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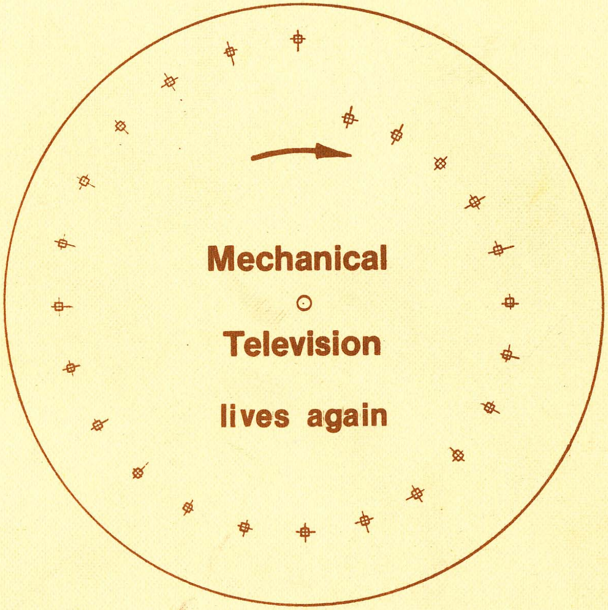

The Mechanics of Television

Peter F. Yanczer

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The Story of Mechanical Television

By Peter F. Yanczer

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Many of the drawings and photographs in this book are the same ones used to illustrate and explain mechanical television, to magazine readers in 1926...1927...1928....... The following figures are reprinted, with the permission of:

"Radio News" magazine.
Sep. 1926, Fig. 2.4a
Aug. 1928, Fig. 8.4
Sep. 1928, Figs. 2.6, 2.7
Nov. 1928, Figs. 7.8, 8.8
Aug. 1930, Figs. 3.1, 3.3
Feb. 1932, Figs. 3.5, 7.2, 7.4
Mar, 1932, Figs. 1.1, 1.2, 1.3

"Television News" Magazine.
Mar/Apr 1931, Figs. 8.5, 8.9
May/Jun 1931, Fig. 2.9
Jul/Aug 1931, Fig. 3.2
Sep/Oct 1931, Fig. 2.8
Mar/Apr 1932, Figs. 2.4b, 2.12, 3.4, 4.4, 4.7, 4.8, 4.19, 8.1, 8.2, 8.10
May/Jun 1932, Figs. 2.11, 7.5

"Radio Craft" Magazine.
Aug. 1941, Figs. 5.2, 5.3, 5.4

P. F. Y.

About the Author . . .

Peter Yanczer began in the field of Radio at the age of 10, with his first crystal set. His interest continued thru his teens and prior to WWII, he was employed, servicing radio receivers. During the Korean conflict, he served in the Navy as a Radar technician. In the following years, he completed courses in electronics and in machine shop practices and received a degree in Electronics from Washington University. Peter Yanczer now has over 20 years of engineering and management experience in electronic design, with two large Aerospace firms in St. Louis, Missouri. He also spent 11 years, teaching Radio, Television and Electronic courses at the Ranken Technical Institute.

Please make the following corrections:

Pg. 77, The bandwidth requirement for 48 lines, 15 frames per second is shown as 8640 Hz. The value should be 17280 Hz.

Pg. 84, Fig. 7.20 shows a type μA7912, regulator I.C. This should be a type μA 7812.

TABLE OF CONTENTS

INTRODUCTION		1
CHAPTER ONE	A Brief History of Television	2
CHAPTER TWO	Scanning and Scanning Disks	10
CHAPTER THREE	Synchronization and motors	24
CHAPTER FOUR	Television Lamps	32
CHAPTER FIVE	Photoelectric Devices	43
CHAPTER SIX	Television Optics	50
CHAPTER SEVEN	The Electronics	64
CHAPTER EIGHT	Television Cameras and Receivers	92
CHAPTER NINE	Building a System	104
INDEX		137
NOTES:		141
Electronic magnification		APPENDIX A
Scanning disk design charts		APPENDIX B
Motor Speed Strobetach		APPENDIX C
Scanning Disk Magnetic Brake		APPENDIX D
Sheet Metal Support Structure		APPENDIX E
Disk Driving Motor Modifications		APPENDIX F

"If a thing is very difficult; it is as good as accomplished; if it is impossible, it will take a little time."

C. Francis Jenkins, 1920

INTRODUCTION

When we sit and are "entertained" by our 25 inch color TV, we seldom if ever think about the research, experimentation and effort that have made these pictures possible. I'm sure we never stop to realize that these efforts go back more than 100 years, to 1847 and before when the first crude picture transmission system was demonstrated. We normally think of TV as a post WWII phenomenon since that was the start of television as we know it.

The efforts, failures and successes of the early pioneers lie forgotten in obsolete texts and dusty magazines. Forgotten they should not be, because they made possible the television of today.

This book is an attempt to collect into a single text, at least a brief description of the more important of these experiments and to give credit to these pioneers of television. It particularly traces the development of the scanning disk equipment which preceded the cathode ray systems we now use.

As an added attraction it includes some circuits using modern technology which can be used to duplicate and enhance the old scanning disk systems. The avid experimenter can use this information along with his own skills and ingenuity to design and build systems which can demonstrate where the TV industry might have gone had it not been for the inventions of Farnsworth and Zworykin and the cathode ray tube.

One hundred and fifty years ago the telegraph captured the imagination of the scientifically minded, much as video and computer systems do today. After the invention of the first practical telegraph system by Morse in 1832, attention centered on means of recording the coded signals. Alexander Bain, a Scottish watchmaker, constructed a printing telegraph model in 1840. His telegraph used a strip of chemically treated paper moving on a metal cylinder under a metal point. When current flowed between the point and the cylinder, the paper changed color to form dots and dashes, corresponding to the telegraph message. Bain also is said to have constructed a crude form of pictorial message system using many wires to convey the information.

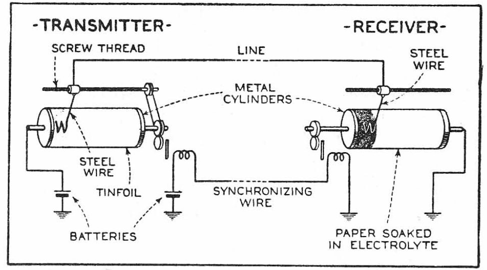


FIG. 1.1 BAKEWELL'S FACSIMILE SYSTEM. 1847

The first practical electrical picture transmitting system was actually set up by Frederick Bakewell in 1847 between the cities of London and Brighton, some 50 miles distant. It transmitted recognizable facsimiles of handwriting or pictures which had been drawn on a sheet of tinfoil coated with insulating varnish. The system included two cylinders about 6 inches in diameter, one at the transmitter, the other at the receiver, (see Fig. 1.1). The message or picture was drawn on varnish coated foil and wrapped around the transmitting cylinder. As the cylinder rotated, a steel wire bore against its surface and was moved along the length of the cylinder by a screw. The surface of the cylinder was therefore "scanned" by one continuous line. When the steel wire touched the part of the picture represented by insulating varnish, the line current was interrupted until the wire again touched the unvarnished tinfoil. At the receiver, a similar cylinder rotated in synchronism with the one at the transmitter. However, the receiver cylinder was wrapped with chemically treated paper, as in Bain's printing telegraph. Another steel wire pressed on the paper and stained the paper blue whenever line current was flowing. The image at the transmitter was therefore reproduced as a blue background on which appeared white lines corresponding exactly to the varnish lines on the tinfoil. Keeping the two cylinders exactly in step was a problem and Bakewell developed a synchronizing method using a pendulum principle, which he later replaced with an electromagnetic device using a separate wire to send synchronizing pulses to both cylinders.

The next step in television was the discovery that selenium changes its resistance when exposed to various levels of light. During the period when the transatlantic cable first came into use, it was observed by one of the workers, that his electrical apparatus was sensitive to light. The effect was traced to components in the equipment that were made of selenium. As a result of this chance discovery, selenium cells of various types were subsequently made.

In 1881, Selford Bidwell described a system with a receiver exactly like Bakewell's except for a small drum which provided a picture about 2 inches square. The transmitter however, operated on a different principle, (see Fig 1.2). The picture or image to be transmitted was projected onto a ground glass screen. Behind the screen, a selenium cell with a pinhole aperture, moved slowly up and quickly down. As it did this, the cell would respond to the various light values of the picture by corresponding changes in resistance. As the selenium cell and its pinhole moved up and down, it also moved across the the picture, 1/64th of an inch for each

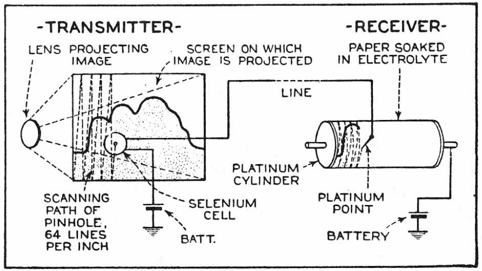


FIG 1.2 BIDWELL'S "STILL TELEVISION." 1881

vertical "sweep". At the receiver, the drum rotated continuously and a lead screw moved a platinum point across its surface, 1/64th of an inch for each rotation. Bidwell pointed out that the pictures being transmitted were not limited to drawings on tinfoil or other material, but were the projected images of actual objects or scenes. Bakewell's system might be called "still television" because the subject would have to hold a pose for several minutes while a picture was being formed at the receiver.

A few years before Bidwell developed his system, the first motion pictures had made their appearance. They depended of course on the persistence of vision. If slightly different poses are seen at a rate of approximately 15 or more per second, it appears as continuous motion. Naturally this idea intrigued those who were interested in electrical picture transmission. A Frenchman, Senlecq, proposed a multiple-wire television system in which the receiving end consisted of a commutator sliding over the terminals of many separate wires connected to individual lights on a large screen. Some 46 years later, in 1927 , Bell Laboratories improved on the original idea by using a special multiple segment neon lamp instead of filament lamps and transmitted pictures by both telephone wires and radio signals.

NIPKOW

One of the best known names in early television is Paul Nipkow. In 1884, the German patent office granted him a patent showing all the details of a complete and workable television system. Fig. 1.3 is based on one of his drawings. Both the transmitter and receiver contain a disk, perforated with small holes along similar spiral curves, which rotate in synchronism. The small holes, sweeping by the picture along successive vertically displaced horizontal lines, trace or "scan" each element of the picture in turn. The scanning disk was the heart of Nipkow's system in 1884 as it was the heart of most television transmitters and receivers through 1932, the last year of any major activity for mechanical systems.

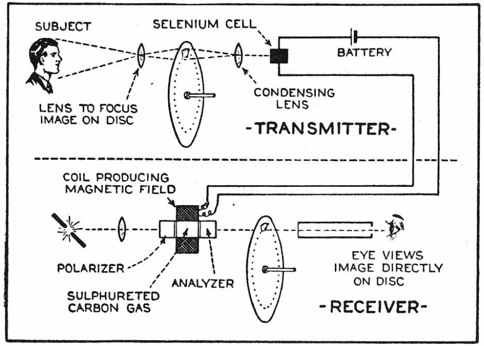


FIG 1.3 NIPKOW'S DISK TELEVISION SYSTEM. 1884

At the transmitter, the image of the subject was focused directly on the disk. On the opposite side of the disk, a condensing lens converged the rays from the image, as they passed through the disk and onto a selenium cell connected with wires to the receiver. At the receiver, an arc light provided illumination through a condensing lens and polarizer. The polarized light then passed through sulphureted carbon gas or other substance which could

modulate the light in accordance with the the changing "picture" currents from the selenium cell. The modulated light passed through the receiving disk and was viewed directly by the eye. This electric modulation of polarized light, proposed by Nipkow in 1884 was applied many years later to theater television projection.

Nipkow also proposed stereoscopic television and the use of infra red light at the transmitter. Years later, these ideas were put into practice by others, but full practical exploitation of Nipkow's ideas had to wait on three developments in other fields. The selénium cell followed the changes in light too slowly for efficient television use. In 1890 Elster and Geitel developed a much improved photo-electric cell. Similarly, the weak picture currents at the receiver were a serious problem for the early experimenter. In 1907, DeForest invented the vacuum tube amplifier, with which signals could be amplified to greater levels. Finally, although the modulated arc light receiver might have been the best system for theater sized images, for smaller installations, the neon glow tube, invented by D. McFarland Moore in 1910, was much simpler and more efficient.

Not until after World War 1, did Nipkow's television principles bear actual fruit in the work of C. Francis Jenkins in America and John L. Baird in England. Baird developed his first prototype in 1922. He improved on the Nipkow disk by mounting a glass lens in each hole on the rotating disk and placed a light sensitive photocell a short distance behind it. In 1923, Jenkins revised the camera scheme by using two rotating disks containing glass prisms. His camera deflected a beam of light to and fro across a stationary subject. A photocell responded to the differing intensity of light reflected by different regions of the subject.

At first, their images were merely outlines, showing no detail. In April, 1925, Baird transmitted television of this sort over the distance of a few feet before the patrons of a London department store. The subject was a ventriloquist's doll which he used in most of his laboratory work. Fig. 1.4 shows Baird's original "Televisor".

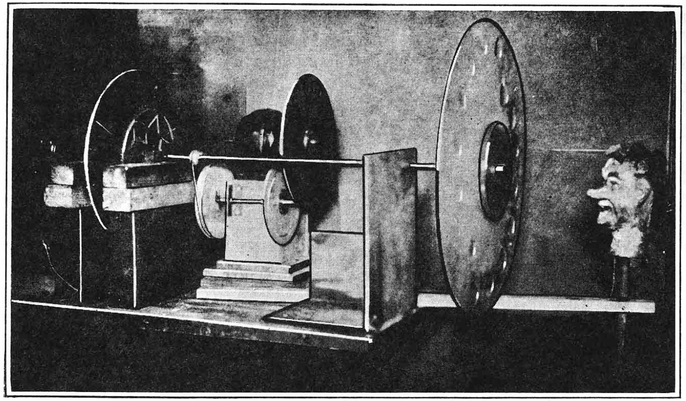


FIG 1.4 BAIRD'S FIRST "TELEVISOR"

This crude but workable apparatus, undoubtedly the result of much labor on the part of Baird, who, like most inventors dependent upon their own resources, had very little money with which to carry on his experiments, gives an idea of how simple is the essential apparatus required for the production of television signals. The various disks function to break up the object to be transmitted into many tiny dots so that the light finally reaching the photoelectric cell is broken up into many consecutive impulses each of which corresponds in intensity to one particular spot of the subject. This original model has been placed on view at the Science Museum, at South Kensington, London

In June, 1925, a group of Washingtonians assembled in Jenkins' laboratory and watched a flickering image of a toy windmill which was seen to revolve. The windmill itself was turning in Anacostia, 5 miles away. The television signal was transmitted by radio. About the same time, he demonstrated the first "Radio Movies", which was the transmission of movie film by radio. During the following January, Baird demonstrated an improved television system, which for the first time produced recognizable faces.

In 1927, television "in the grand manner" was demonstrated in New York by Bell Laboratories. This great research organization quite naturally eclipsed the best efforts of the pioneers. Hundreds of men planned and built the Bell equipment and made vast improvements in existing techniques but they discovered no new principles.

