of hard limiting to the signal provides immunity to noise and amplitude fluctuations. Next the limited FM signal is applied to the FM demodulator which reproduces the original video signal. Final processing of the signal consists of additional amplification and impedance matching.

CONCLUSION

The spacecraft television recorder/reproducer was developed under contract to NASA's Manned Spacecraft Center and is now being tested by NASA to determine its performance in an environment similar to that which will be encountered in space. It is scheduled for possible use during the Apollo Applications Program.

ACKNOWLEDGEMENT

The developments reported here, like many of those accomplished at RCA, must be credited to the combined efforts of personnel from several different activities. In this case, the combined talents of DEP Advanced Technology; Electronic Recording, Broadcast and Communications Division; and the Recording and Television Equipment of the Communications Systems Division formed the technical team.

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Fig. 1—Wideband television recorder.

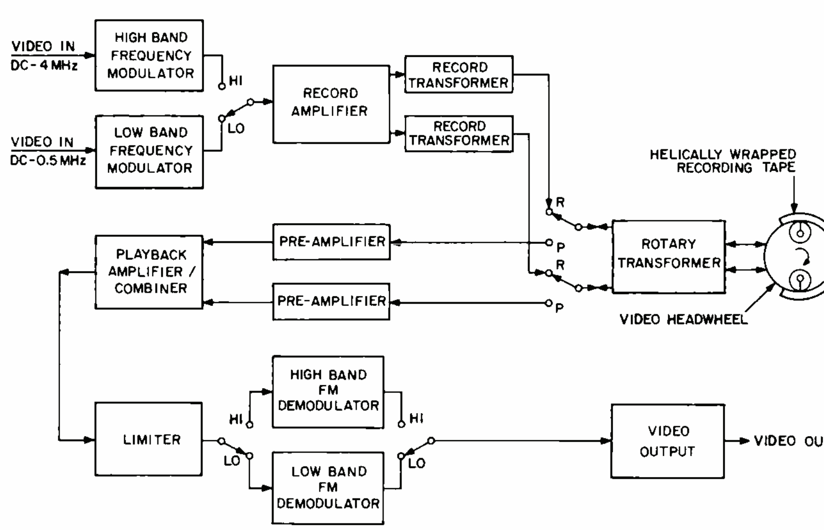

Fig. 2—Wideband television recorder block diagram.

Hybrid Radar Antenna
pedestal-mounted electronic scanning array

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The hybrid radar antenna is a phased array design specifically to mount on a precision pedestal. It provides electronic scanning coverage in a sector which can be accurately pointed anywhere in the hemisphere by the servo-drive system of a precision pedestal. An operational ten-foot diameter array demonstrating these features has been built and tested at C-band by RCA at the Missile and Surface Radar Division, Moorestown, N. J.

IT HAS BECOME almost traditional for radar system users to develop new missions and upgraded performance requirements at a rate that makes even their latest, most sophisticated equipment woefully inadequate for the jobs they want to do. And no agency known today has a budget big enough to replace all its "obsolescent" sensors with new models after only a minimum break-in period. Perhaps the best approach to this dilemma is to surrender to reality and make the best possible compromise between the two opposite poles of modern advanced technology and modest funding available. This paper describes one such approach as it applies directly to the problems of instrumentation radars.

One of the primary missions of instrumentation radars over the past 15 years has been to acquire and track a single target within a small well-defined sector. The majority of radars developed for this objective were pedestal mounted paraboloid devices, emphasizing probability of detection and acquisition and high precision tracking. More recently, requirements in this area have been expanded to include multiple target clusters contained within sectors much larger than the coverage of a single radar beam. Although the number of targets to be handled and their dispersion have expanded enormously, the requirements for precision tracking have not changed. Nor are these requirements restricted to space-object tracking and reentry missions. Midcourse evaluation objectives, air defense and AICBM defense, fire control systems, and air traffic control systems all demand more in terms of complete hemispheric coverage and multiple target tracking.

The obvious answer is the four-faced fixed phased array system which fulfills all the requirements and includes advanced information processing subsystems to handle as much traffic as the radar can see. The immediate problem that arises is that the cost of one such system is very high; the cost of replacing all existing pedestal mounted paraboloid tracking radars is unthinkable. The compromise, which combines the flexibility of electronic scanning with the basically sound precision pedestal-mounted antenna, may prove to be the only truly satisfactory solution to the problem.

As envisioned by the advanced design radar engineers at RCA's Moorestown, New Jersey Missile and Surface Radar Division, the compromise involves a hybrid antenna system which replaces the standard tracking radar paraboloidal dish with a flat-faced phased array. This system, under development and refinement at RCA Moorestown for the past two years, offers the first really low-cost approach to expanded performance of precision tracking radars. An operational 10-ft-diameter array, built and tested at C-band, has proved the capability of such a system to track large numbers of discrete targets within a target complex anywhere in the hemisphere, with the number limited only by the amount of radar and information processing equipment associated with the antenna.

ADVANTAGES OF THE SYSTEM

The system has a number of intrinsic advantages attributable to the basic design approach; others accrue from the novel design concepts applied during system development.

Perhaps the most important single advantage is that with electronic scan superimposed on a servo-driven pedestal complete beam agility is achieved at a

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DR. WILLARD T. PATTON received the BSEE and MS degrees from the University of Tennessee in 1952 and 1958, respectively. He received his PhD in Electrical Engineering from the University of Illinois in 1963. While on the staff of the University of Tennessee Experiment Station, he did research on circular arrays. He was an instructor at the University of Illinois, and he conducted research on log-periodic and simply periodic antennas at the Antenna Laboratory; he also was a consultant with the Radio Direction Finding Laboratory. For 3 years he was Ship Superintendent for DER conversions at the Boston Naval Shipyard. Since joining RCA's M&SR Div., Moorestown, N.J. in 1962, he has done research on large phased arrays. Dr. Patton is the author or coauthor of several technical publictions, and he is a member of the IEEE, AAAS, Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

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W. T. Patton

F. Klawsnik

cost which is miniscule in comparison with any other phased array approach. The radar can emit a pulse at will in any direction within the field of view of the array (Fig. 1). This feature provided the multiple target tracking capability which has assumed such importance in recent years.

Physically, the geometry of the system establishes an important advantage in terms of moment of inertia on the pedestal, as shown in the sketch (Fig. 2) the planar face can be mounted with less outward extension from the pedestal housing, thereby achieving practical operation on existing precision pedestals. Although the new antenna is heavier because of its circuitry and radiating elements, its moment of inertia is actually less than that of existing dishes.

Ease of installation is another important consideration, since the hybrid antenna was designed to bolt onto the existing pedestal structure. The hybrid antenna approach also provides relative ease of calibration for accurate measurement of target radar parameters; this is an important advantage over standard phased array radars.

Specific design features incorporated into the system provide several other major advantages:

A standard state-of-the-art feedhorn can be used with no new technology involved.

An aperiodic arrangement of elements eliminates all but vestigial grating lobes, a major problem in most phased arrays.

The array can be divided into essentially equal area radiating elements using only three shapes over the entire array for the elemental areas.

A 25-to-1 reduction in the number of phase shifters required is achieved over standard phased array designs.

Full dual polarization capability is provided.

The advantages cited above are very real and clearly achievable in practice. The basic design principles of this hybrid antenna system are given in the following sections of this paper, with a final section on calculated and measured performance of RCA's experimental hybrid antenna system.

APERIODIC CIRCULAR GRID ARRAY

In phased arrays of conventional design, the radiating elements are arranged neatly in rows and columns on a regular rectangular grating. When elements on such a grating are phased to produce a beam in a direction θ_s a second beam occurs at the angle θ_L given by $\sin\theta_L = \lambda/d\text{-}\sin\theta_s$ where d/λ is the period of the grating i.e., the spacing between elements of the array. When the array forms this second beam or grating lobe its gain is reduced by about 3 dB. Perhaps more serious than the loss of power, however, is the fact that the radar can receive signals from two different directions between which it can not distinguish. If the period of the grating is less than one-half wavelength, there will be no grating lobe for any scan angle, but when the period is greater than one wavelength, at least one grating lobe will be present for any scan angle. The spacing between elements on a regular periodic grating must be between one-half and one wavelength depending upon the angle of maximum scan or the field of view of the array.

Within the constraint of a regular periodic grating, the number of elements in the array can vary by at most four to one as the field of view varies from one array beamwidth to a maximum of 120 degrees. By employing an aperiodic circular grid, the problem of ambiguous grating lobes is eliminated and elements much larger than one square wavelength in area can be used. The constraint on element size in an aperiodic grid is that the element beamwidth equal the electronic scan field of view of the array. Under this constraint, the width of an element is given by $W/\lambda = 0.44/\sin\theta_m$ where θ_m is the angle of maximum scan. With this design criterion, the gain at maximum scan is 3 dB below the gain at broadside scan. When smaller elements are used, the gain at maximum scan will be higher; however, the design criterion given above will result in the maximum gain at maximum scan for a fixed number of elements.

Although the array is globally aperiodic (Fig. 3) it is approximately periodic locally, with a period equal to the element size. This local periodicity produces a vestigial grating lobe. The level of the vestigial grating lobes varies with the total number of elements in the array approximately as $10/N$. The element pattern will appreciably reduce the level of the vestigial grating lobe except when the array is scanned to the limits of the field of view of the element.

The maximum element area in the circular grid array is determined by the scan coverage requirements. The total array area is determined by the broadside gain. The ratio of these areas determines the total number of elements, and from this the vestigial grating lobe level can be estimated. If the level of the vestigial lobes is excessively high, more elements of smaller area may be used. This reduction in element area will tend to increase the gain at the scan limits and to decrease the effective level of the vestigial lobe at the scan limit.

In the circular grid array, it is possible to use either elements of equal area or elements whose area increases with

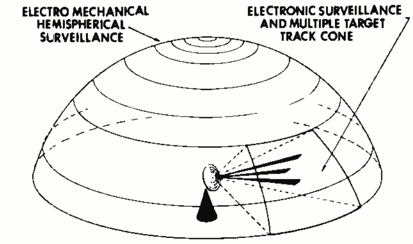


Fig. 1—The hybrid radar antenna provides electronic scanning for surveillance and multiple target tracking within an angular sector that can be accurately positioned anywhere in the hemisphere by a precision pedestal.

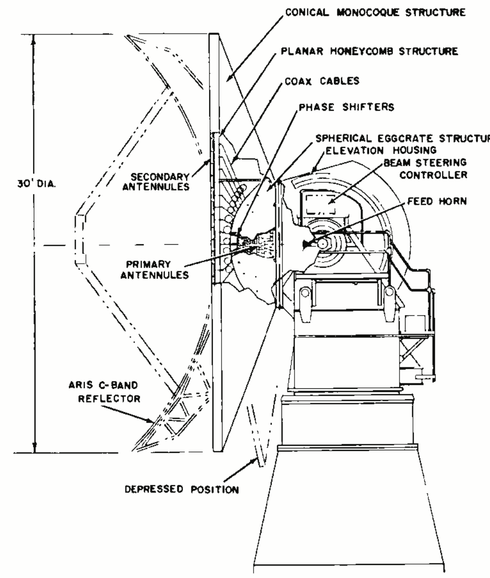


Fig. 2—Proposed antenna configuration in relation to existing structure.

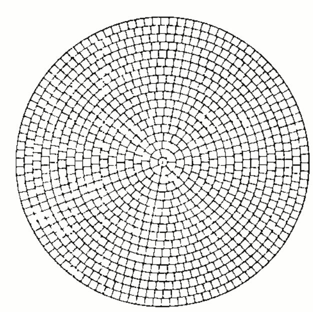


Fig. 3—Circular grid consisting of 18 concentric rings and 1048 antenna elements.