During the next few years, progress came in the form of improved resolution, synchronization and larger, brighter pictures. The improved resolution was the result of more and more lines in the image, the move to higher frequencies for transmission and improved amplifiers. Early systems used 16 or even fewer lines to make up the image. Much of Jenkins early work was done with 24 lines. Images with 48 lines were regularly broadcast by numerous stations and by 1932, some were converting to 60 lines. In Europe and England, some work was being done on systems with 120 or even 240 lines.

During this period there was a move to synchronous motors or variable speed motors, controlled by synchronizing signals transmitted separately or as a part of the picture signal. Images on the disk were generally small, in the range of 1 to 2 inches square. Magnifying lenses were used to increase the size, by a factor of 2, 3 or more times, but always with an associated loss in brightness. Larger and brighter pictures really came in with the use of neon crater lamps in conjunction with disks containing lenses or mirrors....And of course, larger pictures made it necessary to improve the resolution, etc...., again.

CATHODE RAYS

By 1932, as the limitations of Nipkow's disk and other mechanical scanning methods became apparent, one might have expected that someone would think of using the inertialess electron beam of a Braun cathode ray oscillograph tube. It came to the attention of the English-speaking world in 1908, through a letter to the magazine "Nature". In June of that year, Mr. Campbell Swinton wrote: "...may I point out that...this part of the problem of distant electric vision can probably be solved by the employment of two beams of cathode rays (one at the transmitter, the other at the receiver) synchronously deflected by the varying fields of two electromagnets placed at right angles to one another and energized by two alternating currents of widely different frequencies so that the moving extremities of the two beams are caused to sweep synchronously over the whole of the required surfaces within the tenth of a second necessary to take advantage of visual persistence. Indeed, so far as the receiving apparatus is concerned, the moving cathode beam has only to be impinged on a sufficiently sensitive fluorescent screen and given suitable variations in its intensity, to obtain the desired result." Cathode-ray receivers are thus in principle over 75 years old...but that's another story.

THIS IS HOW "FELIX THE CAT" APPEARED ON A 60 LINE RCA SYSTEM IN 1928

SCANNING AND SCANNING DISKS

CHAPTER TWO

The most elementary form of mechanical television system consists of a single motor turning two similar scanning disks on a common shaft. One disk is used to convert the image into a series of picture elements and the other reconstructs the image. In Fig. 2.1(A), the subject, A, on the left, is being viewed by the photoelectric cell, C, through the holes in the rotating disk, E. The varying signal output of the photoelectric cell, produced by the different intensities of light reflected from the light and dark parts of the subject, is amplified sufficiently to cause the brilliancy of a neon lamp, (D), to vary in step. The observer, B, looks at the neon lamp through the spirally arranged holes in disk, F. Although the observer sees the lamp through only one hole at a time, the rapid rotation of the disk gives the impression that there is an image on the lamp.

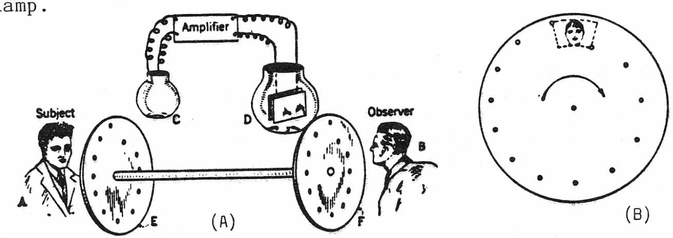


FIG 2.1 DRAWING (A) SHOWS THE ESSENTIAL PARTS OF A SIMPLE TELEVISION CAMERA AND RECEIVER. DRAWING (B) INDICATES THE SIZE AND POSITION OF THE REPRODUCED IMAGE.

What the observer sees is shown in Fig 2.1(B). The dotted line represents the margins of the image. Each hole in the disk passes across the image area and traces the light and dark intensity variations of the subject on the lamp and below the path of the previous hole. This continues until the last hole in the spiral comes around, when the process is repeated.

From this it can be seen that our television system has three important components. The first is the scanning disk, used in the camera to scan and break up the image into a series of picture elements and again in the receiver, where it reconstructs the image by reversing the scanning process. The second is the "eye" of the camera, the photoelectric cell, which converts the minute variations of light passing through the scanning disk holes, into an electrical signal. This signal is then amplified and applied to the third component, the lamp. The lamp brilliancy follows the amplified camera signal exactly and in conjunction with the scanning disk, reconstructs the image.

Each of these components (and others) will be discussed in enough detail to allow those who may be interested, to develop working models of closed circuit mechanical television systems. This is strongly recommended for those who are seeking an in depth understanding of the idiosyncrasies and intricacies of mechanical television.

IMAGES

Images may be defined as the optical counterparts of scenes or subjects. An image is a picture that is formed by mirror or lens action or a combination of both. Image brightness depends on the brightness of the scene or object in the first place. If the object is luminous in itself, such as a lamp, it can be easily seen as an image. If it is not luminous, the brilliance of the image then depends on the amount of light reflected by it. There are various ways to illuminate an object. Lighting may be direct or pass around an object to form a shadow. Light can also pass through as in the case of film. Objects may also be illuminated with a moving, small but intense spot of light.

SCANNING

One of the requirements of television is that the camera be able to divide the image into a series of small parts or picture elements, with each element representing an area reflecting more or less light. The receiver must re-assemble

these picture elements and reproduce each with its corresponding brightness and located in its proper relative position. The method of accomplishing this is called scanning and the simplest device that will do this is the scanning disk. It consists of a circular flat metal plate, rotating at a constant speed and containing a series of small holes or apertures arranged in one or more spiral patterns (see Fig. 2.2).

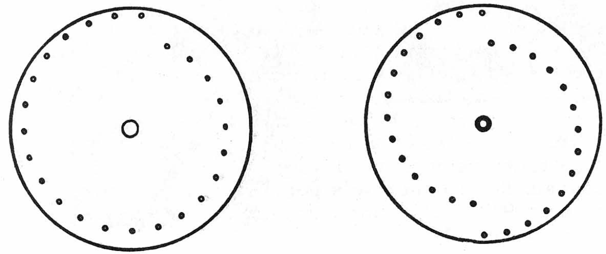


FIG 2.2 SINGLE AND DOUBLE SPIRAL SCANNING DISKS

The disk in the camera scans the image in the form of strips. At the receiver, a similar disk reverses the process by reproducing these strips in the proper order to form the complete scene. Refer to Fig 2.3 and imagine that the small square aperture in the upper left corner of the picture is moving in the direction of the arrow. As it moves to the right side, one can view or scan the top strip and it would appear as strip No. one in the center of Fig. 2.3. If the aperture then moves down the width of one strip and again moves from left to right, it would scan strip No. two. This can be repeated until the entire picture has been divided into strips of picture elements which appear successively, as numbered on the right side of Fig. 2.3.

In actual scanning, the strips are very narrow and appear as lines. They typically number 24, 48 or 60, depending on the amount of picture detail desired. The most common scanning format is the one shown in Fig. 2.3.

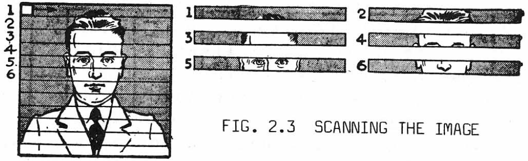


FIG. 2.3 SCANNING THE IMAGE

The image on the disk is scanned from left to right and line by line, from top to bottom. A disk that will provide this format is shown in Fig. 2.1(B). It rotates in a clockwise direction and the image area is located at the top center of the disk (12 o'clock position). Each successive hole is nearer the disk center by one hole width. Therefore, as each hole forms its corresponding line, each line appears just below the previous one, until the last line when the process is repeated. Due to the eye's persistence of vision, a disk operating at 900 rpm or more, appears to develop all of the lines simultaneously.

The 48 and 60 hole disks represent the standards used in the late 1920's and offered improved resolution over the 24 line system, at the expense of reduced brightness and image area. For the same size picture, a 48 hole disk has to be twice the diameter of a 24 hole disk. The holes in the 48 hole disk are half the diameter of those in a 24 hole disk and pass only one fourth as much light. This reduces the image brightness by the same factor. A 60 hole disk reduces size and brightness even further. In addition, 48 and 60 hole disks are more difficult to make and are best left to the trained machinist. For those who are interested, Appendix B consists of tables that show the important dimensions for various size disks, including some with 48 and 60 holes.

If the image area is moved to the three o'clock position, the scanning appears to be a series of vertical lines as shown in Fig. 2.4(A). This picture of a mans face was taken from a disk, operating in a Baird 24 line system in 1926. Fig. 2.4(B) shows a picture from a German 36 line receiver, taken in 1931. This form of scanning was common in Europe and England.

FIG. 2.4 SCANNING IN THE VERTICAL DIRECTION

Other scanning formats have been used and Fig. 2.5 shows one disk with two spirals and another with three. The holes in these spirals do not overlap. Both disks provide forms of interlaced scanning, which can reduce flicker and bandwidth requirements of the system.

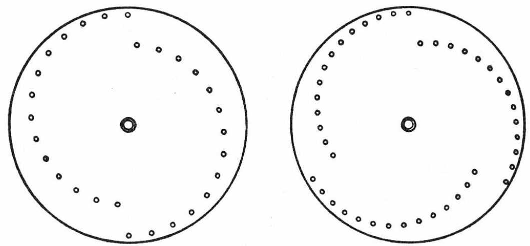


FIG. 2.5 TWO AND THREE SECTOR INTERLACED SCANNING DISKS

Fig. 2.1(B) showed that the total area scanned is as wide as the distance between two adjacent holes in the spiral (the "width" of the image) and the vertical distance between the first and last holes in the spiral (the "height" of the image). This "frame" is slightly narrower at the bottom than the top (keystoned), because the holes are closer together at the inner portion of the spiral. See Fig. 2.6. This becomes more apparent as the disk diameter is reduced.

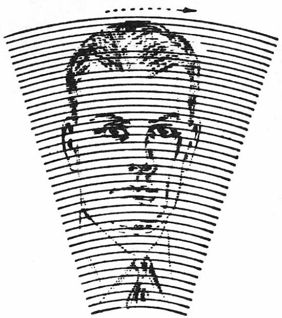


FIG 2.6 KEYSTONED IMAGE, DUE TO LINES BECOMING SHORTER AS RADIUS IS REDUCED.

In most disks the scanning holes are circular. In some, the holes were punched square. The distribution of light is more even with properly located square holes and there will be fewer light or dark streaks across the reproduced picture. Square holes also provide an approximate 25 % improvement in brightness as compared to round holes, but in the smaller sizes, they are are difficult to make (see Fig. 2.7).

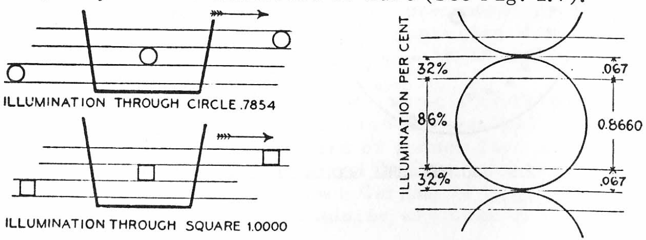


FIG 2.7 A CIRCLE PASSES 78% AS MUCH LIGHT AS A SQUARE AND AT ITS EDGES, ONE-THIRD AS MUCH.

The diameter of the circular scanning holes is equal to the height of the image frame divided by the number of lines in the frame. If the holes are made slightly larger, light from adjacent holes will overlap and any light or dark streaking will be less conspicuous. This also "softens" the image sharpness and makes the line structure less apparent.

Lower disk speeds result in brighter pictures because each hole remains on a given picture element for a longer period of time. Since more light passes through large holes than small ones, the fewer the lines and the larger the holes, the brighter the picture will be, but the poorer will be the detail because of the reduced number of lines.

The aspect ratio is the ratio of the width to height of the television picture. Most movies use a 4 to 3 ratio. With the scanning disk, the image width for a given number of lines is limited by the disk diameter. The height however, is determined by the number of lines and the hole size. A larger picture can be achieved by simply increasing the hole size and the space between them. Aspect ratios of 1 to 2 have been used and 1 to 1.20 or 1 to 1 were common. Whatever ratio is used, it should be the same at the receiver as it is at the camera or vertical distortion of the picture will result.

When the aspect ratio of the subject matter is fixed, as in the case of movie films, the camera and receiver disks should be the same ratio as the film. A suitable compromise for showing films and other types of subjects, is to use a 1:1 ratio for both the camera and receiver.

Scanning disks must revolve on their centers and all holes must be accurately located. If only a few disks are to be used in a system, it is advisable to match drill the disks because common disk errors are less noticeable in the final picture. Disks have been built with adjustable holes or lenses. This is done by having small movable plates, so that each "scanning hole" can be adjusted accurately. Fig. 2.8 shows a 48 hole disk of this type. Fig. 2.9 shows a disk with large cut outs just inside the hole spiral. This is

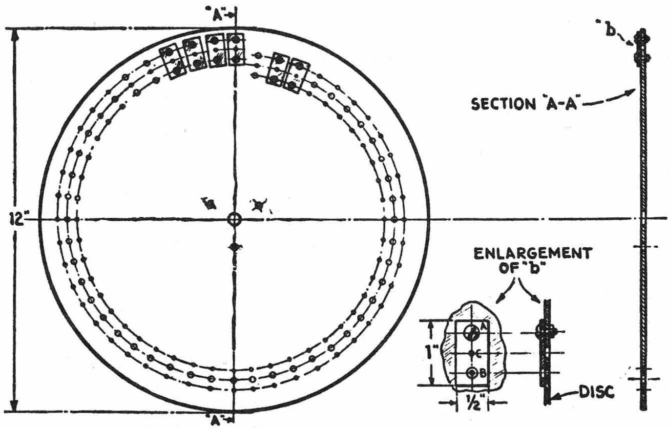


FIG 2.8 SCANNING DISK WITH MOVABLE PLATES, SO THAT EACH "SCANNING HOLE" CAN BE ADJUSTED ACCURATELY.

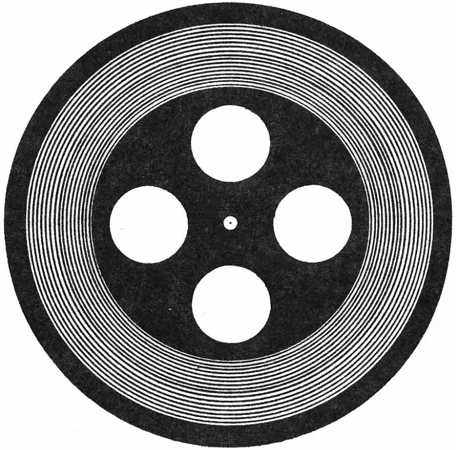


FIG 2.9

SCANNING DISK WITH FOUR LARGE HOLES IN THE CENTRAL PORTION, TO REDUCE WEIGHT AND INCREASE FLEXIBILITY OF THE DISK.

sometimes done to reduce the weight of the disk and to make the disk more flexible. The added flexibility will reduce any tendency for the disk to "wobble" when it is operating at normal speed. A "thin" disk, approximately .025 inches thick, will operate in the same manner. When disks are up to speed, the receiver cabinet should not be suddenly rotated or moved. The gyroscopic action of the disk will cause it to deflect and possibly strike a portion of the supporting structure.

Because scanning disks operate at high speed, they should be checked for proper balance. Excessive vibration can reduce the image resolution and will likely affect motor life. Some larger disks have been totally enclosed to reduce wind noise that might interfere with microphone operation and also reduce the possible safety hazard.

In addition to the flat scanning disks, some have been made in the form of drums with holes spirally arranged on the circumference and with the light source in the center. Traveling belts with holes on a slant have also been used for scanning the image. Both ideas are shown in Fig. 2.10.

Receivers with aperture disks require a large area light source, at least as large as the image on the disk. With a lens disk, a point source is used instead. This will be covered in greater detail in another section.

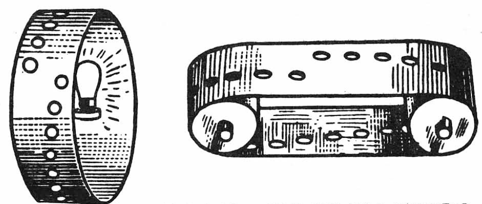


FIG 2.10 DRUM AND BELT SCANNERS

In order to resolve small detail, it is necessary to use small holes in the disk. As the holes become smaller, less light passes through and the picture brightness is reduced. If the hole diameters are reduced by one half ,the image resolution can be doubled but the brightness will be reduced to one fourth of what it was before. In order to overcome this, some disks have lenses mounted in each of the scanning hole positions. A disk with holes might pass only one twenty-five-hundredth of the light available at the disk. A lens disk can concentrate the light falling on its surface and provide pictures that are more than a hundred times brighter.

LENS SCANNING DISKS

The lens scanning disk is important because it will provide relatively large television pictures with improved brightness. The image is formed on a ground glass or similar type of screen, located some distance from the disk (see Fig 2.11). It does this, in conjunction with a modulated point source of light, usually a neon crater lamp. Condensing lenses may be included, to make this method even more light efficient. Instead of restricting the available light to a very small pin hole, the lens concentrates all of the light falling on its surface into an intense spot of light on the screen.

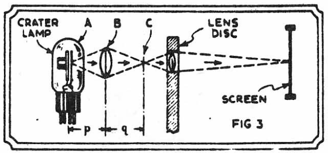
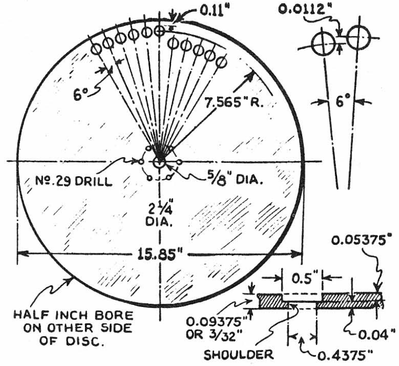
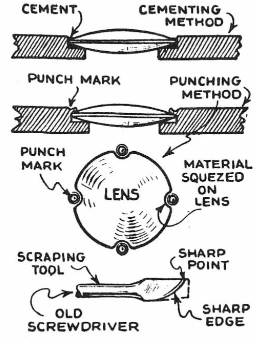


FIG 2.11 OPTICAL ARRANGEMENT FOR NEON CRATER LAMP SYSTEM

Lens disks are laid out in a manner similar to aperture disks except a heavier gauge of material is used. Lens diameter is usually as large as the disk can accept in the space between the innermost holes of the spiral. Fig. 2.12 shows a typical design for a 60 lens spiral with .5 inch lenses, on a disk approximately 16 inches in diameter. The lenses are mounted in counterbored holes and held in place



Layout data for building the lens disc.



Different methods and tool used for fastening lenses.

FIG 2.12 TYPICAL 60 LENS SPIRAL DISK DESIGN

by cementing or some form of staking or peening of the metal around each lens. Cementing is the preferred method because there is less likelihood of damage to a lens. Lens replacement is a simple matter and should the lenses need to be individually aligned, they can be and then cemented in place. Whatever mounting method is selected, lenses must be very secure in the disk.

All of the lenses in the spiral must have good optical qualities and should have matched characteristics. This is difficult to achieve in a glass lens because of the manner in which they are manufactured. This is not the case with precision acrylic or styrene lenses. These are produced from precision polished molds that produce lenses with closely matched characteristics and at relatively low cost. Their optical qualities are as good or better than glass and they have have considerably less weight,

The lenses are rotating at high speed near the edge of a large diameter disk and the centrifugal forces can be very high. As an example, the typical glass lens for a 16 inch, 48 line disk would be .750" in diameter and weigh approximately .32 ozs. In a disk operating at 15 frames per second, the disk would rotate at 900 RPM and the centrifugal force on each lens would be more than 3 pounds.

If styrene lenses are used in this same application, the individual lens weight drops to .035 ozs. and the force on each lens would reduce to .35 lbs. The equation for this force is:

C.F.(lbs)=.00000178 X Wt (ozs) X Radius (inches) X RPM X RPM

Plastic lenses have one major disadvantage and that is that the material from which they are made is soft and will scratch more easily than glass. Therefore, handling and cleaning require extra care.

Lenses as large as 2.0 inches in diameter have been used in disks built for use in theaters, but most scanning disks use lenses that range from .312 to .750 inches in diameter, with focal lengths from 1.0 to 4.0 inches. The equa convex, a lens with front and back surfaces curved or the plano convex, which has one flat surface, will perform equally well. If the plano convex lens is selected, the flat surface should face the lamp.

The hub used on a lens disk is the same as one for a aperture disk. The disk material is also the same, except as pointed out before, a heavier gauge is used to allow room for the counterbore. A .090 inch thickness is a good choice, with the counterbore occupying approximately half the depth. The outer edge of the first lens in the spiral should be located at least .25 inches from the edge of the disk, just as the aperture disk, to prevent spillover of the light source. Lenses can be cemented in place with a very thin coat of epoxy on the edge of each lens as it is placed in the counterbore. Another method is to apply four or five small dabs, evenly placed around each lens. Use an epoxy designed for use with both metals and plastic.

Table 2.3 provides the important dimensions for a 16 inch diameter disk, using 48 standard plano convex, styrene, .768 inch diameter lens, with a 1.8 inch focal length. The lenses are 7.5 degrees apart.

Table 2.4 provides the information necessary for a 20 inch diameter disk with 60 of the same lenses, located 6 degrees apart.

Appendix A includes additional disk design charts.

MOTION PICTURE SCANNING DISKS

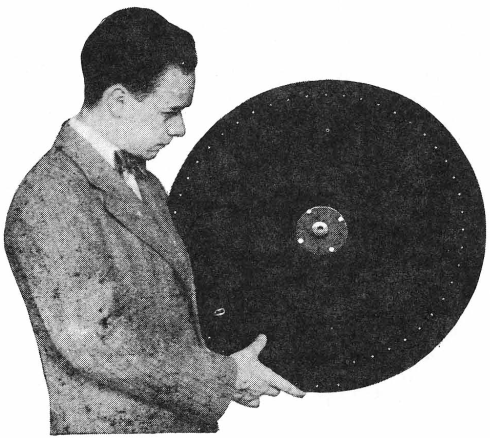
When scanning a subject, the disk, with its spiral pattern of holes, provides both the vertical and horizontal motion components to the elements as they are scanned. In more modern terms, these are referred to as "vertical and horizontal sweep". The hole or lens moving across the image, represents the horizontal sweep and the pitch in the spiral forms the vertical sweep. When movie film is the subject, the film should move through the camera at a constant rate of approximately 15 frames per second (silent film). The motion of the film as it passes through the camera will provide the vertical sweep component of the disk. This is accomplished by moving the film with a linear or constant motion, rather than the start, stop motion commonly used in movie projectors. The film frames should travel past a scanning disk with a circular pattern (not a spiral) of scanning holes or lenses. With the disk holes arranged this way, a single line is repeatedly scanned as it rotates.

A synchronous motor drives the disk directly and through gearing operates the sprockets, moving the film at 15 frames per second. As each frame moves past the disk, 48 scan holes or lenses sweep across the entire frame. A disk with half the number of holes could also be used, if the RPM of the disk is doubled, so that the correct number of line scans occur for each frame. In a 60 line system, 60 holes or lenses scan each frame as it passes by the disk.

BUILDING AN APERTURE SCANNING DISK

When a decision is made to build a scanning disk, certain factors must be decided before layout begins. Some of the factors conflict and so an acceptable compromise is the desired result. Table 2.5 will help by pointing out the important parameters of various types of disks.

If the disk is to be used in an existing system, the number of holes or lines will be fixed by that system. If however, the disk for a new system, select one of the standard formats that were used for single spiral disks. The most common were 24, 48 and 60. The 24 hole system represents the earlier equipment used by Jenkins and Baird and is strongly recommended for a first attempt at producing disks. These disks are easy to build and provide relatively large pictures. They will give recognizable pictures of a wide range of subjects. There is much to be learned and will be learned by developing a 24 line system to a high degree. Chapter 9 contains complete instructions for building disks.



SYNCHRONIZATION AND MOTORS — CHAPTER THREE

Synchronization refers to keeping the disk at the receiver in the same relationship with reference to the scanned area as the disk in the camera. When a given image line is scanned at the camera, the same line is being formed at the receiver. As successive lines are scanned at the camera, the receiver must advance to the exact same line and form it as the picture signal comes through. In very early systems this was accomplished by placing both disks on a common shaft and rotating them with the same motor. Some even used the same disk to both form the picture signal and reproduce it. This method has also been used as a means of monitoring the camera output.

Synchronous motors are the easiest means for maintaining synchronization between the disks at the receiver and transmitter. It is necessary however, that the two units operate upon the same power system or on systems that are controlled accurately; otherwise the two disks will not hold the same relationship.

Early systems used two types of motors. Cameras generally had some form of synchronous motor operating on the local 60 hertz lighting system. The motors operated at 900, 1200 or 1800 RPM and produced 15, 20 or 30 pictures per second respectively.

It would seem obvious that the receiver should also use a synchronous motor operating at the appropriate speed but, power grids for 60 hertz lighting circuits were relatively small in the late 20's. A television signal transmitted from one city and received in another meant that no synchronism was possible through the power lines because different power stations were not synchronized to each other. In addition, many areas had only D.C. power available. As a result, it was common to have a universal or variable speed motor driving the receiver disk. In every case, there was some

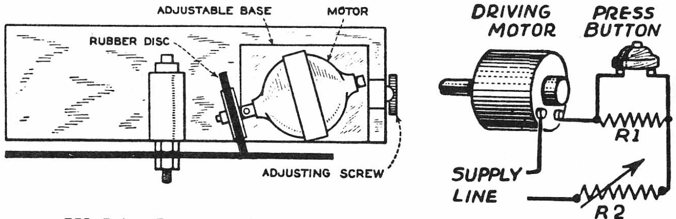


FIG 3.1 MECHANICAL AND ELECTRICAL SYNCHRONIZING CONTROL

sort of mechanical or electric speed control, which required nearly constant attention to achieve synchronization (see Fig. 3.1). Later, synchronization was improved by way of "Phonic Wheels" controlled by a synchronization signal from the station. These wheels were mounted on the motor shaft and pulses from the station energized its coils. The magnetic fields from the coils interacted with gear-like teeth on the wheels and advanced or retarded the disk position each time a synchronizing signal was received (see Figs 3.2 and 3.3).

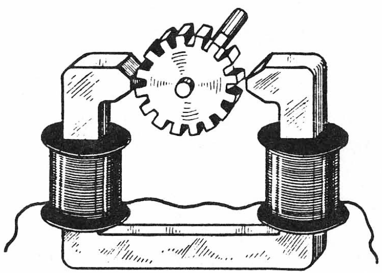


FIG. 3.2 PHONIC MOTOR

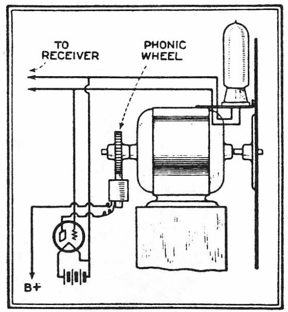


FIG. 3.3 PHONIC MOTOR HOOK-UP

Phonic wheels are a specialized form of synchronous motor with only enough torque to slightly vary the speed of a larger motor attached to the same shaft. The number of teeth on the phonic wheel is the same as the number of lines in a frame. The synchronizing signal was usually nothing more

than the video signal itself. This works because the scanning operation at the camera develops a strong signal at a frequency equal to the frame rate times the number of lines. For a system operating at 15 frames per second with 48 lines, the frequency would be 720 Hertz. Fig. 3.3 shows part of an early schematic that includes the hook up for a phonic wheel. Notice that the receiver drives a neon lamp directly and also an amplifier, which in turn drives the coils for the phonic wheel. Not shown, are the motor leads, which would have connected to the power line through some sort of adjustable voltage control or reostat. In operation, the large motor is adjusted to operate at a near synchronous speed and the phonic wheel then makes the necessary corrections to keep the picture in sync.

It is not enough to simply synchronize the disks in the camera and receiver. There also needs to be a means of positioning or rotating one disk in respect to the other. This is referred to as "framing" the picture. The picture is in frame when the picture elements in the reproduced picture are in the same relative positions as the original scene. Framing is always adjusted at the receiver.

Framing is usually accomplished in one of two ways. The first method was used with AC induction motors or DC motors. It provided a means to interrupt or reduce power to the drive motor with a momentary switch (see Fig 3.1), With the switch closed, the motor operated at whatever speed the reostat was set for. By pulsing the switch and adjusting the reostat while watching the picture, the disk would "slip" or advance and the image could be framed.

An adjustable friction or magnetic brake on the disk will accomplish the same result, but this method has some disadvantages when used with synchronous motors. Since the brake acts as a load on the motor, the motor will operate at a higher temperature. Another disadvantage is that the adjustment operates in one direction only since the receiver disk can only be retarded by this method. If during adjustment, the correct setting is passed, it becomes necessary to let the disk slip one complete revolution in order to frame it. In a closed circuit system, this problem can be corrected by adding a momentary switch to the camera motor circuit, and have it accessible to the operator at the receiver.

The second method is to rotate the outer housing of the motor driving the receiver disk (see Fig. 3.4). This forces the disk to move ahead or back from its previous position in respect to the camera disk. Although it can add considerable mechanical complexity to the receiver, it does allow easy adjustment. With this method, power can be applied to the motor through slip rings or long flexible leads.

One other framing method that saw limited use was found on some Jenkins television kits. It used a special disk that contained two complete spirals, one inside the other. The second spiral was a continuation of the first. Each spiral had the appropriate number of holes for a complete picture, therefore reception of a 60 line image required a disk with 120 holes. Framing was accomplished by raising or lowering the television lamp and image mask assembly, which was located directly behind the disk. Therefore, any hole in the outer spiral could be positioned in the image mask, to become the first line of the viewed image. In operation, the lamp was positioned to illuminate that portion of the two spirals that produced a properly framed 60 line picture.