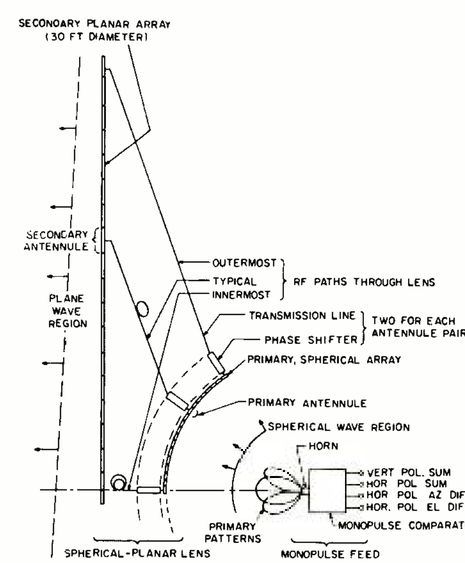


Fig. 4—The spherical primary face of the spherical planar transmission lens array is illuminated by a multimode monopulse feed horn located at its center of curvature. Equal length coaxial transmission lines carry the energy to the secondary (radiating) face through electronically controlled phase shifters used to steer the radar beam.

radius. As long as the same number of elements is used to cover the same total aperture area, the performance of the two approaches will be equivalent. However, when elements of nearly equal area are used in the circular grid, only three different sizes of square elements are required to cover the array with a minimum of uncovered area. When the illumination taper on the secondary array follows the illumination taper on the primary array derived from the feed horn, the flexibility needed to separately optimize the sum and difference patterns is provided.

SPHERICAL-PLANAR TRANSMISSION LENS GEOMETRY

The array for the hybrid radar is called a spherical-planar transmission lens (Fig. 4). It is a transmission lens because it receives energy on one face and retransmits it from the other face. It is spherical planar because the input face on transmission has a spherical curvature, while the output face on transmission is planar. The spherical input face is called the *primary* face; the planar output face, the face which launches the radar beam into the surrounding space, is called the *secondary* face. The spherical curvature of the primary face gives the lens an extremely short mechanical focal length and makes it possible to mount this antenna on a two-axis pedestal system.

The focus of the lens system is at the center of curvature of the spherical primary face. Energy emanating from a feed horn located at the focal point reaches every point on this spherical primary face in phase. Equal length coaxial cables conduct the RF energy from the primary face to the planar secondary face. The energy arrives there everywhere in phase and is launched into a single beam. The shape of the primary feed-horn pattern controls the distribution of illumination across the primary array, and this in turn controls the shape of the beam launched from the secondary face.

A lens geometry such as this gives the designer a great deal of freedom in designing optimum illumination functions, and it gives a degree of independence in the design of sum and difference illumination functions. The feed-horn arrangement with this antenna is very similar to that used for conventional reflector antenna systems, and the techniques developed for feeding the conventional antenna, are directly applicable to the spherical-planar transmission lens antenna.

Variable controllable phase shifters are inserted in the transmission path between the primary and secondary array. These phase shifters can be set electrically to provide a tapered phase distribution across the planar secondary face. This phase distribution determines the direction of the radiated beam relative to the direction normal to the array face. The phase shifters can be switched to a new setting in the order of 10 μs, which represents the time that it takes to shift to a new beam position. Since this time is much shorter than the period between radar pulses, it is possible to radiate each pulse at will in a different direction in space within the field of view of the antenna. The settings of the phase shifters required to point the antenna beam in a given direction are obtained from a small special purpose digital computer mounted in the antenna system.

Several advantages accrue from the spherical-planar transmission lens geometry. Since the antenna is a transmission lens, the feedhorn is mounted on the side of the antenna away from the radiating face. This eliminates aperture blockage by the feed—a factor that contributes to loss of gain and increased sidelobe levels in reflector type antennas. Since every point on the spherical primary face is equidistant from the feedhorn, there is less spillover loss for a given illumination taper. Since every surface element on the spherical primary face is normal to the ray incident from the feedhorn, there is no loss due to oblique incidence, as would be the case for a planar primary array. This also reduces spillover loss.

COORDINATED ORTHOGONAL POLARIZATION

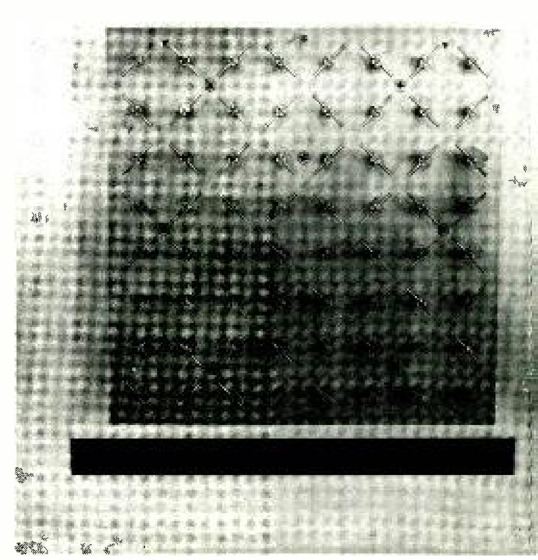
Polarization diversity is generally rather difficult to obtain in array type antenna systems. It ordinarily involves at least doubling the number of antenna components. The antenna system being described here, however, lends itself to a dual orthogonal polarization capability and this capability is used to simplify the design of the antenna. In this antenna, use is made of the fact that any antenna which can handle two orthogonal polarizations independently but coherently can handle any arbitrary polarization applied to it. In the hybrid radar being described, each cell of the antenna can handle dual orthogonal polarizations and thus can handle any polarization applied to it independent of its orientation and independent of the polarizations of the surrounding cells. This gives the entire transmission lens antenna the capability of transmitting any polarization that is applied to it by the feedhorn. It can handle vertical and horizontal polarization as well as either left- or right-hand circular polarization.

The dual polarization capability is provided in each lens cell in the following way. An element of the secondary array is made up of two arrays of dipoles, one orthogonal to the other as shown in Fig. 5. These two arrays in a secondary antennule are each connected to two orthogonal dipoles in the primary array through separate coaxial feed line and its separate phase shifter. The dipoles on the primary array have polarizations corresponding to the dipoles on the secondary array. The total phase length from a primary dipole to a secondary dipole array is the same for each polarization. A field of any polarization incident upon the primary array is resolved there into two orthogonal components. These components are transmitted through phase-coherent channels (in the lens structure) to the secondary array where they are reradiated to reconstitute the incident polarization. Since each lens cell can independently transmit any polarization, it is not necessary to align the polarizations of one antenna cell with respect to other cells. This arrangement greatly simplifies the arrangement of elements in the antenna face.

SECONDARY ANTENNULE

The term antennule—literally a small antenna—is used to denote an element of the transmission lens array. The design of the secondary antennule is especially critical to good performance by the array. This is so because the total aperture efficiency of the antenna is the product of the aperture efficiency of the array and the aperture efficiency of the antennule. Thus, it is important that the secondary antennule have as high a total efficiency as possible.

Fig. 5—A dually-polarized dipole subarray is used as the secondary antennule. This element has a measured efficiency loss of less than 1 dB and has greater than 40 dB isolation between polarization channels.



Efficiency

The aperture efficiency of an antenna can be defined as the ratio of the maximum gain of the antenna to the maximum gain of a uniformly illuminated antenna having the same aperture. It can be shown that the aperture efficiency is given by the ratio of the square of the average illumination intensity to the average power density across the antenna aperture.

$$\eta_a = \frac{\left[\frac{1}{A}\int_A\int f(x,y)\,dxdy\right]^2}{\frac{1}{A}\int_A\int f^2(x,y)\,dxdy}$$

where η_a is the aperture efficiency of an antenna with aperture area A and an illumination distribution function $f(x,y)$. If the aperture is divided into a number of sub-apertures—all with the same distribution function but differing in area E_n and maximum illumination intensity a_n—the aperture efficiency becomes:

$$\eta_a = \frac{\left[\frac{1}{A}\sum_N a_n E_n \frac{\int_{E_n}\int f(x,y)\,dxdy}{E_n}\right]^2}{\frac{1}{A}\sum_N a_n^2 E_n \frac{\int_{E_n}\int f^2(x,y)\,dxdy}{E_n}}$$

Since it is assumed that all sub-apertures have the same illumination distribution, the same average illumination intensity, and the same average power density, this expression can be factored into:

$$\eta_a = \frac{\left[\frac{1}{A}\sum_N a_n E_n\right]^2}{\frac{1}{A}\sum_N a_n^2 E_n} \cdot \frac{\left[\frac{1}{E_n}\int_{E_n}\int f(x,y)\,dxdy\right]^2}{\frac{1}{E_n}\int_{E_n}\int f^2(x,y)\,dxdy}$$

$$= \eta_N \eta_e$$

where η_N is the efficiency of the array and η_e is the efficiency of the element; their product is the total efficiency of the aperture.

Alternate Approaches

Initially two approaches appear very attractive for the secondary antennule design: 1) the corporate-fed dipole subarray and 2) the short horn. The short horn will be considered first because of its fabrication simplicity. This element has a maximum theoretical efficiency of about 81% because of the amplitude distribution in the H-plane and a realizable actual efficiency of 50% (3 dB loss) because of phase errors across the horn. The loss due to phase distribution can be largely compensated by placing a collimating lens structure in the mouth of the horn. The lens structure however will contribute additional losses due to dissipation within the lens structure and due to reflection at the lens faces. A total loss of about 1.5 dB can be expected with a well designed element of this type. However, the addition of the lens structure will increase the fabrication cost of this element and increase its weight.

The corporate-fed dipole subarray, on the other hand, has a theoretical aperture efficiency of 100%. Past experience shows that efficiencies in the order of 75% (1.25 dB loss) have been obtained with this type of antenna element due to losses in the feed structure and mismatch loss at the dipole elements. By carefully matching the dipole elements to the feed structure and by careful design of the junctions in the corporate feed a loss of less than 1 dB has been realized.

Model

A secondary antennule providing a 10-degree field of view in the frequency band from 5.4 to 5.9 GHz was built for the model program at RCA. The antennule was 9.5 x 9.5-inches square and contained 32 dipoles in each of two orthogonal polarizations. Each set of 32 dipoles was fed by a separate rectangular coax corporate feed system. Split-tube balun dipoles spaced approximately 0.84 wavelengths at 5.9 GHz were used, and the dipoles were carefully matched to the 50-ohm impedance of the rectangular coax feed system across the 5.4- to 5.9-GHz frequency band in a waveguide array simulator. This unit achieved a total loss of less than 1 dB and an isolation between polarization channels of greater than 40 dB.

A TYPICAL HYBRID ANTENNA DESIGN

The design of a 30-ft diameter spherical planar transmission lens array providing a 10-degree electronic scan field of view at C-band discussed below will illustrate the design principle. The 30-ft aperture is filled with 1048 antennules arranged on a concentric circular grid. The antennules which form the elements of the array are capable of radiating orthogonal polarizations from two isolated channels. Each channel of a secondary antennule is connected to the appropriate channel of the corresponding primary antennule by a semi-rigid coaxial transmission line through a digital latching ferrite phase shifter.

In an array of conventional design, 27,000 elements and phase shifters would be required to cover an area 30 ft in diameter. The aperiodic circular grid element arrangement, used here however, provides a filled aperture with only 1048 phase shifter pairs. The saving in weight resulting from the 25 to 1 reduction in the number of phase shifters, provided by this technique, permits mounting the array on a pedestal. This saving in weight, coupled with the short moment of inertia, provides mechanical and structural compatibility with an electromechanical scanning pedestal.

The basic array structure (shown in Fig. 6) consists of

1) A planar face to which the secondary antennules are attached;
2) A spherical structure to which the primary antennules are attached; and
3) A truncated conical section joining 1) and 2).

The conical section encloses all electronic components except the secondary antennules. This array structure can be installed in a radar system now operating in the field by unbolting the existing reflector structure and mounting the transmission lens antenna in its place with no major modification to the pedestal. The structural configuration of this antenna will make the wind torque and inertial loads smaller than those that the existing parabolic reflector antenna imposes on the servo drive system.

The primary array is a sector of a 10-ft diameter sphere intercepting an included angle of 60 degrees at the center of the sphere. The primary face is illuminated by a multimode feedhorn located at the center of the sphere. The beamwidth of the feedhorn is 60 degrees between 10-dB points on the sum mode pattern. This feed provides sum mode, traverse difference mode, and elevation difference mode illumination for both horizontal and vertical polarizations.