Many of the early synchronous motors were not self starting. Some where started by hand with a spin of a knob. Others used another motor, such as an induction type, which was disconnected once the synchronous motor came up to speed. Fig. 3.5 shows an unusual design built by Insuline in 1931. The motor has one wound stator, but it has two rotors on a common shaft. One is a squirrel cage type, which is self starting and the other, a synchronous type, which is not. When power is applied, pressure on a hand operated lever moves the synchronous rotor out of the stator while the squirrel cage rotor moves into the stator. When motor comes up to speed, pressure on the lever is removed and motor continues to run synchronous.

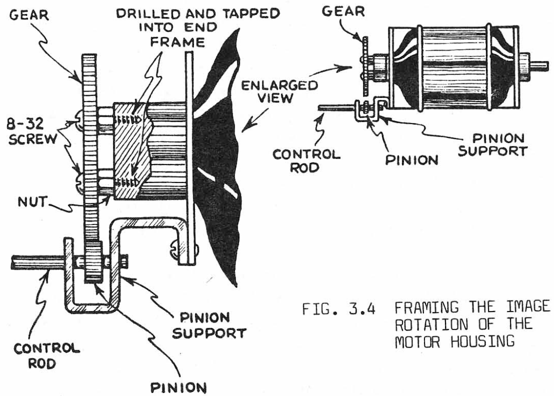
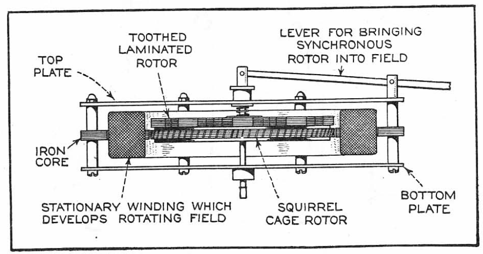


FIG. 3.4 FRAMING THE IMAGE BY ROTATION OF THE MOTOR HOUSING



UNIQUE MOTOR DESIGN

FIG. 3.5 *This sketch illustrates the two-rotor arrangement employed in the motor which drives the scanning disc*

Modern synchronous motors are generally self starting. Most use what is commonly referred to as a permanent split capacitor or two phase winding, with one of the windings energized through a capacitor. The capacitor value is critical and the capacity used should be within 10% of the recommended value. When the value is unknown, it can be determined with an oscilloscope by measuring the phase shift in the capacitor winding, referenced to the in-phase winding. The value required is the one providing a phase shift of approximately 90 degrees. Attempting to change or control the speed of a synchronous motor with reostats, inductors, capacitors or motor controllers is not recommended. Motor damage will be the likely result.

Some synchronous motors, although self starting, are unable to reach synchronous speed with their load attached. Sometimes this can be corrected by operating the motor for a short time on a higher input voltage, until it achieves synchronous speed. Fig 3.6 shows how a small 24 volt transformer, with its output connected to the primary voltage in a series aiding configuration and controlled with a momentary switch, will supply approximately 145 volts for starting the motor.

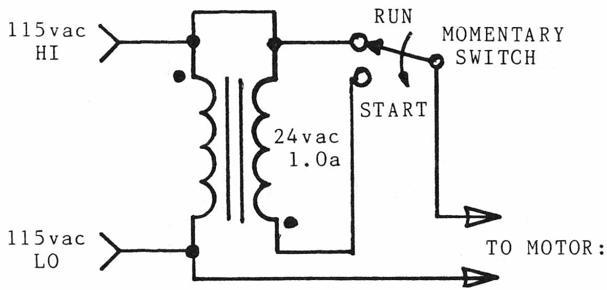


FIG 3.6 VOLTAGE BOOST MOTOR STARTER

One of the most suitable types of motors is the Hysteresis Synchronous. These are commonly used in expensive audio tape recorders, where motor speed is critical. These motors are available in a wide range of speeds, but always at a speed

that is synchronous with the line frequency. The most common are 1800 and 3600 RPM. Less common are those that operate at speeds of 600, 900 and 1200 RPM. Some can even be connected to operate at more than one speed. The most useful speeds for direct drive are 900 and 1200 RPM, which provides 15 or 20 pictures per second, respectively. Motors that operate at 1800 RPM will produce 30 pictures per second in direct drive to a single spiral disk. At these speeds, disks over 12 inches in diameter begin developing considerable wind noise.

Motors that operate at 1800 and 3600 RPM can be reduced in speed by using appropriate ratio gearing or positive drive belting. The range of ratios is very broad in either type of drive. If gears are used, some of the molded plastic types are precision made and will operate with less noise than their steel or brass equivalents. Belt drives must be of the toothed of cog type, sometimes referred to as timing belts. Fig. 3.7 shows one type that is very common. Just as with gears, this type of drive allows no slippage between the pulleys. When gears or belts are used, there should be very little or no play in the assembly. Some synchronous motors "hunt" very slightly and looseness in the drive can aggravate this condition and cause the picture to constantly rock back and forth. Belts are quieter and generally easier to set up and work with, because the flexible belt will tolerate a small amount of mis-alignment. However, timing belts operate under tension and will absorb more power than gearing.

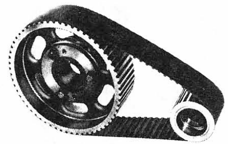


FIG. 3.7 TIMING BELT DRIVE

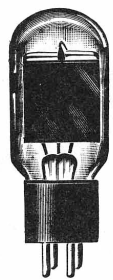
When motors are geared down to a lower speed, the available torque is increased by the ratio of the gearing. But when the gearing is to a higher speed, the torque is reduced. It is a general rule with electric motors; as the designed operating speed is reduced for a given frame size, the torque does not necessarily increase in proportion. Therefore, a motor that seems to have adequate power at a lower speed, may prove to be inadequate if geared or belted to a higher speed. In general, it is recommended that if you must use gearing, gear down.

Hysteresis synchronous motors usually have a considerable temperature rise during operation. 50 degrees centigrade is common, especially of motors operating at 900 RPM or less. Due to the limited efficiency of the internal fans at the lower speeds, the openings in the motor frame must be clear of any obstructions that might restrict the air flow. Some motors are designed to be partially conduction cooled and need to be mounted on a surface able to draw heat out of the motor frame.

Motors are supplied with either ball bearings or sleeve bearings. Ball bearings are inherently more noisy than the sleeve type. Some form of cushioned or rubber mounting can significantly reduce the distraction caused by the noise. If a cushioned mounting is used, it is important that the disk be in good balance because image distortion is more likely to result.

NEON TELEVISION TUBE

The "Telion" neon tube illustrated, submitted by the K. & H. Electric Corp., 68 Springfield Ave., Newark, N. J., is designed especially for television work. Its "striking voltage" as measured, was found to be approximately 180 volts, the current at the "dark point" 11 milliamperes. The recommended safe average current is 50 milliamperes, although the maximum current may reach 125 milliamperes. The tube gave a uniform glow and did not become spotty with changes of current at high frequencies. It is fitted with a base of the UX type. The glow electrode has a surface 1-7/16 inches square, and is made of a special material to promote uniformity of glow with very small currents.



Neon Glow Lamps

One of the essential parts of the mechanical television receiver is the image lamp which, along with its associated scanning device, serves the same purpose in television apparatus that the loud speaker serves in the radio set. The lamp must be capable of producing light variations at the rate of up to 40,000 times per second. This requirement rules out all forms of incandescent lamps.

The most successful lamps utilized Neon gas as the luminous element and provided uniform light intensity over the entire image area of the disk. The color of the lamp is pink or orange depending on the variation and quantity of gas in the bulb. The construction of the lamp is simply two flat metal plates approximately 1.0 or 1.5 inches square, closely spaced and mounted in a glass bulb filled with neon gas (see Fig 4.1).

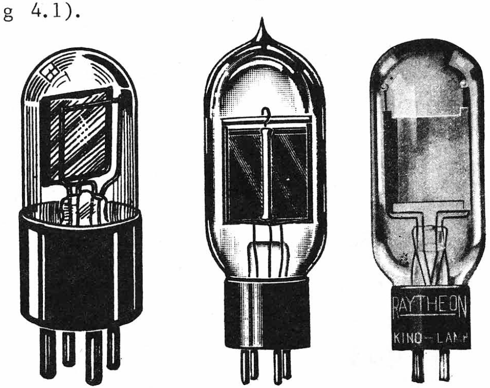


FIG. 4.1

NEON LAMPS FOR TELEVISION

With DC voltage applied to the lamp, the negative plate appears to glow uniformly over its area in a reddish orange characteristic color. The intensity of the glow changes if the current to the lamp is changed. Television neon lamps operate in the range of 5 to 20 milliamps with a supply of 180 volts DC.

Typical connections to a tube type receiver are shown in Fig 4.2. In both circuits the AC signal is mixed with the DC power supply voltage causing the resultant lamp voltage to be varying DC. The minimum lamp current is controlled by the setting of the variable resistor and the maximum current depends on the signal level and conduction in the tube. The resistor is adjusted so that the lamp just barely lights with no signal input.

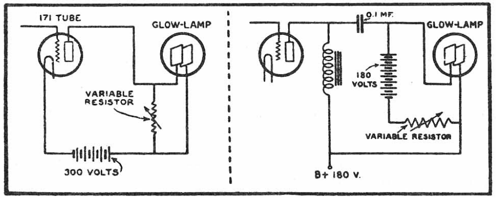


FIG. 4.2

NEON LAMP HOOK-UPS TO RADIO RECEIVERS

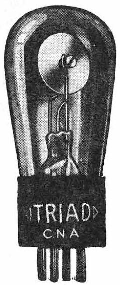
CRATER LAMPS

During the early years of television, the neon lamp was the most commonly used. It served its purpose well, but it did not offer the brightness necessary to allow sufficient enlargement of the picture.

Another suitable light source that was available at the time was the "Crater Lamp" (see Fig. 4.3). These were neon filled and produced a point source of light of the characteristic color of neon lamps.

FIG. 4.3

NEON CRATER ARC LAMP



Description—A crater neon arc type television tube, recently announced for television receiving equipment, employing the lens type of scanning disc. The tube comprises two electrodes, mounted in the same plane and within a few thousandths of an inch from each other. Neon gas surrounds both electrodes and the word "crater," the designation of this type tube, is derived from the way the arc or ionization of the neon gas takes place. The electrode known as the target has a hole of about .025 inch through it, and it is through this hole that the intense beam of light is projected on the lens scanning disc. The striking voltage for the tube is approximately 180 volts, the maximum current 40 ma. and the crater light source .030 inch.

Point source lamps are used with disks containing lenses instead of holes. The lenses are mounted in a spiral around the disk and each one becomes a projection lens producing its own particular line of the final picture. The lenses are matched in focal length and have a diameter as large as practical for any given disk. It is not unusual to have the lenses near the inner radius almost in contact with each other.

The neon crater lamp is a gaseous discharge tube with a highly concentrated and intense discharge glow. This lamp is a current operated device and during operation, has a relatively constant voltage drop across its terminals.The name comes from its construction (see Fig 4.4). The crater has the form of a cylindrical hole in a metallic element, "A". Plate "B" contains a hole or aperture sized to produce the desired spot size. Due to its construction, the glow occurs in the cylinder rather than between the plates. Depending on the tube type, the aperture diameter ranges in size from .015" to .250" inches.

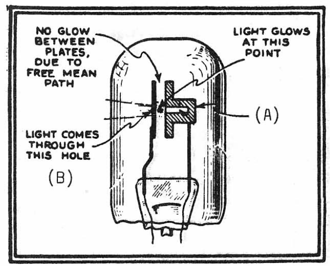


FIG. 4.4 CRATER LAMP CONSTRUCTION

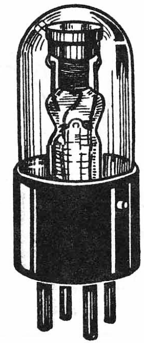


FIG 4.5

CRATER LAMP WITH HEATER

Another version of this lamp was the "Hot Cathode" type, (see Fig 4.5). It included an electric heater to operate the electrodes at a higher temperature, increasing the light emission and frequency response of the lamp.

Light Emitting Diodes (LED's)

Semiconductor light emission was discovered in 1907 by H. J. Round, but it was not until 1960 that efficient light generation in a semiconductor was obtained. The material which made possible this high-efficiency light generation is gallium arsenide (GaAs).

The LED possesses the characteristic voltage-current relationship of most junction diodes. Fig 4.6 shows a graph of voltage versus current for a typical GaAs LED. There is a limit to forward and reverse voltage a LED can withstand without permanent damage. Most commercial LED's can be forward biased up to 50 or 100 milliamps without heatsinking, but higher current levels usually require some sort of heatsinking to prevent thermal damage. Reverse voltage of a few volts can be tolerated in most cases.

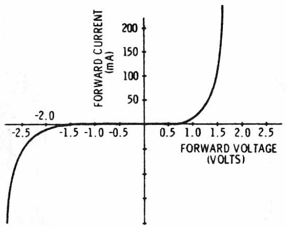


FIG. 4.6

Graph of voltage and current in an LED.

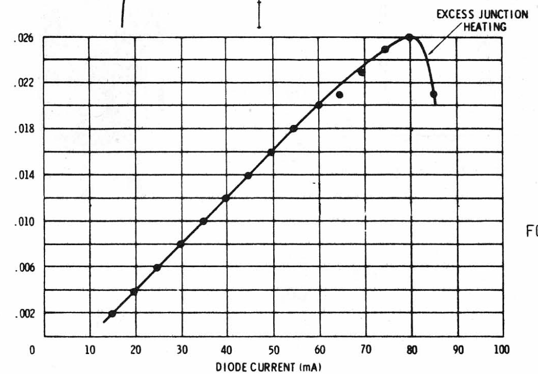


FIG. 4.7

LED OUTPUT VERSUS FORWARD CURRENT

The light output of a typical LED is linear with applied current. Fig. 4.7 is a graph showing the output of a red emitting GaAs LED . Notice that the light output is perfectly linear until a current of 65 milliamps is reached. Beyond 80 milliamps, the light output falls well below the peak value due to overheating of the LED chip. The diode used in this test is an epoxy encapsulated unit, rated for a peak continuous forward current of 50 milliamps. As Fig 4.8 shows, it still operates in an approximately linear region at 80 milliamps.

LED's have very fast response times allowing them to be modulated at frequencies in the megahertz range or higher. They also offer a choice of colors ranging from red to green, with the red and orange variety producing the higher outputs. Finally, LED's are rugged, inexpensive and have rated lifetimes of a hundred thousand hours or more. These factors make the LED a prime candidate as a light source for the scanning disk receiver.

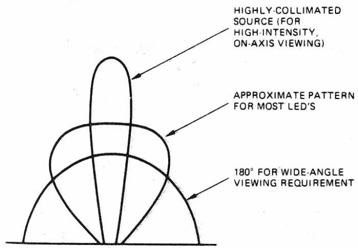
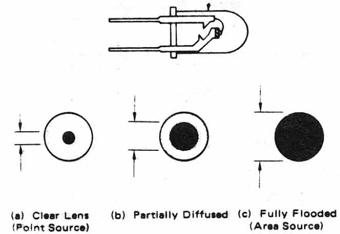


FIG. 4.9 LED BEAMWIDTHS



Epoxy Lenses With Varying Amounts of Diffusants

FIG. 4.10 LED LENS EFFECTS

Most LED's are point sources of light, fitted with a lens to collect and concentrate the emitted light into a beam (see Fig. 4.9). The "High Brightness" or "Superbright" variety, also include a miniature parabolic reflector to capture the edge emission from the diode chip and direct it forward. Because of the reflector, the light from the LED travels in nearly parallel rays. A condenser lens is not required with this form of LED. Some LED's have lenses that are dyed, diffused or both. This converts the LED from a point source to a area source (see Fig. 4.10). True point sources are useful in set-ups employing lenses or other optical components, but area source LED's are more suitable as panel indicators.