A 10-ft diameter engineering breadboard model consisting of the first six rings of the spherical-planar transmission lens array was built and tested. The

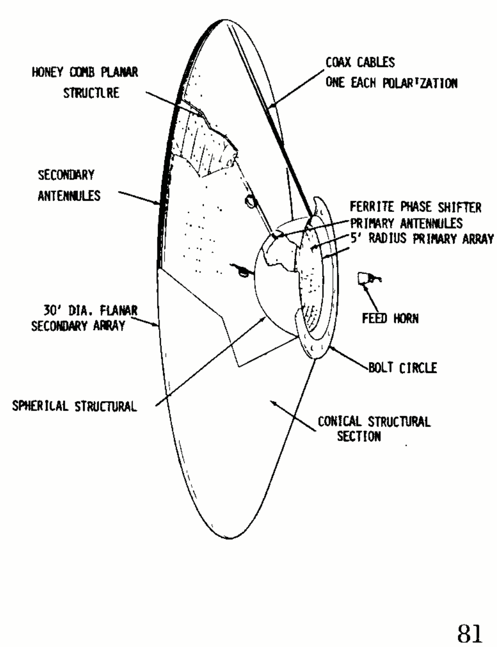


Fig. 6—Cutaway view of spherical-planar lens.

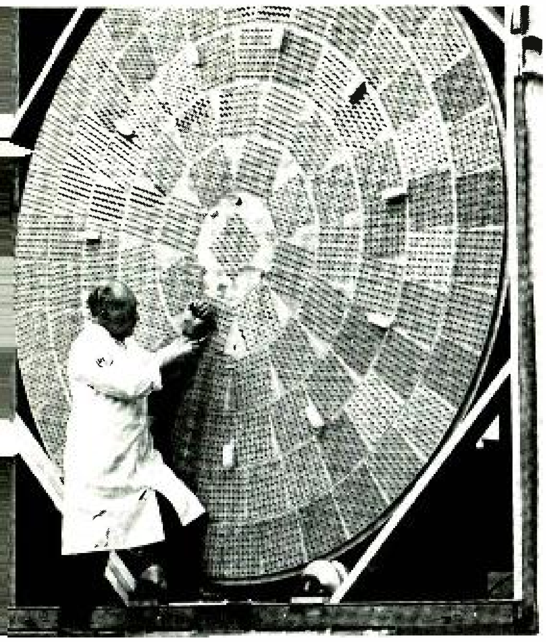


Fig. 7—The 10-ft-diameter engineering breadboard model is a full-scale realization of the 30-ft-diameter C-band antenna system.

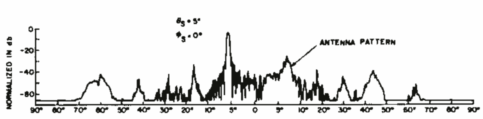


Fig. 8—Calculated circular 1000-grid array antenna patterns: $\theta_s = 5.0°$; $\varnothing_s = 0°$; $\varnothing = 0$, 180 cut.

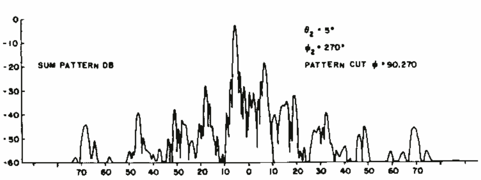


Fig. 9—Calculated circular 100-grid array antenna pattern: $\theta_s = 5.0°$; $\varnothing_s = 270°$; $\varnothing = 90,270$ cut.

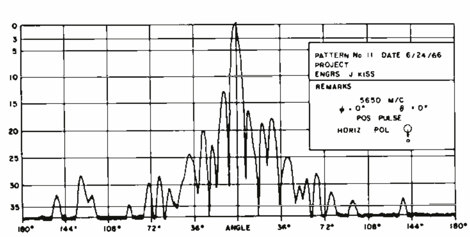


Fig. 10—Measured antenna pattern: $\theta = 0°$, $\varnothing = 0°$, horizontal polarization.

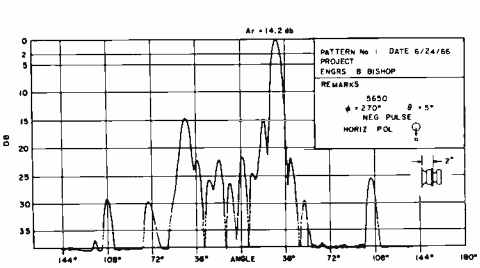


Fig. 11—Measured antenna pattern: $\theta = 5°$, $\varnothing = 270°$, horizontal polarization.

TABLE I—Antenna-Pattern Characteristics

Array Size	Scan Angles θ_s	ϕ_s	Worst Sidelobe Level (dB)	Position (deg)	Remarks
1000 Elements	2.5	160	—24	1.9	First sidelobe
	5.0	133	20.9	—6.3°	Vestigial Grating Lobe
100 Elements	2.5	0	—21	4.5°	First sidelobe
	5.0	90	—15	—7°	Vestigial Grating Lobe

antenna performance measurements made with the aid of this model are in substantial agreement with the theoretical prediction. The model (Fig. 7) is a full scale realization of the center portion of the 30-ft-diameter C-band antenna system. The effect of the circular geometry, equivalent to aperture blockage as can be seen by the portion of the array face not covered with dipole radars, is most pronounced in the first three rings of the model and is negligible beyond ring five.

TABLE II—Antenna System Losses

	Model	Full Scale
Optical Power Divider		
Feedhorn Spillover	0.60 dB	0.45 dB
Antennule Losses	0.28	0.20
Gaps Between Antennule	0.50	0.10
Feedhorn Mismatch	0.30	0.05
Monopulse Comparator	0.10	0.10
	1.78	0.90
Transmission System		
Cables	0.60 dB	0.70 dB
Four-Bit Ferrite Phase Shifters	0.75	0.75
	1.35	1.45
Planar Face		
Secondary Antennule	1.00 dB	1.00 dB
Phase and Amp. Errors	0.50	0.25
Gaps Between Antennules	0.80	0.10
Phase Shifter Quantization	0.06	0.06
Illumination Taper	0.45	0.45
	2.81 dB	1.86 dB
Array Losses	5.94 dB	4.21 dB

CALCULATED AND MEASURED ANTENNA PERFORMANCE

Since the performance of this antennna depends upon the total number of elements it contains, calculated performance figures will be given for both the 30-ft diameter antenna design and for the 10-ft diameter breadboard model design. The latter calculated performance data can be compared with the measurements actually made on the 10-ft-diameter engineering breadboard model. Antenna patterns have been calculated for the two configurations of circular grid arrays designed to scan a 10-degree cone. The 30-ft-diameter antenna design has a pattern at 5° scan shown in Fig. 8. The calculated pattern for the model array at 5° scan is shown in Fig. 9. Both arrays are illuminated with a 10-dB Gaussian taper distribution function. The antenna-pattern characteristics computed for these arrays are summarized in Table I.

Typical patterns measured on the model antenna are shown in Figs. 10 and 11. It may be noted that the first sidelobes are higher than predicted because of the effective aperture blockage but that the vestigial grating lobes are substantially at the predicted level.

The gains for these two antenna designs have been calculated in terms of loss relative to an ideal uniformly illuminated aperture. These calculations are shown in Table II.

In Table II, the feedhorn spillover loss represents the amount of energy radiated by the feedhorn which is not intercepted by the primary array. This loss is larger for the model antenna than for the full-scale antenna because the feedhorn used in the experiment had an actual measured beamwidth greater than 60° at the 10-dB points. The gaps between antennules represent a larger proportion of the total array aperture for the model than for the 30-ft diameter antenna and represent a larger loss on both the primary face and the secondary face of the model. The feedhorn mismatch loss for the model represents measured results on the feedhorn actually used in the experiment and does not represent a final feedhorn design. Since the cables for the model for the 10-ft diameter model are shorter than the cables in the 30-ft diameter model the loss due to this item is somewhat smaller for the model. Other factors contributing to the inefficiency of the array are essentially the same for both designs.

TABLE III—Measured Gain of Scanned Array

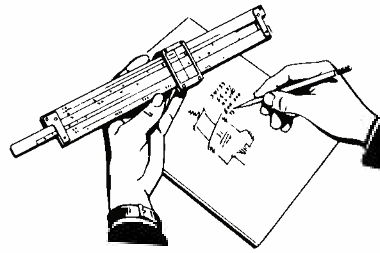
Beam Position 0°	$\phi°$	5.4 GHz	5.65 GHz	5.9 GHz
0	0	38.98	39.54	38.19
2.5	0	38.08	38.64	37.49
2.5	45	38.08	38.84	37.69
2.5	90	37.98	38.69	37.79
5.0	0	36.78	37.04	36.00
5.0	45	36.38	37.09	35.80
5.0	90	36.48	37.09	35.70

A total loss of 5.94 dB has been calculated for the model resulting in an estimated gain of 39.16 dB. The gains measured for the breadboard antenna model at various angles of scan are shown in Table III.

The measured gain at mid-band of 39.54 dB is in good agreement with the estimated gain for the model. It will also be noted in the Table that the gain decreases with scan in accordance with the design prediction.

Engineering and Research NOTES

BRIEF TECHNICAL PAPERS OF CURRENT INTEREST



J. Posivak

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An Improvement to the Design Automation System

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The assembly of the thousands of electrical components in a computer requires that a sizable fraction of interconnections be made on its backplane. The objective of logic design automation is to engender a greater volume of design per logician. This objective is partially fulfilled by relieving the logician of the backplane interconnection-bookkeeping task. In addition, at times each connection is analyzed for crosstalk phenomena to impose routing constraints upon the connection.

Errors in input data to DAS-7 (Design Automation System-7), used at ISD-West Palm Beach, must be filtered out before computer programs can generate manual and/or wire-wrap machine instructions.

A method of input-data preparation for logic design automation, which has inherent error-checking features, has been implemented at the RCA Graphic Systems Division. An initial inventory of punched cards is generated; one card for each pin on the backplane. Logic functions which are packaged into circuit modules are interconnected by writing the same signal name to all pin-cards comprising the signal "tree."

Signal names are handwritten on cards which were previously punched and printed with backplane "row," "column," and "pin" identification (Fig. 1). These are submitted for keypunching. Keypunch personnel find this process of reading the card faster than reading design-automation keypunch forms. If a card is missing during initial punched card inventory depletion, it is assumed to have been previously (and probably incorrectly) assigned. Such discrepancies are entered upon a handwritten error list.

The cards are sorted by backplane "row," "column," and "pin" after the first pass of keypunching. The results of the first pass are compared with a handwritten list of errors which were discovered during the first pass of punched-card inventory depletion. Incorrectly assigned cards are destroyed, their substitutes submitted for keypunching via design automation keypunch forms.

This procedure prevents the assignment of a pin to two different trees, and exposes errors on circuit-module data sheets.

A FORTRAN program for generating as many as nine nests (rows) of original pin-cards was written (Fig. 2). This program assigns a pseudo Design Automation Keypunch Form page number and line number to each card, in addition to the "row," "column," and "pin" numbers.

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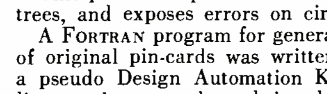


Fig. 1—Row, column, and pin identification cards.

```
        PAGE=1
        LINE=0
        READ 1, NEST1, NEST2
  1     FORMAT(I7,I1,I12,I1)
        DO 10 NEST=NEST1,NEST2
        DO 10 COL=1,40
        DO 10 PIN=1,32
        LINE=LINE+1
        IF(LINE.LE.20)GOTO10
        LINE=1
        PAGE=PAGE+1
  10    PUNCH 20, PAGE,LINE,NEST,COL,PIN
  20    FORMAT(2I2,2X,'A A',I3,I2,I3)
```

Fig. 2—Program for generating nests.

COSMIC—a computer program library for engineering applications

F. M. Brock
Microwave Engineering
Commercial Electronic Systems Div.
Camden, N.J.

F. M. Brock

Reprint RE-13-6-23/Final manuscript received February 23, 1968.

For the past few years, there has been a growing use of digital computers to solve engineering design and systems problems. The similarity of these problems in many areas of industrial and government engineering work has already produced many valuable programs.

The advance towards common use of high-level problem-oriented programming languages such as FORTRAN IV allows the use of these programs on similar sized computers of different manufacture, with usually only minor alterations. If a specific program, known to provide desired computations for a certain problem or class of problems, is available, considerable engineering and programming time can be saved. In many cases, the program may be used "as is," but even if the program should not be directly useable, it can often provide a useful starting point for a new program to solve the problem at hand.

Computer program libraries are being built up within industrial firms using computers in research and engineering; in customer-oriented computer service centers; in university and college computer centers; and in many government scientific centers such as NASA.

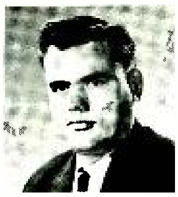
NASA offers a program library service through which programs can be obtained at a nominal charge. This program library service has a code name, COSMIC, and is administered by the Computer Center at the University of Georgia. Copies of each program can be obtained for a fee of $75.00 per card deck or magnetic tape copy. Copies of the program documentation are available at a nominal charge. Requests for program copies and documentation should be sent to:

Donald F. Kennedy, Project Director
COSMIC, Computer Center
University of Georgia
Athens, Georgia 30601

A catalog of available COSMIC programs up to the end of 1967 (approximately 200 programs), including program abstracts, can be seen by contacting the author. To present a view of the scope of these programs, a limited listing is given below:

Program	*Description*
COSMIC 10	Matrix Algebra Interpretive System
COSMIC 40	Step Input Pressure Response
COSMIC 60	Orifice Sizing for Fluid Systems
COSMIC 70	Antenna Voltage Breakdown Study
COSMIC 90	Cross-Spectral Analysis
COSMIC 100	Random Vibration Analysis
COSMIC 110	Subroutines for Plotting
COSMIC 130	FORTRAN IV Flowchart Producer
COSMIC 140	Rigid Body Response
COSMIC 160	Partial Differentiation of Algebraic & Transcendental Expressions
COSMIC 170	Symbol Mapping
COSMIC 220	Moment of Inertia
COSMIC 270	General Matrix Multiplication
COSMIC 290	Gain & Phase of Transfer Function & Matrix Curve Fit
COSMIC 340	Compressible Flows in Pipes
COSMIC 360	Heat Transfer in Complex Structures
COSMIC 370	Double Precision FORTRAN
COSMIC 400	Weight, Center of Gravity & Moment of Inertia of Rocket Engines & Components
COSMIC 400	Transient Behavior of Inventories
COSMIC 470	Time Controlled Equation Solver
COSMIC 490	Adams-Moulton Integration Subroutine
COSMIC 510	Frequency & Time Response Package
COSMIC 530	Evaluation of Ion Engines
COSMIC 540	Automatic Mathematical Translator
COSMIC 550	Passive Network Synthesis Subject to a Quantized Value Restraint
COSMIC 560	Function Contouring
COSMIC 580	Bearing Analysis
COSMIC 590	Root Factoring
COSMIC 630	Stress Analysis of Torsional Members
COSMIC 640	Torsional Vibration
COSMIC 680	Three-Dimensional Heat Transfer
COSMIC 700	Aerodynamic Supersonic Flow Parameters
COSMIC 730	Pipe Stress
COSMIC 1200	Z-Plane Nyquist Plot
COSMIC 1230	COBOL Braille Translator
COSMIC 1240	Root Solver
COSMIC 1280	FM Spectral Analysis
COSMIC 1540	Least Squares Analysis of Variance

—and many, many, others.



W. R. Walters

A Triac Amplifier for Servo Control—small size, low cost, and low power drain

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In servo control systems, it is often desirable to control an AC phase-control circuit with a DC voltage. This is usually done with a DC controlled trigger circuit which in turn fires the SCRs or recently a triac thru a complexity of capacitors, pulse transformers, and the like. It also was normal to have at least one (if not two) rectified DC voltages available for the trigger circuit. These voltages collapse when the thyristor(s) fire and reset the trigger timing capacitors.

In keeping up with the advances being made in the thyristors themselves, I have found a simple way to convert from manual control (variable resistor) to servo or DC control using a standard triac phase control circuit as the basic design reference. The typical phase-control circuit is shown in Fig. 1. This circuit uses a gate-controlled full-wave AC silicon switch (triac) with an integral triggering element (File 257, *RCA Databook*). By adding one high voltage transistor and two diodes as the active elements I can control the load voltage over a wide range.

In understanding how this is done it is best to review the basic circuit. Fig. 1 shows the trigger circuit as an AC load in series with the control resistor. The voltage source is the voltage across the triac. Each time the AC voltage reverses polarity, the triac extinguishes and becomes an open circuit. At this time the total AC voltage is applied to the control resistor and the AC trigger load. When the voltage at the triac gate becomes sufficient to fire the device, the triac becomes a short circuit until the next zero cross over. This, of course, means the voltage applied to the control resistor and the AC trigger load is collapsed. This allows the trigger circuit to get set for the next voltage swing. Varying the resistor varies the trigger time constant and, therefore, controls where (in the half cycle) the triac will fire. This, of course, will vary the relative power to the load.

By thinking of the triggering circuit as an AC load in series with the control resistor, it can be seen that by varying the resistor, the voltage applied to the trigger circuit will change. Also, if the control resistor could be varied with a DC level, the objective would be accomplished. It was found by the same token that if a DC-controlled AC load was put in parallel with the triggering load, the AC load voltage could be controlled just as in the original circuit. This is shown in Fig. 2.

The DC-controlled AC load is simply two power supplies of opposite polarity, loaded with one transistor. An external DC bias controls the amount of loading the transistor applies to the power supplies, which in turn draw more or less AC current. This, of course, acts as AC loading. Each power supply is made up of a diode, one resistor, and one capacitor. The transistor load is one transistor and one resistor.

This circuit is set up by first setting the DC bias current to zero and then adjusting the control resistor for a higher-than-desired load voltage. Finally, adjust the DC bias to bring the load voltage into the desired control range. The final circuit is shown in Fig. 3.

A final word should be said about ground reference. It is fine to say this is a DC control—but to what reference? The error signal should use the AC reference or common as its ground reference. In some system applications, a separate power supply with the line common as a reference for the main servo error circuits can be used to achieve isolation at the error transducer. Also, an isolation transformer between the line and this circuit would allow the common to be the same as system ground.

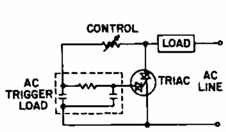

Fig. 1—Trigger circuit as an AC load in series with the control resistor.

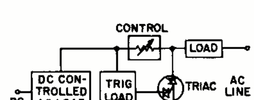

Fig. 2—DC load in parallel with the triggering load.

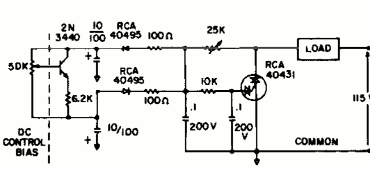

Fig. 3—The final circuit.

Optimized Synergetic Plane Change Maneuver

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A number of recent papers[1,2,3] have dealt with the rotation of the plane of an orbiting vehicle by means of an aerodynamic maneuver during which a continuous thrust is used to cancel drag. In each case, the vehicle's lift was directed horizontally and the thrust was directed along the velocity vector, although the effect of thrusting along other axes was evaluated in Ref. 3. This note shows that for low lift-to-drag ratio (L/D) a significantly more efficient maneuver may be made with the proper thrust orientation.

If the thrust axis is deflected from the velocity vector by the angle δ in the horizontal plane, the thrust magnitude (T) required to cancel drag (D) is $T = D \sec \delta$. The total lateral force (R) tending to rotate the velocity vector is then:

$$R = L + T \sin \delta = (L/D) T \cos \delta + T \sin \delta \qquad (1)$$

For the most efficient use of thrust, we wish to maximize the ratio of R to T, which requires that

$$\cot \delta = L/D \qquad (2)$$

Thus, the thrust vector should be directed normal to the total aerodynamic force vector. Since the vehicle would fly at its optimum L/D throughout the maneuver, a fixed orientation of the thrust axis is required and can be specified in the design stage when L/D is known. From Eqs. 1 and 2, the optimized ratio of lateral force to thrust is:

$$R/T = [(L/D)^2 + 1]^{1/2} \qquad (3)$$

which is to be compared to the value L/D in the case in which the thrust is aligned with the velocity vector. The results of the referenced papers may be reinterpreted by using the above value of R/T whenever L/D appears. (A miniscule decrease in orbital impulse would also occur, since less aerodynamic force is required than previously indicated and thus one need not descend quite as far into the atmosphere.)

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Regulator Supplies Two Complementary Regulated Outputs

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This regulator is used in airborne data-link equipment which has a zero-center meter for one of its visual displays. The meter is driven from a digital-to-analog converter (dacon) system, supplied with seven bits of binary information. A balanced dacon system (2-wire) was used rather than a single-ended system (1-wire and chassis ground) to utilize a complementary regulator which is a "dual" shunt regulator. This "dual" shunt regulator circuit supplies ±3 VDC to a 7-bit DC dacon. The voltages are supplied to a dacon resistor network through transistor bilateral switches. The overall loading effect of these switches is represented by the 200-ohm and 250-ohm resistors. For this application the dacon output is fed to a balanced output differential amplifier, the output of which is referenced to ground.

The regulator (Fig. 1) is supplied power from +8 volt ±5% and −8 volt ±5% sources. Initially, variable resistor *R12* adjusts the magnitude of the regulator output voltages (meter full-scale deflection) and variable resistor *R5* centers the output voltages about ground (meter set at zero).

Regulation design is concerned with the ability of a power supply to maintain a constant output voltage as the input voltage, load current, and temperature change:

$$dE_o = \frac{\partial E_o}{\partial E_i} dE_i + \frac{\partial E_o}{\partial I_L} dI_L + \frac{\partial E_o}{\partial T} dT$$

To maintain the 7-bit accuracy, for this application, the design goal for the total differential, dE_o, is ±30mV.

The regulator has the following calculated regulation factors and output impedances for three different values of beta:

$\beta = h_{fe}$	15	30	45
$\frac{\partial E_o}{\partial E_a} \approx \frac{\partial E'_o}{\partial E_a}$	0.08%	0.01%	0.01%
$\frac{\partial E_o}{\partial E_b} \approx \frac{\partial E'_o}{\partial E_b}$	*−1.27%	−0.69%	−0.47%
$Z_{OUT} = \frac{\partial E'_o}{\partial I_L}$	0.111Ω	0.0143Ω	0.004Ω
$Z'_{OUT} = \frac{\partial E'_o}{\partial I'_L}$	<0.0001Ω	<0.0001Ω	<0.0001Ω

* Minus sign is used to signify phase.

These regulation factors are sufficient for this application. Any comparable regulator circuit design would have similar values of regulation factors and output impedances since they are primarily dependent on the number of transistor amplifier stages (on total gain). This final circuit uses four differential amplifiers—two NPN and two PNP types—which have minimum betas greater than 30 over a temperature range from −55°C to +75°C. The output differential amplifiers, Q2 and Q4, are mounted on one 3x5x3/16-inch aluminum heat sink since they must dissipate 180 milliwatts.