When LED's are used individually, the location of the LED in respect to the illuminated surface depends on the shape of the emitted beam. This can be easily determined by experiment. LED's may also be used in groups. When a large area, such as a ground glass, is to be illuminated by more than one LED, the LED's can be mounted in a cluster, a short distance from the glass, with each LED positioned to illuminate a portion of the total glass area.

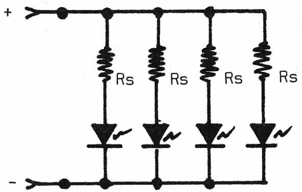


FIG 4.11 PARALLEL LED SOURCE

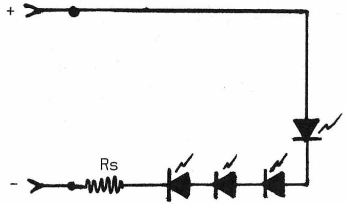


FIG. 4.12 SERIES LED SOURCE

LED's being operated as a group should not be connected directly in parallel, because LED's will not share the input current equally. Each must have a current limiting resistor in its anode or cathode circuit (see Fig. 4.11). When operated as a group, LED's may not have equal brightness. This can be corrected by selecting the individual resistor values. LED's can also be connected in series, in which case there is one series resistor and the brightness of each LED is adjusted by connecting a suitable value resistor in parallel with it (see Fig. 4.12).

LARGE AREA LED SOURCE

A source large enough for most scanning disk receivers is shown in Fig 4.13. The source uses one or more LED's, depending on the amount of light required. From one to four are sufficient for a 24 line system and three to six will be

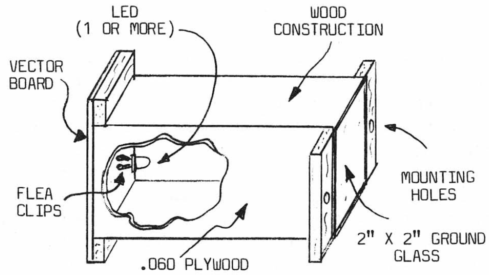


FIG. 4.13 LED SOURCE

adequate for 48 lines. The LED's are focused on the rough side of a ground glass measuring two by two inches. This source is described further in Chapter 9.

Zirconium Concentrated Arc Lamp.

A lamp of simple construction, but with very useful characteristics, is the the Zirconium Concentrated Arc lamp (see Fig. 4.14). This lamp uses a bulb filled with argon gas and produces a high intensity spot of white light. However, unlike the neon variety, the brilliance of this lamp cannot be modulated. These lamps operate with approximately 20 to 30 vdc, but require a minimum of 1000 volts to start the arc. This lamps application for mechanical television is as as the light source in a flying spot type of camera using a lens disk. These lamps are produced in sizes that range from 2 to 300 watts. The 10 watt size has a spot diameter of .016 inches and suitable for the average small scene.

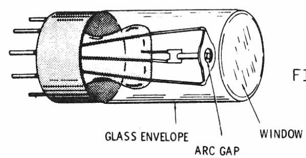


FIG. 4.14 ZIRCONIUM ARC LAMP CONSTRUCTION

Arc Lamps

Many of the early flying spot television cameras used arc lamps as their light source. The lamps were of the exposed arc variety. The electrodes were carbon rods, brought together to initiate the arc and then separated to allow the arc to form. This lamp produces white light of very high brightness and a small spot size. Arc lamps require a means of positioning the carbon rods as they burn away. This is difficult to control without automatic equipment. AC or DC operation is possible, with AC preferred because both rods burn away at the same rate. Approximately 20 to 30 volts is used with a ballast resistance to limit current to safe values. When working with this type of lamp, some form of protection from intense ultra violet radiation is necessary.

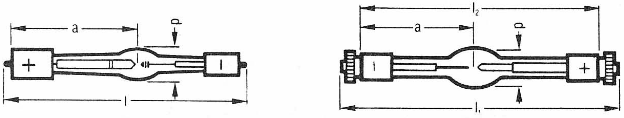


FIG. 4.15 HIGH INTENSITY SHORT ARC LAMPS

Another high intensity lamp is the high pressure short arc mercury lamp (see Fig. 4.15). This lamp is in a quartz bulb and produces high brightness white light with a small spot size. The 100 watt lamp has a spot size of .010 inches square. Lamps are available in 50 to 500 watt sizes and operate with 20 to 75 volts. Starting the arc in this lamp requires a pulse of 20 kilovolts or more. Mercury lamps produce strong ultra violet radiation. Take precautions with this lamp.

A lamp with similar characteristics in many respects is the xenon short arc lamp. It is available in similar packages and wattages but operates on 15 to 20 volts. It also produces white light, but with slightly larger spot sizes.

Arc lamps can be used to form television images, if some form of external means of modulation is included. The earliest type was one used Nipkow (see Fig. 1.4). It

consisted of a coil of wire around a transparent vial containing sulphurated carbon gas. This device was used with two light polarizers, (one is referred to as analyzer). The video signal was applied to the coil in the form of a varying current. This current changed the polarization of the light passing through the gas and had the effect of twisting one polarizer in respect to the other. This modulated the the light intensity in accordance with the video signal. Another device that operates by polarizing light is the Kerr cell (see Fig. 4.16). It is a capacitive device containing a dielectric fluid such as nitro-benzol and requires very high voltage for its operation. A similar type of device is the Pockels cell, which uses certain crystals to accomplish the same effect.

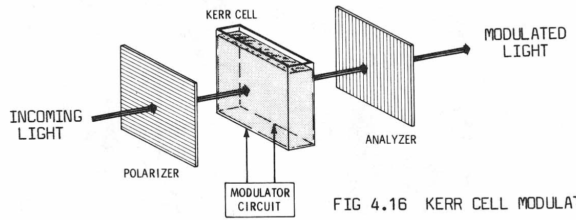


FIG 4.16 KERR CELL MODULATOR

Mechanical light modulators, such as one used to produce the sound track on movie film, are not suited for this purpose, due to their limited frequency response .

TUNGSTEN LAMPS

Tungsten lamps, in particular the halogen variety, offer the greatest light output for the money and are a good choice for general illumination requirements. These lamps may be used to illuminate a scene when the camera has an aperture disk with the photocell located behind it (see Fig. 4.17). If a lens disk is used, a small fixed aperture and photocell may be located behind the disk (see Fig. 4.18). Another way to use the tungsten lamp is to place the lamp behind the disk and focused on it, with the holes passing the light

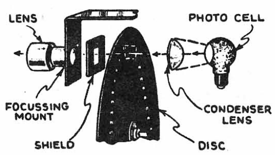


FIG. 4.17 APERTURE DISK CAMERA

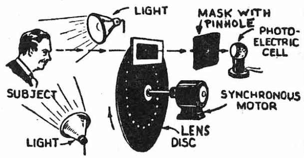


FIG. 4.18 LENS DISK CAMERA

onto the scene. In this case the photocell is in front of the disk, responding to light reflected from the scene (see Fig. 4.19). This is commonly referred to as a "flying spot scanner".

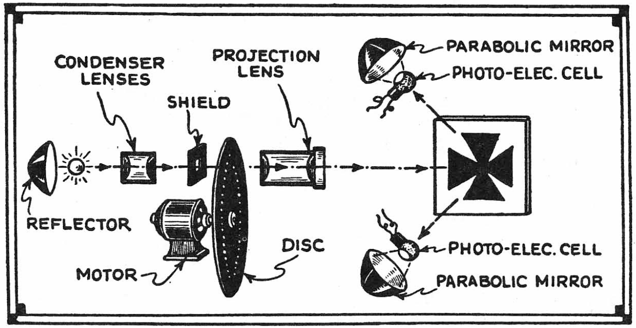


FIG. 4.19—*Optical system used in the "flying spot" television image pick-up arrangement. The light ray passes out through the scanning disc and lens on to the subject, the reflected light rays being picked up by the photo-cells.*

Tungsten halogen lamps are available in a large variety of sizes and shapes. Some will operate on as little as 6 volts. Many types are available for 12 to 24 and 115 volt operation. Their distinct advantages are that the glass bulb does not darken with use and little or no forced air cooling is required for their operation.

When the amount of light required is less than 25 watts, there are a number of types in the "Hi Intensity" variety, that operate from 6 or 12 volts. Some have long and narrow filaments designed for general illumination. Others have folded filaments that will approximate a point source and are better suited to imaging systems.

Tungsten lamps are usually operated on AC current. Those with a filament of small cross section, will produce light that is modulated by the 60 Hertz line frequency. If this type of lamp is part of a camera pick-up, the video signal may include the lamp modulation. This can be corrected by operating the lamp on DC current. A full wave rectifier and capacitive filter with approximately 10,000 microfarads per ampere of lamp current is recommended.

XENON AND KRYPTON LAMPS

These are familiar to most of us in the form of electronic flash attachments for cameras. They produce a brilliant pulse of white light each time they are triggered by the camera shutter. They are made of glass or quartz tubing and contain no filament. There are many varieties of this lamp and the operating voltage depends on the length of the tubing that makes up the lamp. Some operate with as little as 300 volts (see Fig. 4.20), but those with many turns of tubing may require as much as 2500 volts or more (see Fig. 4.21). All of these lamps require a 10 to 20 kilovolt pulse to initiate the light. The lamp power is always supplied by a capacitor kept charged by some form of dc power supply. This lamp has a special application in mechanical television and it will be described fully in the section dealing with camera systems.

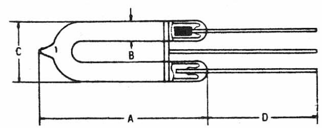


FIG. 4.20 300 VOLT XENON LAMP

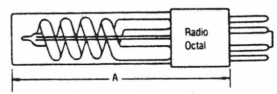


FIG. 4.21 900 VOLT XENON LAMP

PHOTOELECTRIC DEVICES

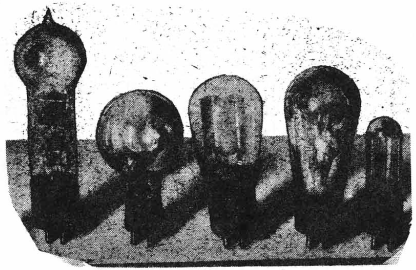
CHAPTER FIVE

In 1887, Heinrich Hertz discovered the photoelectric effect, which is the emission of electrons from certain substances when illuminated by optical radiation. The photoelectric effect appears in three forms; photoemission, photovoltaic and photoconduction.

The first photoelectric cells were selenium types and they remained popular until better substances were discovered during and after World War I. Selenium is characterized by two electrical properties. When the element is exposed to light, the resistance falls dramatically. Light also induces an electromotive force in the selenium. These two phenomena are called, respectively, the photoresistive and photovoltaic effects. The photoresistive effect is a form of photoconduction.

FIG. 5.1

VINTAGE PHOTOTUBES



PHOTOTUBES

Photoemission is the liberation of electrons from a light sensitive photocathode surface usually made up of thin layers of cesium or cesium oxide. A device that operates on this principle is a phototube, which is an evacuated or gas filled glass tube containing a light sensitive photocathode and an electron collecting anode (see Fig. 5.1). In operation, light striking the photocathode liberates electrons that are attracted by the anode, which has a positive charge from an external circuit. This constitutes a photocurrent in the anode circuit which can be easily amplified. If the light striking the photocathode is varied,

the output current will also vary in direct proportion. Early phototubes were of the vacuum variety and could be operated with as much as 500 volts of bias. Their frequency response was limited only by their internal lead inductance and cacpacitance. Examples of vacuum phototubes are: 1P39, 922 and 929. Later it was found, that the addition of a small quantity of certain gases increased the sensitivity of the cell, five times or more. Examples of gas type photocells are the: 927, 930 and 968. Gas phototubes can only be operated at 100 volts bias or less. Higher voltages cause the gas to ionize and the output is then no longer light dependent. Also, the frequency response is reduced by the gas. A typical vacuum photocell can easily provide a 50 kilohertz bandwidth when operated with a bias voltage of 90 volts. A similar phototube, except gas filled, would provide a bandwidth of approximately 10 kilohertz. This characteristic of the gas phototube can be changed by reducing its bias voltage, for its response will improve as the voltage is reduced until approximately 15 volts is reached. At this potential, the gas phototube acts the same as a vacuum type with the same voltage applied.

Phototubes have seen extensive use in motion picture sound reproduction and light beam control systems, but they have been superseded by the more sensitive semiconductor type cells and the highly sensitive electron multiplier phototube.

The photocurrent of a conventional phototube is very small and considerable amplification is necessary for practical applications. The electron multiplier phototube, or photomultiplier tube, provides this amplification internally (see Fig. 5.2). Photomultipliers contain a series of six to fourteen electrodes called dynodes, which by means of secondary emission, give off approximately five electrons for every one incoming electron. Fig. 5.3 shows a sectional top view of the structure of a type 931 nine stage photomultiplier tube. When light strikes photo cathode 0, electrons are emitted and are directed along curved paths by the fixed electrostatic fields, to the first "secondary emitter" (a dynode). Each electron that strikes this dynode

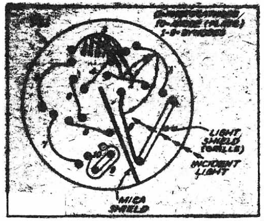


FIG. 5.3 PHOTOMULTIPLIER INTERNAL STRUCTURE

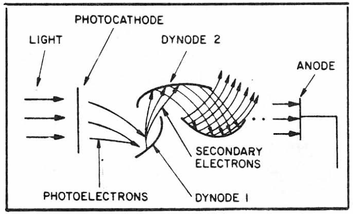


FIG 5.4 THE MULTIPLYING PROCESS

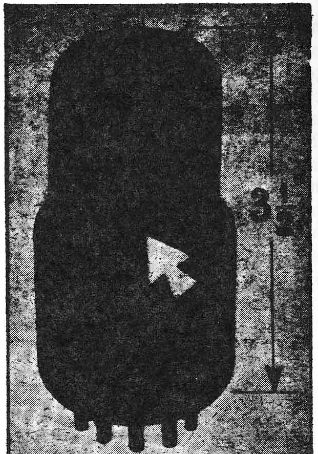
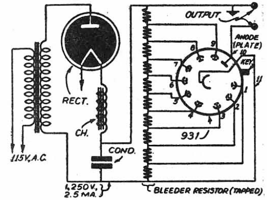


FIG. 5.2 PHOTOMULTIPLIER TUBE

The 931 tube incorporates 9 stages of voltage amplification in an envelope only 3½ inches high! The arrow is pointing to the light-sensitive cathode.

will knock off many other electrons (see Fig. 5.4), depending on the speed of the electron as it strikes the dynode electrode. This multiplying process is repeated as each new electron reaches the next successive dynode, until a greatly amplified number of electrons are emitted by dynode 9 and collected by the final anode 10.