Factors affecting the temperature stability of this regulator were calculated for three different values of beta:

$\beta = h_{fe}$	15	30	45
$\frac{\partial E_o}{\partial V_{R1}} \approx \frac{\partial E'_o}{\partial V_{R1}}$	0.499	0.500	0.500
$\frac{\partial E_o}{\partial V_{be_{2A}}} \approx \frac{\partial E'_o}{\partial V_{be_{2A}}}$	−0.0476	−0.0239	−0.0159
$\frac{\partial E_o}{\partial V_{be_{2B}}} \approx \frac{\partial E'_o}{\partial V_{be_{2B}}}$	0.001	0.0002	0.0001
$\frac{\partial E_o}{\partial V_{be_{4A}}} \approx \frac{\partial E'_o}{\partial V_{be_{4A}}}$	<0.0001	<0.0001	<0.0001
$\frac{\partial E_o}{\partial V_{be_{4B}}} \approx \frac{\partial E'_o}{\partial V_{be_{4B}}}$	<0.0001	<0.0001	<0.0001
$\frac{\partial E_o}{\partial \Delta V_1} \approx \frac{\partial E'_o}{\partial \Delta V_1}$	0.998	1.000	1.000
$\frac{\partial E_o}{\partial \Delta V_2} \approx \frac{\partial E'_o}{\partial \Delta V_2}$	0.499	0.500	0.500

where ∂V_{R1} is the change in the reference zener diode with temperature; and $\partial \Delta V$ is the change in the differential offset voltage with temperature ($\Delta V_1 = | V_{be_{1A}} - V_{be_{1B}} |$; $\Delta V_2 = | V_{be_{3A}} - V_{be_{3B}} |$).

Now the worst total differential, dE_o, can be calculated (assume $\beta = 30$).

$$\frac{\partial E_o}{\partial E_i} dE_i = \frac{\partial E_o}{\partial E_b} dE_b = 0.0069 dE_b$$

$$\frac{\partial E_o}{\partial I_L} dI_L = 0.0143 dI_L$$

$$\frac{\partial E_o}{\partial T} dT = \frac{\partial E_o}{\partial \Delta V_1} d\Delta V_1 + \frac{\partial E_o}{\partial \Delta V_2} d\Delta V_2 + \frac{\partial E_o}{\partial V_{R1}} dV_{R1} + \frac{\partial E_o}{\partial V_{be_{2A}}} dV_{be_{2A}}$$

$$= \partial \Delta V_1 + 0.5 d\Delta V_2 + 0.5 dV_{R1} + 0.0239 dV_{be_{2A}}$$

For the differentials, let: $dE_b = 0.05 \times 8 = 0.4\ V$

$$dI_L = \frac{E_a - E_o}{R_L} = \frac{8.0 - 3.3}{250} = 0.019A$$

$$d\Delta V_1 = 4\ \text{mV}$$

$$d\Delta V_2 = 4\ \text{mV}$$

$$dVR_1 = 9\ \text{mV}$$

$$dVbe_{2A} = 0.3V$$

Then,
$$dE_o |_{\beta = 30} = 0.0069 \times 0.4 + 0.0143 \times 0.019 + 0.004 + 0.5 \times 0.004 + 0.5 \times 0.009 + 0.0239 \times 0.3 = 0.021V$$

Likewise, for β = 15 or 45, the total differentials are:

$$dE_o |_{\beta = 15} = 0.032V$$

$$dE_o |_{\beta = 45} = 0.017V$$

Temperature tests using several differential amplifiers showed the following drift characteristics:

Temperature Range (°C)	*Supply (volts)*	*Drift (mV)*
+25 to +75	+3	+14
	−3	+ 4
+25 to −25	+3	−12
	−3	+ 1
+25 to −55	+3	−24
	−3	+ 4

An initial regulator design used two PNP transistors (2N995 and 2N1132) instead of *Q2* (MD1130) for the +3-volt-output amplifiers and two NPN transistors (2N706 and 2N697) instead of *Q4* (2N2914) for the −3-volt-output amplifiers. This version is less expensive and does not require a heat-sink; however, the minimum h_{fe} of the transistors is half that of the differential amplifiers. Consequently, at low temperatures the total differential, dE_o, can exceed the design limit of 30 mV ($dE_o/_{\beta = 15} = 32$ mV).

Temperature tests on the initial design showed that from 25°C to 75°C the +3-volt supply drifted 17 mV positive and the −3-volt supply drifted 9 mV negative. From +25°C to −55°C, the +3-volt supply drifted 31 mV negative and the −3-volt supply drifted 6 mV positive. Thus, the initial design was marginal for a 30 mV design limit.

This particular regulator application involving a zero center meter necessitates that the two outputs of the supplies track each other over the temperature range so as not to cause a significant off-set error. A slight change in the magnitude of the two outputs causes a slight change in the slope (scale factor) of the meter performance which is not a significant error as compared to an off-set error.

The final design is within the design goal of ±30 mV as verified by some design analysis and laboratory tests. Laboratory tests also showed that the final design has a two-to-one tracking improvement for the two outputs when compared to the initial design.

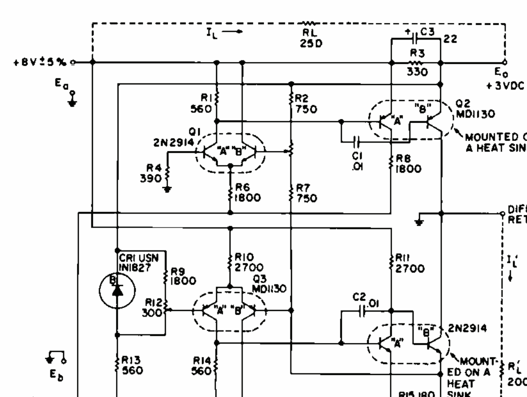
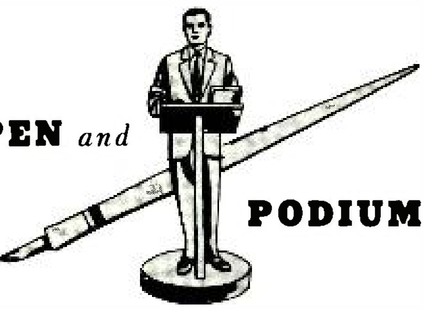


Fig. 1—Schematic diagram of the regulator.



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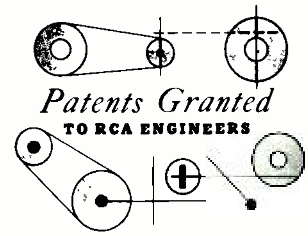

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PROFESSIONAL MEETINGS

DATES AND DEADLINES

Be sure deadlines are met—consult your Technical Publications Administrator or your Editorial Representative for the lead time necessary to obtain RCA approvals (and government approvals, if applicable). Remember, abstracts and manuscripts must be so approved BEFORE sending them to the meeting committee.

APRIL 30-MAY 2, 1968: **Spring Joint Computer Conference**, G-C, AFIPS, Convention Hall, Atlantic City, New Jersey. **Prog info:** T. R. Bashkow, Columbia Univ., 1312 S.W. Mudd, New York, N.Y. 10027

MAY 5-10, 1968: **103rd Technical Conference of the Society of Motion Picture and Television Engineers**, Plaza Hotel, Los Angeles. **Prog info:** Warren Strang, Hollywood Film Co., 956 N. Seward St., Hollywood, Calif. 90038

MAY 6-7, 1968: **Human Factors in Electronics Symposium**, G-MMS, Marriott Twin Bridges Motor Hotel, Washington, D.C. **Prog info:** H. P. Birmingham, U.S. Naval Res. Lab., Code 5120, Washington, D.C. 20390

MAY 6-8, 1968: **Aerospace Electronics Conference (NAECON)**, G-AES, Dayton Section, Dayton, Ohio. **Prog info:** IEEE Dayton Office, 124 E. Monument Ave., Dayton, Ohio

MAY 6-8, 1968: **Packaging Industry Tech. Conference**, G-IGA, Pheasant Run Lodge, St. Charles, Illinois. **Prog info:** IEEE Headquarters, 345 E. 47th St., New York, N.Y.

MAY 8-10, 1968: **Electronic Components Conference**, G-PMP, EIA, Marriott Twin Bridges Motor Hotel, Washington, D.C. **Prog info:** F. M. Collins, Speer Res. Lab., Packard Rd. & 47th St., Niagara Falls, New York 14302

MAY 14-17, 1968: **Int'l Electronics Conference**, G-ED, G-MTT, JCQE, AIP, Everglades Hotel, Miami, Florida. **Prog info:** R. W. Terhune, Ford Motor Co., Dearborn, Michigan

MAY 20-22, 1968: **International Microwave Symposium**, G-MTT, Howard Johnson Motor Lodge, Detroit, Mich. **Prog info:** G. I. Haddad, Univ. of Mich., Dept. of EE, Ann Arbor, Mich. 48105

MAY 23, 1968: **Vehicular Communications Systems Symposium**, G-VT, Int'l Hotel, Los Angeles, Calif. **Prog info:** C. R. Lindholm, Rand Corp., 1700 Main St., Santa Monica, Calif. 90406

JUNE 12-14, 1968: **Int'l Communications Conference**, G-ComTech, Philadelphia Section, Sheraton Hotel, Univ. of Penna., Phila., Penna. **Prog info:** R. S. Caruthers, IT&T Corp., 320 Park Ave., New York, N.Y. 10022

JUNE 17-18, 1968: **Chicago Spring Conf. on Broadcast & TV Receivers**, G-BTR, Chicago Section, Marriott Hotor Hotel, Chicago, Illinois. **Prog info:** N. T. Watters, Zenith Radio Corp., 6001 W. Dickens Ave., Chicago, Illinois 60639

JUNE 17-19, 1968: **Microelectronics Symposium**, G-PMP, G-ED, G-CT, St. Louis Section, Sheraton Jefferson Hotel, St. Louis, Missouri. **Prog info:** Remo Pellin, Monsanto, 800 N. Lindbergh, St. Louis, Missouri

JUNE 20-22, 1968: **IFAC Symposium on Optimal Systems Planning**, G-SSC, IFAC, Case Inst. of Technology, Cleveland, Ohio. **Prog info:** L. F. Kirchmayer, Gen'l Electric Co., Schenectady, N.Y. 12305

JUNE 23-28, 1968: **Summer Power Meeting**, G-P, Chicago Section, Sherman House, Chicago, Illinois. **Prog info:** IEEE Hdqs., Tech. Conf. Services, 345 E. 47th St., N.Y. 12305

JUNE 24-25, 1968: **Case Studies in Systems Control Seminar**, G-AC, Univ. of Michigan, Ann Arbor, Mich. **Prog info:** J. B. Lewis, Pennsylvania State Univ., Univ. Park, Pa.

JUNE 25-27, 1968: **Computer Conference**, G-C, Int'l Hotel, Los Angeles, Calif. **Prog info:** Harold Petersen, Rand Corp., 1700 Main St., Santa Monica, Calif.

JUNE 25-28, 1968: **Precision Electromagnetic Measurements Conference**, G-IM, NBS, URSI, Nat'l Bureau of Standards, Boulder, Colorado. **Prog info:** D. D. King, Philips Labs., 345 Scarborough Rd., Briarcliffe Manor, N.Y. 10510

JUNE 26-28, 1968: **Joint Automatic Control Conference**, G-AC, AACC, Univ. of Mich., Ann Arbor, Mich. **Prog info:** Michael Athans, EE Dept., MIT, Cambridge, Mass. 02139

JULY 15-18, 1968: **Design Automation Workshop**, SHARE-ACM, G-C, Washington Hilton Hotel, Washington, D.C. **Prog info:** H. Freitag, IBM Watson Res. Ctr., P.O. Box 218, Yorktown Heights, N.Y. 10598

JULY 15-18, 1968: **Nuclear & Space Radiation Effects Conference**, G-NS, Univ. of Montana, Missoula, Montana. **Prog info:** R. S. Caldwell, 23-72, Radiation Effects Lab., Boeing Co., P.O. Box 3707, Seattle, Wash.

JULY 23-25, 1968: **Electromagnetic Compatibility Symposium**, G-EMC, Benjamin Franklin Hotel, Seattle, Washington. **Prog info:** J. E. Maynard, 14589 S.E. 51st St., Bellevue, Washington 98004

AUG. 13-16, 1968: **Intersociety Energy Conversion Engineering Conference**, IEEE et al, Univ. of Colorado, Boulder, Colorado. **Prog info:** A. A. Sorensen, Martin-Marietta Corp., Mail Sta. 8600, Box 179, Denver, Colorado

AUG. 20-23, 1968: **Western Electronic Show & Convention (WESCON)**, Region 6, WEMA, Biltmore Hotel, Sports Arena, Hollywood Park, Los Angeles, Calif. **Prog info:** WESCON, 3600 Wilshire Blvd., Los Angeles, Calif. 90005

SEPT. 3-6, 1968: **Solid State Devices Conference**, IEEE, U.K. & Rep. of Ire. Sec., Inst. of Phys. & Physical Soc., IERE, Univ. of Manchester, Manchester, England. **Prog info:** IEEE Hdqts. 345 E. 47th St., New York, N.Y.

SEPT. 9-11, 1968: **Electrical & Aerospace Systems Convention (EASCON)**, G-AES, Sheraton Park Hotel, Washington, D.C. **Prog info:** David Coddington, Page Comm. Engrg., 3300 Whitehaven St., Washington, D.C. 20007

Calls for papers

AUG., 1968: **Society of Photographic Scientists and Engineers**, Tutorial Seminar on Ultra-Microminiaturization. **Deadline info:** Stuart Held, Ehrenreich Photo-Optical Industries, Inc., 623 Stewart Avenue, Garden City, New York 11533

SEPT. 9-12, 1968: **International Broadcasting Convention**, IEE, U.K. & Rep. of Ire. Sec., IERE, Royal Television Society, Grosvenor House Hotel, London, England. **Deadline info: 3/21/68 (syn) to:** R. G. Cox, IEE, Savoy Place, London, W.C. 2, England

SEPT. 12-13, 1968: **Solid State Sensors and Transducers Conference**, G-ED, Twin Cities Section, G-ED, Leamington Hotel, Minneapolis, Minn. **Deadline info: 4/1/68 (abst) to:** M. M. Atalla, Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304

SEPT. 25-27, 1968: **Ultrasonics Symposium**, G-SU, Statler Hilton Hotel, New York, N.Y. **Deadline info: 7/15/68 (abst) to:** R. W. Damon, Sperry Rand Res. Ctr., Sudbury, Mass.

NOV. 6-8, 1968: **Northeast Electronics Research & Engineering Meeting (NEREM)**, New England Sections, Sheraton Boston Hotel, War Mem. Auditorium, Boston, Mass. **Deadline info: 6/30/68 (papers) to:** IEEE Boston Office, 31 Channing St., Newton, Mass. 02158

NOV. 7-8, 1968: **Canadian Symposium on Communications**, Canadian Region, Montreal Section, Queen Elizabeth Hotel, Montreal, Quebec, Canada. **Deadline info: 4/30/68 (sum) to:** Alain Breton, P.O. Box 802, Station B, Montreal 2, Quebec, Canada

NOV. 12-14, 1968: **Automatic Support Systems for Advanced Maintainability Symposium**, St. Louis Section, G-AES, Sheraton Jefferson Hotel, St. Louis, Missouri. **Deadline info: 9/15/68 (papers) to:** IEEE Hdqts. 345 E. 47th St., New York, N.Y.

DEC. 2-3, 1968: **Applications of Simulation Conference**, G-C, G-SSC, ACM, SHARE, Roosevelt Hotel, New York, N.Y. **Deadline info: 4/1/68 (abst) to:** IEEE Hdqts., 345 E. 47th St., New York, N.Y.

DEC. 2-3, 1968: **Second Conference on Applications of Simulation**, Hotel Roosevelt, New York, N.Y. SHARE, ACM, IEEE, SCi. **Deadline info: 4/1/68 (abst) 7/31/68 (illus) 9/30/68 (papers) to:** Arnold Ockene, Program Committee Chairman, IBM Corporation, 112 East Post Road, White Plains, New York 10601

DEC. 4-6, 1968: **Circuit Theory Symposium**, G-CT, Hotel Hilton Plaza, Miami Beach, Florida. **Deadline info: 8/1/68 (papers) to:** B. Kinariwala, Univ. of Hawaii, Honolulu, Hawaii 96822

DEC. 9-11, 1968: **National Electronics Conference**, Region 4, et al, Conrad Hilton Hotel, Chicago, Illinois. **Deadline info: 8/1/68 (papers) to:** Nat'l Electronic Conf., 228 N. LaSalle St., Chicago, Ill. 60601

JAN. 21-23, 1969: **Reliability Symposium**, G-R, ASQC, IES, SNT, Palmer House, Chicago, Illinois. **Deadline info: 5/1/68 (papers) to:** J. E. Condon, Office Reliability & Quality Assurance, NASA Hdqts., Washington, D.C.

JAN. 26-31, 1969: **Winter Power Meeting**, G-P, Statler-Hilton Hotel, New York, N.Y. **Deadline info: 9/15/68 (papers) to:** IEEE Hdqts., 345 E. 47th St., New York, N.Y.

MAY 18-21, 1969: **Power Industry Computer Application Conference**, G-P, Brown Palace Hotel, Denver, Colorado. **Deadline info: 11/15/68 (abst) to:** W. D. Trudgen, Gen'l Elec. Co., 2255 W. Desert Cove Rd., P.O. Box 2918, Phoenix, Arizona

JUNE 22-27, 1969: **Summer Power Meeting**, G-P, Sheraton Dallas Hotel, Dallas, Texas. **Deadline info: 2/15/69 (papers) to:** IEEE Hdqts., 345 E. 47th St., New York, N.Y.

Engineering NEWS *and* HIGHLIGHTS

DR. BIEDENBACH ON PRODUCT ENGINEERING STAFF

Dr. Joseph M. Biedenbach was recently named Manager of Engineering Educational Programs by **Wendell C. Morrison,** Staff Vice President of Product Engineering. In this capacity, Dr. Biedenbach will be responsible for the Current Concepts in Science and Engineering Program and the Continuing Engineering Education Program.

Dr. Biedenbach received the BS in Engineering and the MS in Education from the University of Illinois in 1950 and 1951 respectively. He received the MS in Physics from the University of Michigan in 1957, and in 1964 received the PhD in Higher Education from Michigan State University. Dr. Biedenbach comes to RCA from the Indianapolis Campus of Purdue University where he served as the Assistant Dean for Administration since 1964. In addition, during the past year he has been the Acting Chairman of the Mechanical and Industrial Engineering Technology Department. As Senior Technical Instructor at General Motors Institute from 1951-1960, Dr. Biedenbach taught college physics, wrote laboratory manuals, developed a Nuclear Physics Lab and published a section entitled "Radioactive Decay" in Radioisotopes in Industry, a book developed for United Nations Peaceful Uses of Atomic Energy Program. As Senior Project Engineer in the Research Lab of A. C. Spark Plug Division of General Motors Corporation from 1961 to 1963, he served as Group Leader investigating encapsulation of gyro components, and high temperature ceramics. During this same period, he developed a film-type pocket dosimeter for use by the Armed Forces, an epoxy resin that was capable of impregnating calcium aluminate cement with a similar linear expansion coefficient as wire would on gyro armatures.

Dr. Biedenbach has been active in civic affairs and in 1960 was named "Young Man of the Year" by the Junior Chamber of Commerce in Flint, Michigan. In 1962 he was the recipient of the Silver Beaver award from the Boy Scouts of America. Among his current memberships in professional societies are: American Association of Physics Teachers, American Society for Engineering Education, American Society for Training and Development, Adult Education Association, National University Extension, Phi Delta Kappa, and the Cooperative Education Association.

NEW POST FOR JOHN WENTWORTH

John W. Wentworth was recently appointed Director of Educational Systems Engineering. In his new position, Mr. Wentworth reports to **C. V. Newsom,** Vice President of Education. Mr. Wentworth was graduated from the University of Maine with the BSEE degree in 1949, and joined RCA in July of that year. After several years of development and design work on color television studio equipment, he became Manager of TV Terminal Equipment Engineering, a position he held from 1953 to 1959. He then directed his attention to the field of educational technology, and served several years as Manager of Educational Electronics for the Broadcast and Communications Products Division. Teaching, writing, and lecturing activities were prominent throughout his career with the Broadcast Division. He developed and taught after-hours courses in color television engineering that were attended by several hundred RCA and NBC engineers; he authored numerous papers and a complete textbook on color television engineering; and he developed several courses for customer training in television tape recording and other aspects of broadcast technology. In early 1964, Mr. Wentworth was appointed Manager of the Current Concepts in Science and Engineering Program, an RCA staff activity aimed at supporting engineering managers and leaders in their efforts to stay abreast of new and fast-changing technologies. His title was then changed to Manager, Engineering Educational Programs in recognition of the fact that the scope of his position had widened to embrace the development of additional programs of continuing education for RCA engineering personnel. Mr. Wentworth is a Fellow of the SMPTE, and holds memberships in Tau Beta Pi, Phi Kappa Phi, the Society of the Sigma Xi, and the IEEE. He is a Registered Professional Engineer in New Jersey.

SID MILLER ELECTED TO AIAA

Sidney G. Miller, Manager of SEER, has been elected an Associate Fellow in the American Institute of Aeronautics and Astronautics. Announcement of Mr. Miller's election was made by the AIAA Membership Committee. Associate Fellow membership in the AIAA is accorded to individuals who have been in charge of significant engineering or scientific work, or who have done original work of outstanding merit, or who have otherwise made outstanding contributions to the arts, sciences or technology of aeronautics or astronautics.

As manager of SEER for RCA, Mr. Miller is responsible for the development and technical direction of new system concepts, proposals and programs for RCA Defense Electronic Products. Mr. Miller received an MA degree in Physics from Temple University in 1951 and an MS degree in Aeronautical Engineering from the Massachusetts Institute of Technology in 1954. He is a licensed Professional Engineer in the State of New Jersey.

LICENSED ENGINEERS

J. W. Kaufman, DEP-CE, PE-16069, N.J.

H. W. Brown, Jr. DEP-DCSD, PE-14672, N.J.

R. B. Marsten, DEP-AED, PE-15891, N.J.

S. Russell, DEP-AED, PE-15962, N.J.

On February 9, 1968, the Defense Communications Systems Division honored its authors for 1967 with a party at the Plaza Hotel in Camden. Some of DSCD's authors are shown at the registration desk. Left to right are Wes Fields (Host and DCSD Editorial Representative), Neal Van Dieft, Larry Wolff, Herb Goldman, Ralph Aiello, and Mike Frankel.

STAFF ANNOUNCEMENTS

Commercial Electronic Systems Division

B. Kreuzer, Division Vice President and General Manager, has announced the appointment of **J. P. Taylor,** Division Vice President, Marketing Programs.

A. F. Inglis, Division Vice President, has announced the appointment of **A. L. Hammerschmidt,** Division Vice President, Broadcast Engineering and Product Management.

Defense Electronic Products

I. K. Kessler, Division Vice President, appointed **S. Sternberg** Division Vice President and General Manager, West Coast Division.

J. M. Hertzberg, Division Vice President, International Communications Projects, announced the organization of International Communications Projects as follows: **W. B. Kirkpatrick,** Division Vice President, International Communications Marketing; **F. E. Greene,** Manager, International Policy and Negotiations; **R. Guenther,** Manager, Technical and Product Planning; **P. J. Schneider,** Manager, Advanced Telecommunications Systems; **C. W. Slaybaugh,** Manager, Transmission Sytems Marketing; **S. Spaulding,** Manager, Advanced Transmission Systems.

J. H. Sidebottom, Division Vice President and General Manager, Missile and Surface Radar Division; **M. N. Cinelli,** Plant Manager, Missile and Surface Radar Plant.

Information Systems

S. W. Cochran, Division Vice President and General Manager, Graphic Systems Division, appointed **P. C. Haines,** Manager, Marketing Department, Graphic Systems Division.

Research and Engineering

M. E. Karns, Vice President, Patents and Licensing, appointed **A. D. Gordon,** Manager, Planning and Coordination.

S. S. Barone, Staff Vice President, International Licensing, appointed **L. C. Dalto,** Manager, Licensee Relations—Far East.

W. C. Morrison, Staff Vice President, Product Engineering, appointed **J. M. Biedenbach,** Manager, Engineering Educational Programs.

RCA Communications, Inc.