The voltage across each stage of the multiplier is made equal, but the dynode voltage of each succeeding stage must be successively higher than that of the previous stage. The gain of the multiplier increases rapidly as the voltage is increased and can be as much as 1,000,000 times. Fig. 5.5 shows a typical operating circuit in which the positive terminal of the power supply would be referenced to ground. The resistive voltage divider supplies the sequential voltage levels to each successive dynode. The resistors in the divider are of equal value, generally in the range of 50,000 to 1,000,000 ohms. The power supply should be well filtered and have a minimum output of 300 volts but not more



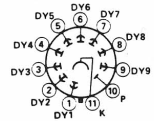


FIG. 5.5 931A POWER SUPLLY AND PIN CONNECTIONS

than 1250 volts. Photomultipliers are the most sensitive photoelectric cells available and have a very high frequency response. They are the ideal choice for use in flying spot scanners where the light levels are usually very low.

Electrostatic fields inside the photomultiplier structure are sensitive to external AC or DC magnetic fields. Motors and transformers, operating from the 60 hertz line , develop large external fields that can modulate the output from these tubes. A strong permanent magnet field can seriously reduce the gain of these tubes. A good rule of thumb is to locate the photomultiplier at least 6 inches away from these components.

SEMICONDUCTOR PHOTOCELLS

Variations of the pn-junction diode make up an important family of light sensitive detectors that include solar cells, photovoltaic detectors, photoconductive detectors and avalanche detectors.

All semiconductor junction devices have some degree of light sensitivity. In fact, the first plastic cased transistors were found to be sensitive to light and it was necessary to add light absorbing material to the plastic. Even light emitting diodes are sensitive to light.

The photovoltaic effect is the potential difference that occurs between terminals of diode cells made up of certain semiconductors when exposed to light. The result is a current flow without the assistance of anything other than the light. Photo diodes operating in the photovoltaic unbiased mode are characterized by faster response times than selenium or other photoresistive cells. When Photo diodes are reverse biased, the cell operates in the photoconductive mode. Silicon is the most common photovoltaic material and cells are available in a wide range of sizes.

A common type of photovoltaic device is the solar cell. They are inexpensive and their large surface area (up to several square centimeters) usually permits operation without precise alignment or an external lens. Solar cells are relatively slow in response, but when loaded with a resistor of approximately 22 Kohms, response out to about 50 Khz can be achieved from the 3/8ths inch square units. Solar cells should always operated in the photovoltaic mode.

The phototransistor is very sensitive and its operation can be considered similar to that of a photodiode having internal gain. Since no external base-bias current is required for amplification to occur, many phototransistors are made without a base lead. Darlington phototransistors are particularly sensitive. Phototransistors are available in a wide variety of configurations at relatively low cost. Because of their small sensitive area, they usually require an external lens. Like solar cells, phototransistors have a relatively slow response time, but there are special circuits which can be used to speed up their response. The Darlington types are even slower and not recommended for video frequencies. Light sensitive field effect transistors (FOTOFET's) have characteristics similar to phototransistors except that their response time is better by a factor of ten or more. These are also small area devices, so an external lens is usually necessary for best results.

The chief advantage of the phototransistor over a photodiode is gain. Unlike the photodiode, however, the phototransistor does not have linear gain and it saturates easily. This can reduce the "tonal" values in the video signal. Some form of intensity control of the light source may be required for the phototransistor.

Photodiodes are available in the widest range of sizes, with the larger ones being 5/8ths inches square or more. As the active area becomes larger, the need for external lenses becomes less critical, but capacitance and cost increase significantly. A good compromise is a photodiode with an active are of approximately .2 inches square. These are available in a number of packages, including hermetically sealed types.

When photodiodes are used in the photovoltaic mode, they operate best with an equivalent short circuit termination. This yields the most linear light to current conversion. The short circuit termination is achieved using an operational amplifier with a transimpedance connection. A typical circuit is shown in Fig. 5.6. The voltage on the photodiode is always zero, therefore, the connections to the photodiode can be reversed, which will reverse the polarity of the output signal. In this type of circuit, frequency response is usually limited by the characteristics of the operational amplifier.

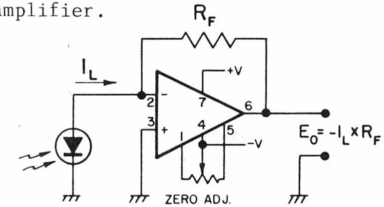


FIG. 5.6 PHOTODIODE AMPLIFIER

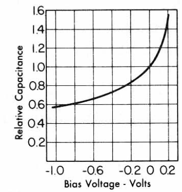


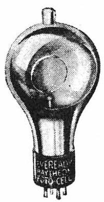
FIG. 5.7 DIODE JUNCTION CAPACITANCE

Large area photodiodes used in the photovoltaic mode exhibit large amounts of internal capacitance which can have serious effects on high frequency response. A photodiode with a chip area of .2 inches square, might exhibit a capacitance of as much as 350 pico-farads. If necessary, the effective capacitance can be reduced by operating the cell in the photoconductive mode. With reverse bias applied to a photo diode, the internal capacitance can be reduced to approximately half its prior value. Fig. 5.7 shows the effects on the capacitance when reverse bias is applied. Usually .6 to 1.0 volts of bias is applied, which reduces the capacitance to approximately 60 % of its former value.

Avalanche photodiodes are similar in construction to a standard photodiode, but are operated with a reverse bias at a precise voltage, just millivolts below the avalanche breakdown point. At this point, the sensitivity is at its maximum and it can compare favorably with photomultipliers. Photodiodes with higher breakdown voltages have higher gain. Special fabrication techniques permit some diodes to be operated at more than 1500 volts before breakdown occurs, thus providing maximum possible gain. Due to its temperature sensitivity (a result of tiny fluctuations in avalanche voltage with temperature),special purpose power supplies must be used to provide the highly regulated voltage required voltage required for proper operation. Avalanche photodiodes are suited for very low levels of light. The major drawbacks of the avalanche photodiode are its temperature sensitivity and its cost.

Photoresistive cells include cadmium sulfide (CdS) and cadmium selenide (CdSe). While these cells are economical and have excellent sensitivity, they have very slow response times. Being photoresistive, they are commonly found in circuits operating with AC current such as, dusk to dawn light controller.

Photocells do not respond equally to all light frequencies of the spectrum. Depending on the type of light sensitive material used, some types will show greater efficiency in the infra red and red region and others, in blue or ultra violet. Phototubes generally favor the blue end of the spectrum and photodiodes work best in the red region. When possible the light source characteristics should complement the sensitivity of the photocell. Tungsten lamps are well suited to photodiodes.



Optics is the science of the nature and laws of vision and light. It pertains to mechanical television because of the need for optical systems in cameras and receivers.

Many examples of optical systems are familiar to us and used in every day life. They are found in devices such as movie projectors, cameras, automobile headlamps, .telescopes, mirrors and products of similar nature. All of these things are made possible by taking advantage of knowledge in the field of controlling light energy.

So far as television is concerned, the use of optical systems is necessary in the primary stage of converting the light content of the scene into a form suitable for transmitting by wire or air. No matter what form of illumination is used at the camera, the light must be directed to the proper position and in sufficient quantities for the pick up device to respond to the scene. The receiver may also require an optical system and the form depends on the type of reproduction desired. Early receivers produced a comparatively large picture by placing a large magnifying lens in front of the scanning disk. Later receivers projected an image on a thin ground glass or ground film, using a disk fitted with lenses or mirrors instead of holes.

LIGHT

Scientists have concocted many odd and ingenious theories to explain the mystery of light, but the one generally accepted today is the wave theory, first proposed by a Dutchman, Christian Huygens. According to his theory, light is just another form of electrical wave energy operating through the ether. Other electromagnetic impulses are cosmic rays, gamma rays, X-rays, ultra-violet rays, infrared rays and radio waves. Light waves differ from these others only in their wavelength; gamma rays being among the shortest, and radio waves among the longest, and light rays, the ones visible to the eye, being about half way in between.

REFLECTED LIGHT

When you look at a blazing bonfire or a burst of fireworks in the sky, you are looking at direct light. What you see is the actual source of light. When you look at the moon, or a curvey torso on the beach, or a face in a mirror, you are seeing reflected light. Practically all of the light you see is reflected light.

Light rays reflect like bouncing balls. When they strike a hard smooth surface at any angle, they change direction. The angle at which they strike the surface is called the angle of incidence and the angle at which they leave is called the angle of reflection. A law of optics that governs this relation says: the angle of incidence is equal to the angle of reflection. This means that a ray of light, striking a surface at thirty degrees to one side of an imaginary perpendicular set up at the point where the light touches the surface, will be reflected from the surface at an angle of thirty degrees on the other side of the perpendicular.

Reflection increases with the degree of polish of the surface or the obliqueness of the angle of incidence. You can prove the obliqueness part of this statement very easily. Take an ordinary sheet of white paper, one that does not have a shine to it and hold it near a hi-intensity reading lamp. Normally, the paper diffuses the light reflected from it and no reflected image of the lamp filament will be seen. Tilt the paper at a sharp angle so that you will be glancing across the surface at the light source. You will see a reflected image of the lamp filament where before there was just diffused light.

LIGHT SOURCES

Practically all "natural light", comes to us from the sun. It may be direct or reflected and is best known as daylight. We think of daylight as white light, but it is nothing of the sort. It is composed of every color of the rainbow. When we see a rainbow, we are actually seeing the colors which, blended together, produce white light. White light is

composed of seven primary spectral colors. When they all travel together in parallel lines, they give the sensation of white light. White light can also be simulated with three or more selected colors of artificial light.

Although the sun is a very large object, its distance is so great, that it appears to be a "point source", that is, the light appears to come from a small point in space. An important characteristic of a point source is that objects illuminated by it, will cast very distinct shadows. Another is that light intensity decreases as the square of the distance, better known as the inverse square law. When the distance between a point source and a lighted surface is doubled, the light spreads out and covers four times the area, but each quarter receives only one-fourth as much light. At three times the distance, the light covers nine times the area, but with one-ninth the intensity. Fig 6.1 shows why this happens.

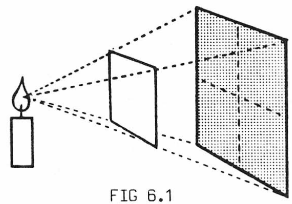


FIG 6.1

INVERSE SQUARE LAW. At 2 feet from the source a unit area receives only one-quarter the light it gets at 1 foot, as the same amount of light spreads over 4 times the area.

Artificial light can be produced in two ways: by chemical action and by electrical action. All of the other ways are variations or combinations of these two. The chemical action forms include oil lamps and candle flames and have no purpose here. The electrical types include the carbon arc, mercury arc, incandescent, flood lamps, xenon and others. All can have an application here.

Point light sources include the mercury arc, carbon arc, xenon arc, neon crater arc, zirconium arc, and some forms of incandescent lamps with small folded filaments. The size of the light emitting source in these lamps ranges from less than a millimeter square for the mercury arc and zirconium arc types to approximately four millimeters square for some of the small tungsten halogen lamps. The electrical load of these lamps range from as little as two to more than a hundred watts input.

A large assortment of medium sized point sources are available in the form of film projector lamps. The emitting area in these lamps ranges from five millimeters square to approximately twenty millimeters square. Their electrical load ranges from fifty to over one thousand watts. Some of these lamps include an internal reflector that performs the same function as external condenser lens. Large area light sources include incandescent photo-flood and high wattage household lamps with reflectors and fluorescent lamps.

SHADOWS

There are two kinds of shadows, those made by a point source of light and those made by a large source of light. The difference between them is that the point source makes a "hard" shadow with a sharp edge and the other a translucent shadow with a soft edge. Fig. 6.2 shows how this happens.

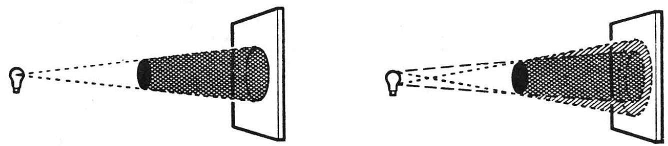


FIG. 6.2

A POINT SOURCE CASTS A SHARP SHADOW LARGER THAN THE SUBJECT

A LARGER SOURCE CASTS A DIFFUSED SHADOW OF A DARK CORE AND BLURRED LIGHTER RIM

LENSES

Any transparent substance having at least one curved surface is known as a "lens". A lens provides a means for directing light rays to given points or areas by making use of the natural refracting properties of the substance that makes up the lens. Glass and certain plastics are natural refracting agents that lend themselves to modern manufacturing methods. Glass lenses are produced in small groups by careful grinding and polishing, while plastic lenses are molded in precision dies and tend to be very uniform in characteristics. Glass lenses are generally more expensive than their plastic counterparts.

TYPES OF LENSES

Lens elements may be classified by their shape, the manner in which they bend light, or their application. However, lenses are most easily defined by their shape. There are six basic configurations of simple lenses with spherical surfaces, as shown in Fig. 6.3. When used individually, only the first three, which are converging lenses, can form real images. Of these, the first two or variations of these are generally used in mechanical television equipment, with the exception of camera lenses. Camera lenses are complex, multi-element optical systems that contain one or more of all of the lens types shown in Fig. 6.3. . Camera lenses will be considered only as a complete units.

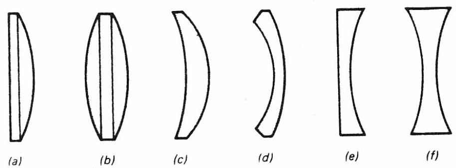


FIG. 6.3 — Various types of spherical lenses: plano-convex, *a*; double convex, *b*; meniscus (concave-convex) — positive, *c*; and negative, *d*; plano-concave, *e*; and double concave, *f*.

A plano-convex lens has a flat surface on one side and an outwardly curving surface on the other, making the lens thicker in the center than at the edge. These lenses will converge incident light, have a positive focal length and can form a real image. Plano-convex lenses are used in microscopes, binocular eyepieces and magnifiers. They are also used as condenser lenses in film or slide projectors. Sometimes, two identical lenses are mounted with the convex sides facing each other to improve lens quality and reduce focal length by one half. Another application is when light passes through a scanning disk onto a photocell. A condenser lens located between the disk and photocell will concentrate the light from the total image area, at its focus and allow the use of a much smaller cell.

Double-convex lenses have the same basic properties as plano-convex lenses. The radii of its surface curvatures can be the same (symmetrical) or different (asymmetrical).

Aspheric lenses are modified plano or double-convex lenses that have at least one surface that is non-spherical. Any aspheric lens may have a much shorter focal length than is possible with a spherical lens of the same diameter, a useful feature where space is limited. Used singly, aspherics can function as condenser lenses, but should not be used for image forming.

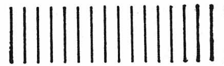
Fresnel lenses consist of a thin plastic plate containing small concentric grooves on one face, extending from the center to the edge. Each groove is a small refracting facet that can bend light. Short focal lenses are possible with large diameters. Fresnel lenses are lightweight and can be use as condensers and magnifiers.