H. R. Hawkins, President, has announced the executive responsibilities of RCA Communications, Inc. as follows: **E. D. Becken,** Vice President, System Operations; **L. R. Engler,** Vice President, Commercial Activities; **J. C. Hepburn,** Chief Engineer; **T. D. Meola,** Vice President, Traffic Operations; **E. W. Peterson,** Vice President, Finance; **H. Polish,** Vice President, Personnel; **G. A. Shawy,** Manager, Public Affairs; **L. W. Tuft,** Vice President and General Attorney.

Corporate Staff

T. A. Smith, Executive Vice President, Corporate Planning appointed to the staff of the Systems Development organization **R. H. Barnaby,** Manager, Programs, and **F. U. Everhard,** Manager, Systems and Technology.

Education

C. V. Newsom, Vice President, Education has appointed **J. W. Wentworth,** Director, Educational Systems Engineering.

A. B. Corderman, Director, RCA Instructional Systems has appointed **B. J. Pine,** Manager, Product Planning.

Electronic Components

J. B. Farese, Executive Vice President, Electronic Components appointed **C. H. Lane,** Division Vice President and General Manager, Industrial Tube Division.

H. A. DeMooy, Manager, Receiving Tube Operations Department, announced the organization of the Receiving Tube Operations Department as follows: **G. W. Farmer,** Plant Manager, Harrison Plant; **F. J. Lautenschlaeger,** Plant Manager, Woodbridge Plant; **N. A. Stegens,** Plant Manager, Cincinnati Plant; **W. H. Warren,** Manager, Receiving Tube Engineering; **E. Rudolph,** Manager, Equipment Design and Development; **G. A. Hiatt,** Manager, Quality and Reliability Assurance.

R. H. Pollack, Manager, Solid State Engineering has announced the organization of Solid State Engineering as follows: **M. B. Alexander,** Manager, Engineering Administration; **W. E. Babcock,** Staff Engineer; **M. Bondy,** Manager, Technology and Advanced Projects; **D. R. Carley,** Manager, HF Device Engineering; **E. E. Moore,** Manager, Signal Device Engineering—Digital; **E. M. Troy,** Manager, Engineering Services; **C. R. Turner,** Manager, Power Transistor Applications; **N. C. Turner,** Manager, Power Transistor Design; **B. V. Vonderschmitt,** Manager, Signal Device Engineering—Linear; **H. Weisberg,** Manager, Thyristor and Rectifier Engineering.

M. Bondy, Manager, Technology and Advanced Projects, announced the organization of Technology and Advanced Projects as follows: **H. S. Veloric,** Manager, Advanced Materials and Processes; **W. J. Greig,** Engineering Leader, Process Technology; **B. R. Czorny,** Engineering Leader, Materials Technology; **G. F. Damon,** Engineering Leader, Chemical Technology; **H. S. Veloric,** Acting Engineering Leader, Metallurgical Technology; **F. G. Block,** Manager, Equipment Technology; **W. B. Hall,** Engineering Leader, Advanced Equipment Concepts; **F. G. Block,** Acting Administrator, Technical Services; **H. C. Waltke,** Manager, Mechanical and Electrical Equipment Design; **J. H. Thorn,** Engineering Leader, Mechanical Equipment Design; **J. R. Hays,** Engineering Leader, Electrical Equipment Design; **R. Glicksman,** Manager, Optical Devices Design and Applications; **P. Nyul,** Engineering Leader, Design; **M. J. Grimes,** Engineering Leader, Packaging and Ceramics; **R. R. Gold,** Engineering Leader, Hybrid Circuits; **L. P. Garner,** Staff Engineer.

D. R. Carley, Manager, HF Device Engineering announced the organization of HF Device Engineering as follows: **J. W. Englund,** Engineering Leader, VHF Applications and Custom Products; **R. A. Duclos,** Engineering Leader, Process Development; **G. J. Gilbert,** Engineering Leader, VHF Device Design; **H. C. Lee,** Engineering Leader, UHF Applications; **L. R. Shardlow,** Engineering Leader, Packages and Mechanical Projects; **H. Sobol,** Manager, Microwave Microelectronics; **P. L. McGeough,** Engineering Leader, UHF/Microwave Device Design; **R. Rosenzweig,** Engineering Leader, Module Integration; **H. Sobol,** Acting Engineering Leader, Microwave Applications.

E. E. Moore, Manager, Signal Device Engineering—Digital announced the organization of Signal Device Engineering—Digital as follows: **J. Hilibrand,** Manager, Design and Technology; **R. R. Painter,** Engineering Leader, Bipolar I.C. Design; **M. Blumenfeld,** Engineering Leader, Bipolar I.C. Process, Assembly and Packaging; **A. H. Medwin,** Engineering Leader, MOS I.C. Design; **M. S. Saunders,** Engineering Leader, MOS I.C. Process, Assembly and Packaging; **M. V. D'Agostino,** Engineering Leader, Circuit and Array Development; **D. R. Gipp,** Engineering Leader, Bipolar I.C. Applications; **R. Heuner,** Engineering Leader, MOS I.C. Applications.

E. M. Troy, Manager, Engineering Services, announced the organization of Engineering Services as follows: **H. Miller,** Manager, Power Device Prototype Fabrication; **E. V. Space,** Manager, Photomask Operation; **G. L. Finne,** Manager, Design; **V. H. Ulrich,** Manager, Quality Assurance; **G. Wolfe,** Manager, Engineering Standards; **M. J. Sarullo,** Engineering Leader, Test Standards; **P. G. Webster,** Engineering Leader, Product Standards; **M. Zanakos,** Manager, Signal Device Prototype Fabrication.

C. R. Turner, Manager, Power Transistor Applications LF/MF has announced the organization of Power Transistor Applications LF/MF as follows: **R. S. Hartz,** Engineering Leader, Low/Medium Power Applications; **W. D. Williams,** Engineering Leader, Medium Frequency Applications; **R. L. Wilson,** Engineering Leader, High Power Applications; **C. R. Turner,** Acting Engineering Leader, Custom Products.

N. C. Turner, Manager, Power Transistor Design LF/MF has announced the organization of Power Transistor Design LF/MF as follows: **J. W. Gaylord,** Engineering Leader, Low Frequency Design; **H. R. Meisel,** Engineering Leader, Plastic Power/PCF Design; **J. Ollendorf,** Engineering Leader, Low Frequency Design; **N. C. Turner,** Acting Engineering Leader, Low Power/Medium Frequency Design.

B. V. Vonderschmitt, Manager, Signal Device Engineering—Linear has announced the organization of Signal Device Engineering—Linear as follows: **R. A. Santilli,** Manager, Linear Applications; **H. M. Kleinman,** Engineering Leader, I.C. Applications; **R. V. Fournier,** Engineering Leader, Discrete Custom Products; **R. G. Rauth,** Engineering Leader, I.C. Custom Products; **S. Reich,** Engineering Leader, Discrete Applications; **I. H. Kalish,** Manager, Design and Technology; **R. E. Kleppinger,** Engineering Leader, Discrete Device Design, Process and Assembly; **S. L. Starger,** Engineering Leader, I.C. Processsing, Assembly and Package; **H. Khajezadeh,** Engineering Leader, I.C. Design; **R. L. Sanquini,** Engineering Leader, Circuit Development; **B. J. Walmsley,** Engineering Leader, Test Technology.

H. Weisberg, Manager, Thyristor and Rectifier Engineering has announced the organization of Thyristor and Rectifier Engineering as follows: **D. E. Burke,** Engineering Leader, Applications Engineering/Circuit Development; **L. S. Greenberg,** Engineering Leader, Design Engineering Advanced Projects; **J. V. Yonushka,** Engineering Leader, Applications Engineering/Customer Service.

J. J. Hemberger, Manager, Equipment and Devices, Distributor Products has announced the organization of Equipment and Devices as follows: **R. J. Liska,** Manager, Merchandising and Planning, Electronic Equipment; **E. A. Dymack,** Manager, Electronic Equipment Operations; **J. F. Sterner,** Manager, Electronic Instrument Engineering; **J. P. Conroy,** Manager, Product Control and Quality Assurance; **W. J. Seaton,** Manager, Battery Products.

STAFF ANNOUNCEMENTS (cont'd)

K. M. McLaughlin, Manager, Equipment Design and Development has announced the organization of Equipment Design and Development of Television Picture Division as follows: **J. J. Biese,** Manager, Technical Service; **L. F. Blew,** Manager, Equipment Development Shop; **A. W. Comins,** Manager, Equipment Engineering—Lancaster; **E. H. Loomis,** Manager, Equipment Design and Development Administration; **C. E. Shedd,** Manager, Process Advanced Development; **J. F. Stewart,** Manager, Equipment Engineering—Marion; **M. R. Weingarten,** Manager, Equipment Advanced Development.

D. W. Epstein, Manager, Conversion Tube Operations appointed **R. E. Simon,** Director, Conversion Devices Laboratory—Princeton.

C. A. Meyer, Manager, Commercial Engineering Technical Services appointed **Miss E. McElwee,** Manager, Engineering Publications.

International Division

Robert L. Werner, Executive Vice President and General Counsel appointed **S. K. Nadelson** Senior Counsel, RCA International Division.

PROMOTIONS

to engineering leader and manager

RCA Communications, Inc.

Tin Win: from Design Engr. to *Ldr., RFID* (Mgr., Satellite & Radio Engineering, N.Y.)

Consumer Electronics Division

W. E. Davis: from Mbr., Engrg. Staff to *Ldr., Engrg. Staff* (R. D. Flood, Indpls.)
W. M. Workman: from Mbr., Engrg. Staff to *Ldr., Engrg. Staff* (R. D. Flood, Indpls.)
B. L. Borman: from Mbr., Engrg. Staff to *Ldr., Engrg. Staff* (R. D. Flood, Indpls.)
R. R. Russo: from Mbr., Engrg. Staff to *Ldr., Engrg. Staff* (M. F. Troy, Indpls.)
D. E. Roeschlein: from Engrg. Admin. & Servs. to *Ldr., Liaison Engrg.* (Indpls.)

RCA Service Company

W. R. Haldane: from Engr. to *Ldr., Engrs.* (B. M. Brush, Gov't Support Systems)
R. L. Lindberg: from Ship Instruments Engr. to *Mgr., Radar-Ship* (B. L. Dillon, ARIS Ship)
J. D. Maines: from Sys. Serv. Engr. to *Ldr., Site Maint. Analysis* (H. S. MacGregor, Thule)
D. D. Selle: from Sys. Serv. Engr. to *Ldr., Sys. Serv. Engrs.* (A. C. Hodges, Springfield, Va.)
S. S. Nenson: from Assoc. Engr. to *Mgr., Navigation & Data Handling* (M. J. Van Brunt, MTP, Cocoa Beach, Florida

Electronic Components

J. A. Stumpf: from Ldr., Prod. Devel. to *Mgr., Prod. Engrg. Conv. Tube* (Mgr., Vidicon Operation, Lanc.)
R. E. Berlin: from Sr. Engr. to *Mgr., Thermoelectric Tech. Devel.* (L. J. Caprarola, Hr.)
G. Silverman: from Engr. to *Admin. Thermoelectric Engr. Plans & Prop.* (L.J. Caprarola, Hr.) West Coast Division

West Coast Division

D. A. Vigil: from Sr. Mbr., Engr. Staff to *Ldr., Engr. Staff* (Cornwall/Groce, Van Nuys)

Defense Communications Systems Division

J. Pane: from AA Engr. to *Ldr., D&D Engr.* (T. L. Genetta, Camden)

Information Systems

J. J. Schell: from Ldr., Tech. Staff to *Mgr., Comm. & Spec. Sys. Design* (H. N. Morris, W. Palm)
W. E. Salzer: from Sr. Mbr., D&D Engr. to *Ldr., Tech. Staff* (H. N. Morris, W. Palm)
J. Bragdon: from Sr. Mbr., D&D Engr. to *Ldr., Tech. Staff* (H. N. Morris, W. Palm)
J. V. Williamson: from Ldr., Tech. Staff to *Mgr., Test Equip. Design* (R. E. Acuff, W. Palm)
D. H. Montgomery: from A Engr. to *Ldr., D&D Engrs.* (G. Wass, Camden)
M. E. Steiner: from A Engr. to *Ldr., D&D Engrs.* (G. Waas, Camden)
M. F. Kaminsky: from A Engr. to *Ldr., D&D Engrs.* (J. K. Mulligan, Camden)

PROFESSIONAL ACTIVITIES

Advanced Technology, Camden, N. J.

M. S. Corrington Leader, Computer Applications, was re-elected Chairman-Sponsor for the 1969 International Solid State Circuits Conference. **B. Walker,** Leader, Computer Circuits and Packaging, was recently appointed Chairman, Packaging Sub-Committee, Computer Elements Committee, IEEE Computer Group. **R. J. Farquharson** who holds office in both the local and national levels of the IEEE Group on Parts, Materials, and Packaging Techniques will be chairman of a technical session on interconnections at the Electronic Components Conference in Washington, D. C., May 10. —*G. Boose*

Central Engineering, Camden, N. J.

M. S. Gokhale, Central Engineering, participated as a guest lecturer in the first of a series of ASTM Seminars on Standardization. The program provided basic instruction for those relatively new in the field, and served as a refresher course for those who have been working with Standards. The seminar was developed primarily for middle management personnel in industry, business, government and universities, i.e. for those who because of their other experiences, are called upon to undertake standardization activities.—*J. R. Hendrickson, Sr.*

Electronic Components, Lancaster, Pa.

Merle V. Hoover, formerly of Super Power Tube Operations at RCA, Lancaster, Pa. and currently Manager of Linear Integrated Circuit Planning of RCA Somerville, was the speaker at the Susquehanna Section of the IEEE at Lancaster, Pa. Mr. Hoover's topic was "Monolithic Integrated Circuits . . . Yesterday, Today, and Tomorrow." —*J. M. Forman*

Astro-Electronics Division, Princeton, N. J.

J. McClanahan and **J. Fagan** have been appointed to the Nominations Committee, Mid-Atlantic Chapter, Institute of Environmental Sciences. **A. G. Holmes-Siedle** has been named Vice-Chairman (Publications), Radiation Effects Committee of IEEE-GNS. **S. H. Durrani** was appointed to Editorial Review Board of *Telecommunications* magazine, published by Horizon House. —*S. Weisberger*

RCA Communications, Inc., New York, N. Y.

A. Avanessians and **A. Canfora** have been appointed members of the Education Committee of IEEE Communications Technology group. In this capacity they are participating in meetings and help in organizing the lecture series on Integrated Circuits. —*M. L. Hutchins*

Medical Electronics Division, Trenton, N.J.

Ulrich Frank, Vice-Chairman of the Philadelphia Chapter of the Group on Parts, Materials, and Packaging of the IEEE, has been elected a Senior Member of IEEE. **L. E. Flory,** Chief Scientist of the RCA Medical Electronics Division, was guest speaker for the Mohawk Valley Engineers' Executive Council, commemorating 1968 National Engineers' Week held at Twin Ponds, Utica, N. Y., Feb. 21, 1968.

AWARDS

Astro-Electronics Division, Princeton, N. J.

P. Wood of the Systems Engineering Activity at AED was named "Engineer of the Month" for January. Mr. Wood devised a system that uses a general purpose computer in special test equipment for economic and reliable testing of spacecraft. Earlier he devised a method for increasing the accuracy of earth photographs using scan-correction techniques on a general purpose computer.

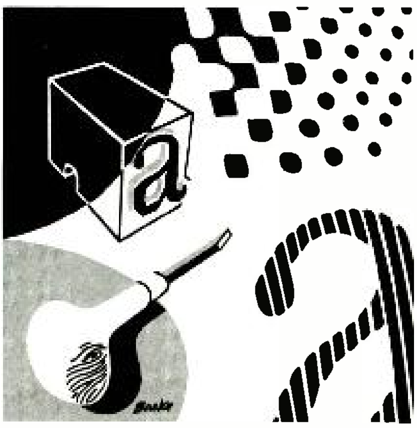
Aerospace Systems Division, Burlington, Mass.

H. W. Silverman of Systems Support Engineering was selected December "Engineer of the Month" at ASD for his technical accomplishments on Project CCOS. Mr. Silverman extended the concepts of multiprogramming to handle automatic test stations, each having a man-machine interface.

Missile and Surface Radar Division, Moorestown, N. J.

The following M&SR engineers were selected to receive Technical Excellence Awards for the Third Quarter of 1967: **R. D. Bachinsky**—For outstanding technical effort on the SPARTA Data Analysis, particularly for his work on the frequency dependence of radar back-scatter from the wake of reentering vehicles. **E. G. Crenshaw**—For outstanding performance in real-time computer programming and the attendant system integration of the Coherent Signal Processing installation on the FPQ-6 radar at Wallops Island, Virginia. The simulations and ambiguity resolutions by the computer are considered state-of-the-art program techniques. **N. V. Harding**—For outstanding performance on the ICW Transmitter Feasibility Study. Mr. Harding had the drafting responsibility for the densely packaged modulator unit of this transmitter including layouts, fabrication, and modification drawings required to build the unit. **J. O. Horsley**—For resourcefulness and creativity in the design and development of the Transmitter Control Group for the ADAR program. He helped design the computer interface to maximize the use of existing RCA circuit designs. Then by clever logic design, he reduced the complexity of the sub-system.

about graphic arts—a brief look at this issue



To the editors, grubby with graphite and printer's ink, the high quality result of the electronic typesetter and the color separator (see the inside cover of this issue) is an eye opener. We congratulate the Graphic Systems Division for their new electronic "upstarts"—Videocomp and Color Scanner —that promise to revolutionize the printing industry.

This issue—devoted to Graphic Systems and Devices—started two years ago with early planning ideas by **Jack Gold, Nelson Crooks,** and **Chet Sall.** Those early plans were altered and updated every two months until finally the manuscripts were ready for approval editing, and printing.

Special thanks go to **Jack Gold,** author of the introductory paper and coordinator of the entire issue. He molded the early plans, issued a timetable for abstracts and rough manuscripts, and followed through to a successful conclusion. Jack's paper provides some much-needed "stage-setting" by describing the purpose, engineering organization, and facilities of the Graphic Systems Division; in addition, he includes a glossary of graphic-arts terminology . . . a jargon of the graphic arts that has both befuddled readers and amused editors for years—and behold, here it is used in nearly every paper this issue. For once, someone is talking a new technology that *we* can understand.

The reader's introduction to this intriguing field of graphic arts is further enhanced by **John Walsh's** survey; through history and example, he bridges the gap between the old artisan craft and the present, automated, giant industry. Although Walsh's paper contains some introductory material on the development of typefonts, it emphasizes mainly the printing industry. **Alan Taylor**—a type designer by profession and manager of typefont development for GSD —provides a more thorough look at typefont development, starting with Gutenberg's movable wooden blocks and closing with Videocomp's scanning electron beams, introducing along the way, some of the type designer's rationale. Complementing Taylor's paper, **Gerry Walter**—chief engineer of GSD—covers type design as it relates specifically to the Videocomp electronic typesetter.

When reading the papers in this issue that discuss Videocomp, it might be well for the reader to think of the Videocomp system as consisting of three subsystems:

1) The *keyboard input subsystem* which is used by several operators to keyboard manuscript data and typographic instructions onto paper tape;
2) The *composition data processing subsystem* which uses the paper tape and suitable programming instructions to generate a magnetic tape containing specific page information; and
3) The *output subsystem* which consists of three major elements: a magnetic tape reader; a digital control unit; and a photocopy unit. This subsystem writes the various characters, as specified by the magnetic tape, on the face of a cathode ray tube. These characters are then transferred to photographic film as the final output copy.

Relating strongly to the data processing subsystem, the paper by **Walt Stephan** explains the many uses of the computer at GSD; also, the paper by **Bob Rorke** describes the methods for automatically hyphenating words and justifying lines of type using the computer. **Harold Morris** of Information Systems Division describes the Series 1600 computer, a general purpose system that satisfies the specific needs of the digital controller portion of GSD's new Videocomp 70/830 line.

Supporting the photocopy portion of Videocomp are two papers: **Fred Schrotz** covers the recording system—CRT, lens, and photographic film—and describes the various parameters that determine output quality; **Dick Klensch** and **Elvin Simshauser,** discuss the heart of the photorecording system, the CRT.

Culminating the more detailed discussions of Videocomp, **Joel Greenberg** and **Roger Schubert** present an implementation of the system as it could be applied to automate the composing operations.

Ray Hallows and **Dick Klensch** describe some of advanced methods now being considered for producing halftone photographs electronically. Traditional methods change dot size to achieve varying density; one method proposed in the Klensch, Hallows article is an FM-technique which holds dot size constant and varies the spacing between dots.

Some of the advanced thinking in Graphic Arts is represented in the three Electrofax papers by **Gil Gillespie, Dr. Alex Ross,** and **Sig. Johnson**—all of the RCA Laboratories. Yet a further extension of Videocomp can be seen in **Bill Stephens's** paper, which describes how printing plates could be produced by using controlled laser beams instead of the electron beams that are now used to write letters on the face of a CRT. **Dennis Woywood's** article shows a present application of this laser-beam-writing concept applied to the production of very high-resolution photos.

Because we are professionally dedicated to improving communications among engineers, we are proud of developments described in this magazine; they are helping to bring more information to more people—faster! Likewise, we are justifiably proud of two papers in this issue that deal directly with the problems of engineers communicating. **Lytton Bulwer's** paper, occupying the "Engineer and the Corporation" slot, gives one engineer's opinions on conducting an effective meeting. **Mike Geverd,** responsible for helping to publish the work of our engineers and scientists in coordination with the TPAs, provides basic information on how, why, when, and where to publish.

In every issue regardless of theme, there are several excellent non-thematic papers that the reader shouldn't overlook. This issue is no exception (see pages 70 through 82). The editors also call your attention to the bantam-sized gems always contained in the "Notes" section of every issue (pages 83 through 85).

As we go to press with this Graphic Systems issue, we are pleased to acknowledge the announcement of a new product—the Videocomp 70/830. This new Videocomp typesetter, writing 6000 characters per second, can set the complete text for a magazine page in less than four seconds, or write information for microfilm storage at computer speeds. A more complete story of this new product is covered in the April 1968 issue of TREND.

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The RCA Review is published quarterly. Copies are available in all RCA libraries. Subscription rates are as follows (rates are discounted 20% for RCA employees):

	DOMESTIC	FOREIGN
1-year	$4.00	$4.40
2-year	7.00	7.80
3-year	9.00	10.20

RADIO PHONOGRAPH ENGINEERING RELOCATES

The Radio Phonograph Engineering design section of the Consumer Electronics Division has moved to new facilities in the Rockville Road Plant on the western outskirts of Indianapolis. This engineering facility has been split into two sections: RV Engineering and AM/FM Tuner Operations. The latter facility has designed (and will operate) the new computer control component assembly and test operations for the manufacture of the AM/FM tuner amplifier for both radio phonograph and television.—*K. A. Chittick*

ERRATA

In my article, "A Survey of the Last Decade of Computer Development" in the Dec. 1967-Jan. 1968 issue of the RCA ENGINEER, I said that the LARC computer was a failure both technically and financially and that it did not meet its design goals. It appears that I had some bad information. W. F. Simon of Univac who supervised the acceptance test of LARC at Livermore (in 1960) has informed me that although the machine was late and underpriced, it did meet all its original design goals. I wish then to concede my error and to apologize both to Mr. Simon and to LARC.—*Saul Levy*

DEGREES GRANTED

H. Amemiya, AT, Cam. ....PhD., Electrical Engineering, Univ. of Tokyo, 12/67
A. Reich, MSR, Mrstn. ....PhD., Electrical Engineering, Univ. of Penna., 8/67
B. R. Schwartz, CE, Cam. ....MBA, Drexel Inst. of Tech., 3/68
A. J. Korenjak, Labs., Pr. ....PhD., Electrical Engineering, Princeton Univ., 10/67

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