LENS ACTION

If a ray of light travels through empty space outside the earth's atmosphere, or in a vacuum, it does so at constant speed. But when it passes through a transparent substance like air,water, glass or plastic, its velocity is reduced.

The speed of light through a transparent material depends on the density of the material and the wavelength of the light passing through.

When light travels horizontally, the waves that compose it move vertically at right angles. The wave fronts are all parallel, like a row of buttons strung on a thread. Looking at them sideways, they look like this:



As long as this wave travels through one homogeneous medium, the space between the lines, which represents the wavelength of the ray, will remain the same. But when the light wave enters a medium of greater density, the wave is slowed up, see Fig. 6.4. Here we see the wave passing from air, through a cube of glass, and out into air again. Because the wave slowed up in in the glass, the waves are packed together more closely, which means the waves are shorter. When the light leaves the glass, it picks up speed again and the distance between the lines increases, which means the wave is longer.

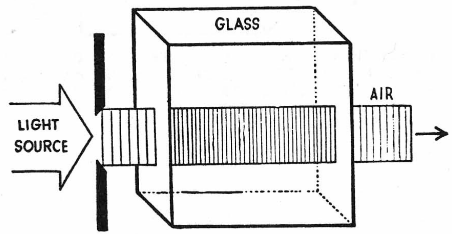


FIG. 6.4 **HOW LIGHT PASSES THROUGH A TRANSPARENT OBJECT THE SURFACES OF WHICH ARE PLANE PARALLEL**

If the glass cube is changed to a prism by cutting one of its surfaces on an angle, see Fig 6.5, the light will now enter the glass obliquely. The first wave impulse to enter the glass makes contact at A. It is slowed up at that point. While that part of the wave starts to travel through the glass, a denser medium, the rest of it is still in air. The result is that the wave begins to pivot on A, which changes its direction. When it leaves the glass again, C exits the glass first and swings away, forcing the wave to pivot at B, thus changing its direction once more. Light is always bent towards the perpendicular of the surfaces when it passes from a rare to a dense medium. Obversely, it is bent away from the perpendicular when it passes from a dense to a rare medium. This bending action is what causes lenses to work as they do.

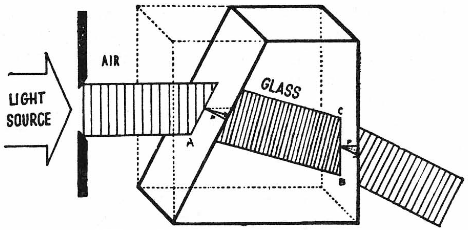


FIG 6.5 **HOW LIGHT IS REFRACTED AND PARTLY DISPERSED WHEN PASSING THROUGH A TRANSPARENT OBJECT THE SIDES OF WHICH ARE NOT PLANE PARALLEL**

Because of the bending action, light can also be dispersed. Sunlight is composed of seven spectral colors: violet, indigo, blue, green, yellow, orange and red. We see them as such because certain vibrations of light produce these sensations of color in our eyes. When they travel together in parallel lines, we get the sensation of white light. When they travel through a dense medium, the surfaces of which form an angle, the rays will be dispursed, or spread out and no longer travel in parallel lines. The result of this is shown in Fig. 6.6. A triangular prism is used to bend the light even more sharply and increase the dispersion.

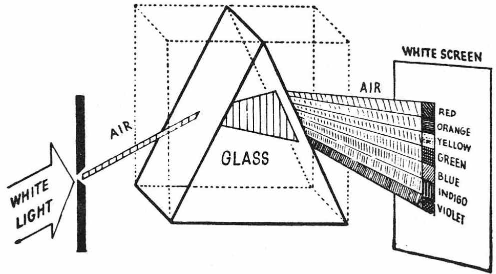


FIG. 6.6 **HOW LIGHT IS DISPERSED WHEN PASSING THROUGH A PRISM**

By cementing two prisms together as in Fig. 6.7, an approximation of a double convex lens can be made.

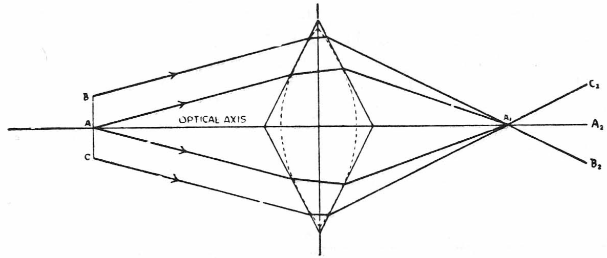


FIG. 6.7 **THE ACTION OF LIGHT RAYS THROUGH TWO CEMENTED PRISMS**

The plano-convex and the double convex lenses are the best suited for the particular requirements of mechanical television. Since either type can be designed to have the same characteristics, the following applies to both types.

A simple description for a lens of a given shape would be its diameter and focal length. The diameter is somewhat of a measure of its light gathering power, and its focal length is the distance from the center of the lens on its axis, to the point where parallel light rays, on the other side of the lens are brought into focus, see Fig. 6.8.

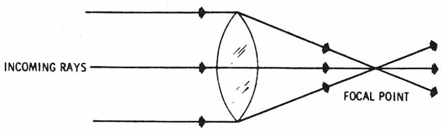


FIG. 6.8 ***Focusing radiation from a distant source.***

FOCAL LENGTH

Most of us at one time or other have used a magnifying lens or "reading glass" to focus the sun's rays on a piece of paper, to see the paper burst into flame. The glass was a few inches from the paper, but it had to be a certain distance, to obtain maximum effect. The distance was the focal length of the lens. It isn't necessary to have the sun to determine the focal length of a lens, as any ordinary light source can provide the same information. Select any lamp, located 30 or more feet away and use the lens to focus its inverted image on a small piece of paper. Measure the distance from the center of the lens to the paper and you have the focal length. It helps perform this test in a dimly lighted area.

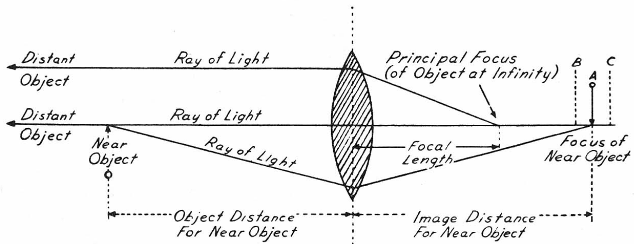


FIG. 6.9 HOW A CONVEX LENS FORMS AN IMAGE

As the subject is moved closer to the lens, the point of focus increases and moves away from the lens, but the focal length of the lens does not change, see Fig. 6.9. The point of focus can be determined by experiment or it can be calculated with this equation:

$$1/p + 1/q = 1/f$$

where: (p)= the object distance
(q)= the image distance
(f)= the focal length of the lens.

A convex lens can also change the direction of light rays originating from a point source, to a group of parallel rays as shown in Fig. 6.10. This is the purpose of a condenser lens, commonly found in film projectors.

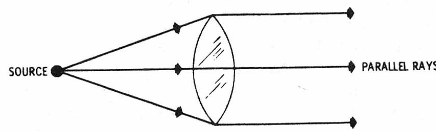


FIG. 6.10 ***Collimating radiation from a source.***

A useful number is the "f-number" of a lens. This number designates the actual light gathering power of the lens. It can be determined by the equation:

f-number = focal length / lens diameter

(all values should be in the same units)

From this it can be seen, that large diameter lenses with short focal lengths pass the most light. The short focal length places the lens near the source, where the intensity is high and the larger diameter captures a greater angle of the light radiated by the source.

MIRRORS

A mirror is a polished surface that reflects rays of light in accordance with certain optical laws. Mirrors may be either flat or curved and made of glass, metal or plastic. An ordinary glass "second surface" mirror has one of its surfaces coated with a thin layer of silver, which is in turn covered with protective paint. Light striking the mirror, must pass though the glass before it can reach the reflective silver coating and back though the glass again, after reflection. Since the light passes through the glass, any imperfections in it will cause a loss of light or distortion of the image. Frequently, glass or plastic mirrors are coated with a thin film of aluminum, the glass or plastic being merely a base or support for the film. Light is reflected directly by the film, without first passing through the base. These are commonly referred to as "first surface" mirrors and reflect almost 90% of the light striking their surface. This surface is very fragile and must be handled carefully. Metal mirrors are more costly to produce than glass or plastic types and are rarely as high a quality. Mirrors are used to lengthen or change the direction of the light path in optical systems and have been used on scanning disks and drums instead of lenses.

Spherically curved mirrors can serve the same purpose as a lens in many kinds of optical apparatus. A concave mirror behaves like a positive lens, i.e., it will bring into focus, the parallel rays falling on it, except that the focus is on the same side as the light source,(see Fig 6.11). These mirrors are found behind the projection lamp in some film projectors. Their purpose is to collect the light radiated from the rear of the lamp and direct it forward where it can combine with the light from the front of the lamp, thereby increasing the optical efficiency of the light source.

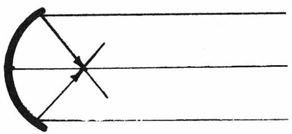


FIG. 6.11 REFLECTION FROM A CURVED MIRROR. PARALLEL RAYS OF LIGHT ARE REFLECTED BACK TO A FOCAL POINT. THIS IS SITUATED AT A DISTANCE EQUAL TO HALF THE RADIUS OF CURVATURE OF THE MIRROR.

Another type of mirror that has application to mechanical television is the circular reflector used with common household light bulbs or photoflood lamps. These range from four to twelve inches in diameter and have a spherical or parabolic shape. Their shape causes them to have lenslike qualities that focus the light entering the reflector and concentrate it at the focal point. Some also have their internal surfaces polished, making them more efficient. Reflectors are useful for concentrating the light directed on the subject and also for concentrating the light reflected from the subject and onto photocells.

LENS ABERRATIONS

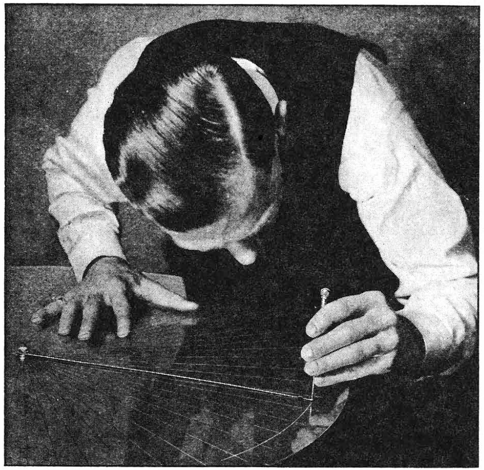
Lens aberrations are generally not a serious problem, because of the limited resolution available from the system. Any lens or lens element, in good condition, originally designed for cameras or associated equipment, telescopes or projectors, should be adequate.

MOUNTING OPTICAL COMPONENTS

Glass and plastic materials are subject to stress cracking if excessive pressures are applied. If clamps are used, they should apply minimal pressure to the element and allow for expansion or contraction of the various parts of the assembly, due to temperature changes. Optical components may be cemented in place if the cement is used sparingly and dries or cures to a pliable consistency. Contact cement is one such material. Rigid cements are not recommended.

CARE OF LENSES etc.

NEVER put your fingers on the surface of a lens or first surface mirror and never use alcohol or other solvents to clean them. The best way to clean a lens is to brush its surface gently with a small camel's hair brush, reserved for that purpose, or to blow the dust away with a rubber ear syringe. If further cleaning is necessary, use dry lens tissue or an old linen handkerchief that has been freshly laundered, first breathing on the lens (very, very lightly) and then softly wiping the surface with the tissue in a rotary motion. Frequent cleaning is not recommended, as it can lead to surface scratches and dulling of the highly polished surfaces.



THE ELECTRONICS

In order to pick up and reproduce the television images that were broadcast in the late 20's, one needed only a small assembly of equipment, some of which was probably on hand and some which had to bought. By August 1928, television images were being transmitted regularly by stations like WRNY in New York, on both broadcast and shortwave bands simultaneously. If one lived in the New York city area and obtained satisfactory loud-speaker results from regular WRNY transmissions, all one needed to add was a separate audio amplifier of the resistance coupled type and the scanning mechanism. The amplifier was needed because many of the early receivers used transformer coupled audio stages. Most transformer amplifiers had slight irregularities or a peak in their response characteristics, but with voice or music, it was not very noticeable to the ear. When television images were being reproduced, even the slightest irregularity in response would cause the already crude images to break up and assume strange and peculiar shapes. The general experience of television experimenters was that resistance coupled amplifiers were more satisfactory for both television transmitters and receivers, at least at this stage of the art. Fig. 7.1 shows the schematic to a typical

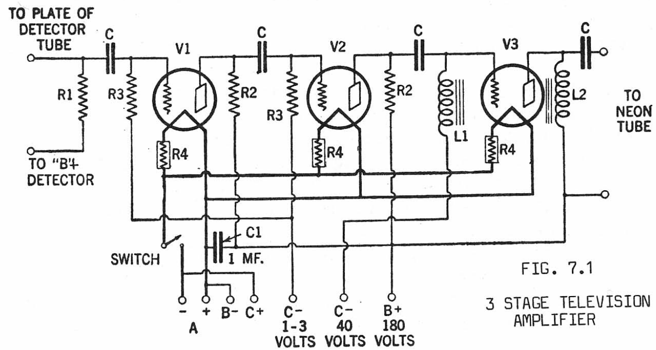


FIG. 7.1

3 STAGE TELEVISION AMPLIFIER

good three stage television amplifier, that was generally assembled on a wooden board or purchased as a completed item. It could also operate a speaker which disconnected the neon lamp when it was plugged into the jack.

The early television transmissions from WRNY were on 920 kilohertz. Using the broadcast band limited the picture signal bandwidth to 5 kilohertz. The bandwidth required for a television system can be roughly determined by "squaring" the number of lines in the image and multiplying that by half the number of pictures per second. The transmissions from WRNY were for a 48 line system, showing 7.5 pictures per second. This works out to a bandwidth requirement of 4320 hertz. The 7.5 hertz frame rate was used because of the narrow band of frequencies available and the resultant images had very strong and unpleasant flicker. In spite of the 5 kilohertz limit, recognizable images were obtained.

The requirement to limit the bandwidth to 5 kilohertz in the broadcast band led to the use of short waves for television, where up to 100 kilohertz of bandwidth was available. About this time, C. F. Jenkins was transmitting his "Radio Movies" on a frequency of 6424 kilohertz. He began with a series of moving silhouettes, similar to movie cartoons and later went to films with half tone shading. His system also used 48 lines, but with 15 frames per second. This improved the smoothness of image motion and reduced the flicker to an acceptable level. Many people reported good results in receiving these movies.

Many of the radio receivers manufactured in the late 20's were equipped with a switch and pair of pin jacks or screw terminals marked "Television". The majority of these receivers were actually designed for audio reception, but contained a "wide band" audio amplifier and the necessary additional components to operate the neon lamp. Fig. 7.2 shows a schematic to a 1932 model Insuline short wave television receiver. Those familiar with common receiver circuits, will immediately see the similarity to standard voice receivers of this period. The Insuline receiver was specifically designed as a television receiver, although it

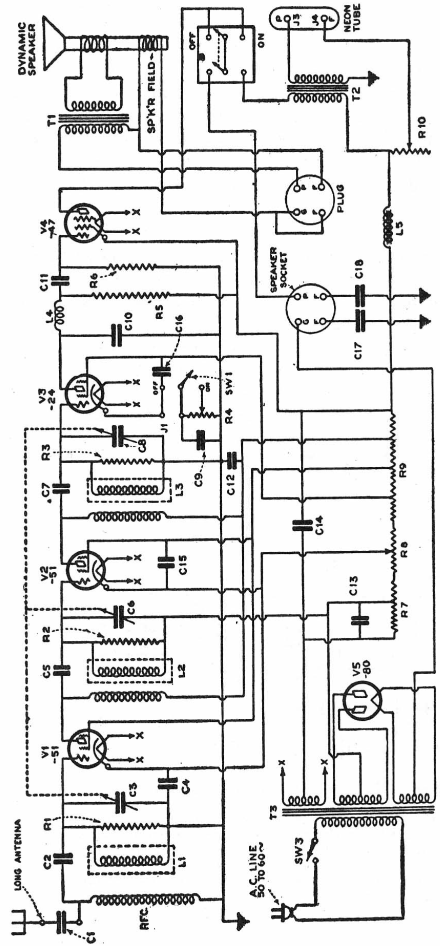


FIG. 7.2 1932 MODEL INSULINE SHORTWAVE TELEVISION RECEIVER.

THIS RECEIVER WAS DESIGNED TO COVER THE FREQUENCY RANGE OF 75 TO 200 METERS OR 1.5 TO 4.0 Mhz. BY MEANS OF A TOGGLE SWITCH (LOCATED ON THE RIGHT SIDE OF THE RIGHT SIDE OF THE SCHEMATIC), IT COULD BE CHANGED FROM SHORT-WAVE RECEPTION TO TELEVISION. A SECOND SWITCH (SW1) IS PROVIDED FOR CHANGING THE RECEIVER TO A PHONOGRAPH AMPLIFIER. A MAGNETIC PICK UP CAN BE CONNECTED TO J1.

THE IMPEDANCE MATCHING TRANSFORMER BETWEEN THE NEON TUBE AND OUTPUT PENTODE IS DESIGNED TO PASS A WIDE BAND OF FREQUENCIES.

also could receive short wave voice signals and operate as a phonograph amplifier. It tuned over the frequency range of 1.5 to 4 megahertz and with a toggle switch, could be changed from television to short wave voice reception. Normal operating procedure was to tune in the television signal using the speaker, then flip the toggle switch to operate the neon lamp and adjust the scanning apparatus for a picture. If successful, slight re-adjustment of the tuning and volume controls could be attempted for possible further improvement.

Just as it was with the receivers, early transmitters required very little change or modification, in order to be used for television. Other than the scanning apparatus and lighting equipment, only a minor change to the signal circuits was required. The picture signal was developed by a photoelectric cell and its output was generally at a very low level. The cell required a positive bias in order to function and because of the gain following the cell, the bias voltage had to be "hum free". Very often, a battery was used for this purpose (see Fig. 7.3).

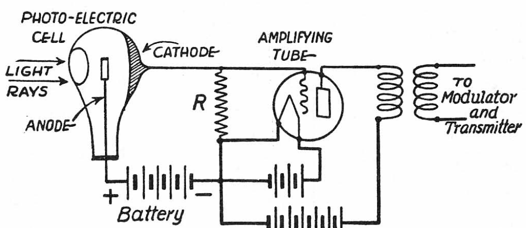


FIG. 7.3 —Connection of Photo-electric Cell To Amplifier.

Light rays entering the cell cause an emission of electrons from the cathode and they are attracted to the positively charged anode. The electron flow is through the battery and the resistor *R* back to the cathode. Electron flow or current flow through the resistor causes a voltage drop between its ends, the voltage varying according to the amount of emission in the photo-electric cell as produced by varying amounts of light.

In order to amplify the signal to usable levels, it was necessary to have very high gain, well shielded low noise amplifiers. To improve the signal to noise ratio, it was common to use four or more photocells, mounted in large reflectors and have them all connected in parallel. (This was before photomultipliers were available). Two to four stages of amplification were usually adequate for driving the low-level transmitter audio circuits.

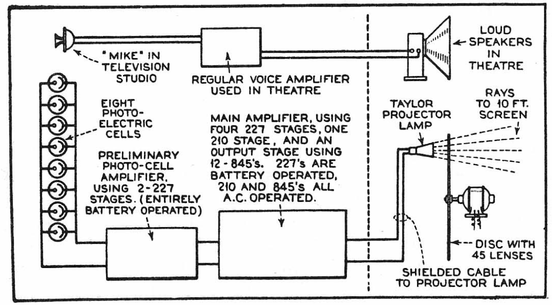


DIAGRAM OF THE THEATRE EQUIPMENT

FIG. 7.4 ***The transmitter equipment for both image and sound are shown to the left of the broken line. To the right are the loud-speaker and the television projector equipment***

Fig. 7.4 shows a block diagram of a theater television system developed in 1932 by U. A. Sanabria. The amplifier used eight amplifying stages and consisted of a battery operated pre-amplifier, followed by a power amplifier operating a modified form of crater arc lamp. The output stage used twelve tubes in parallel and the input to the pre-amplifier was eight photocells connected in parallel.

In the event that the receiver scanning apparatus included a "phonic wheel", it was necessary to add a circuit similar to Fig. 7.5, which connected to the output of the receiver, at the connection to the neon lamp. This amplifier actually filtered out and amplified the strong 720 hertz energy component inherent to the 48 line, 15 frame signals. The output of this amplifier was sufficient to drive the phonic wheel and "lock" the scanning disk into synchronism.

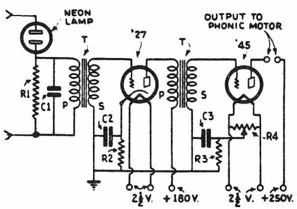


FIG. 7.5 CONNECTIONS BETWEEN THE NEON TUBE AND A PHONIC MOTOR IN A TELEVISION RECEIVER.

CAMERA CIRCUITS

Fig. 7.6 shows the block diagram for a typical mechanical television system. The camera is of the flying spot variety and the scanning disk, in conjunction with the light source and lens system, causes a small spot of light to sweep back and forth, up and down across the subject. This camera is operated in a darkened room and the only light reaching the photocells is that which reflects off the subject as the

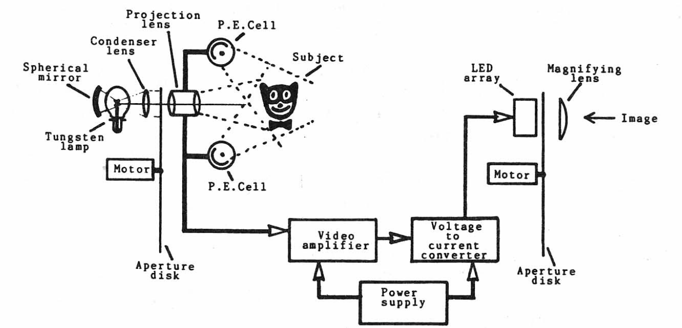


Fig. 7.6 Flying Spot Scanner System

subject as the spot scans over it. The output voltage of the photocells is a function of the intensity of light in the flying spot, the amount of light reflected by the subject, and the sensitivity of the photocells, along with their associated reflectors. The output is generally in the microvolt to millivolt range. The photocell output is a varying DC voltage that is amplified by the video amplifier, followed by a stage that amplifies it further and converts it to a varying DC current driving the LED array. An array might use two or three to as may as ten individual LED's and each requires upwards of fifty milliamps, for its operation.

Not shown in the figure, is the power source for the lamp used to develop the scanning spot. Depending on the nature and construction of the filament, it may require a filtered DC source. Some lamps, when operated from 60 hertz, produce an output containing 120 hertz modulation that appears as shading in the image. A system suffering from this condition and operating at 15 frames per second, will show four evenly spaced horizontal bars across image.

INPUT CIRCUITS AND VIDEO SIGNAL POLARITY

The subject being scanned by the camera has a form or shape that we can perceive, because the subject is made up surfaces that reflect more or less light, causing these surfaces appear to be light or dark in shade. With a camera of the type shown in Fig 7.6, which is mono-chromatic, any colors or hues in the reflecting surfaces are converted to a corresponding light values, which are reproduced as a shades ranging between light and dark.

When light reflecting from various parts of the subject arrives at the photocell, the cell and its circuit responds by providing an output voltage. The level depends on the intensity of the reflected light and the sensitivity of the cell, with the lighter parts of the subject producing a higher cell output. The polarity or "phase" of the output can be positive or negative. Fig. 7.7 shows a standard connection for a type 929 vacuum phototube. The output signal appears across the 1 megohm load resistor and as more

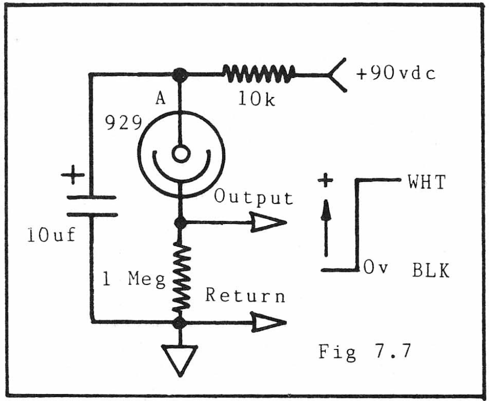


Fig 7.7

light is received by the cell, the output increases in a positive direction as shown. Therefore, when the cell output is at or near zero, the input to the cell represents a black or dark part of the subject and when a white portion of the subject is scanned, the output increases to its maximum positive value (positive phase).

Amplification is always required between the photocell and image lamp because, at best, the photocell output is in the millivolt range. The voltage appears across a load resistor of 10,000 or more ohms and the signal power at the cell is probably less than ten microwatts. On the other hand, the image lamp will require two to five watts for its operation, thereby making an amplifier mandatory.

When the photocell output signal is amplified and connected to the image lamp, the more positive excursions of the signal must result in an increased output from the lamp, because it was the brighter parts of the subject that caused the positive excursions. Note: This may require a negative going output from the amplifier. If the signal is inverted when it is applied to the lamp, the picture will appear to be a negative of the original (out of phase), see Fig. 7.8.

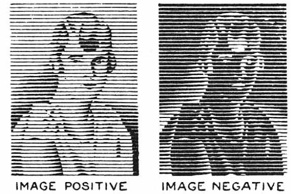


Fig 7.8

Depending on type, an amplifier may or may not invert the signal as it passes through. Common emitter transistor amplifiers alway invert the phase of the input signal, while the common base and emitter follower amplifiers do not. The popular operational amplifiers can be configured either way.

When necessary, the picture signal phase can be changed by altering the amplifier or by using a different photocell circuit. Fig. 7.9 is a schematic for a phototube circuit that is similar to the one in Fig 7.7, except that it provides a negative going output signal. The phototube is

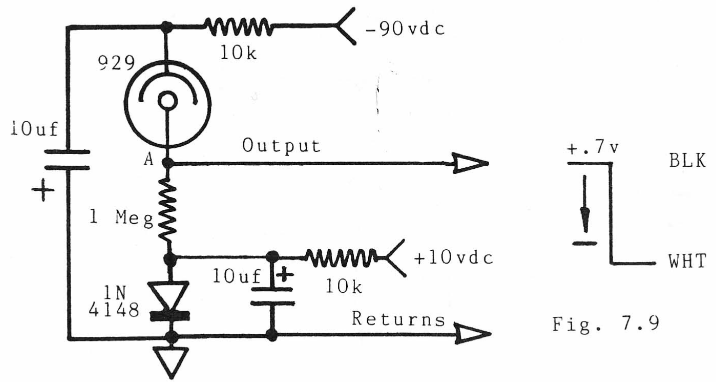


Fig. 7.9

biased with a -90vdc supply and its output is offset in a positive direction with a silicon diode. If no light reaches the phototube, the output of this circuit is approximately +.7vdc. When the phototube receives an input of light, the circuit output goes in a negative direction towards ground or return. Although the output voltage is always positive, the output level is reduced with an increase in light at the phototube (negative phase). If the +.7vdc offset voltage is not desirable, it can be eliminated by connecting the lower end of the 1 Megohm resistor to return and removing the diode and its two associated components. Connected this way, the output will be near zero volts with no light input to the cell and increase in a negative direction as light is applied (negative phase).

INPUT CIRCUITS

The silicon photodiode, see Fig. 7.10, being an isolated device, can provide a positive or negative output, by connecting its anode or cathode to the return buss. The circuit in Fig. 7.11 shows a photodiode in a reverse biased mode. This is sometimes done because it improves the frequency response of certain cells. This circuit provides a positive going signal output. A cell operating in this mode will provide a lower level output signal. Photodiodes are not well suited for flying spot scanners, but do operate very well in film or 35mm slide cameras.

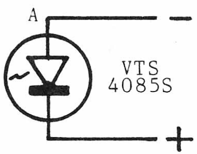


Fig. 7.10

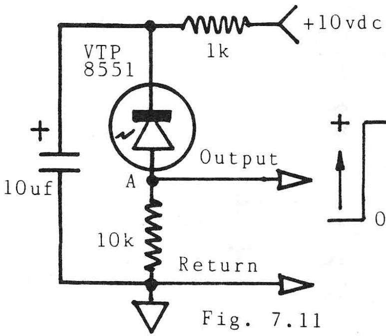


Fig. 7.11

Another good input device is the 929 phototube mentioned earlier. Its photo sensitive surface is designed to be used at the red end of the optical spectrum. This tube is well suited for use with an incandescent light source, but if it is to be used with a flying spot scanner, at least four should be connected in parallel and each mounted in the focus of six to twelve inch reflectors. The circuits in Fig. 7.7 and Fig. 7.9 include an RC filter in the anode circuit, to remove any noise or ripple that might otherwise appear in the output.

The phototube best suited for flying spot scanning is the photomultiplier. Some types provide gain of up to 1,000,000 times or more and are reasonably priced. A good choice is the type 931A, which will operate with as little as 300vdc or as much as 1250vdc. Gain is dependent on the supply voltage and a minimum of 500 volts is recommended.

Fig. 7.12 shows a schematic to a photomultiplier and its power supply. Transformer T1 can be a small 50ma. tube type power transformer with a 500 to 600 volt secondary and one or two filament windings. Only the hi-voltage secondary winding is used in this application.

The operation is as follows. The hi-voltage secondary output from T1 is rectified by diode bridge, D1 through D8 and smoothed by an LC filter, C1 through C4 and a 7 henry choke. Bridging resistors on the capacitors forces the voltage to divide across them equally. Negative polarity output from the filter is applied to the photomultiplier tube through a resistive divider. The output (anode) is referenced to ground or return and goes negative with an increase in light to the phototube. Due to its high amplification factor, it is important to shield or exclude all extraneous light from the phototube. Failure to do so can result in a high average DC output from the phototube, causing saturation and loss of video in the amplifier stages that follow. The tubes are also sensitive to stray magnetic fields such as those associated with power transformers. A copper or iron shield around the tube, can prevent the influence of these fields.

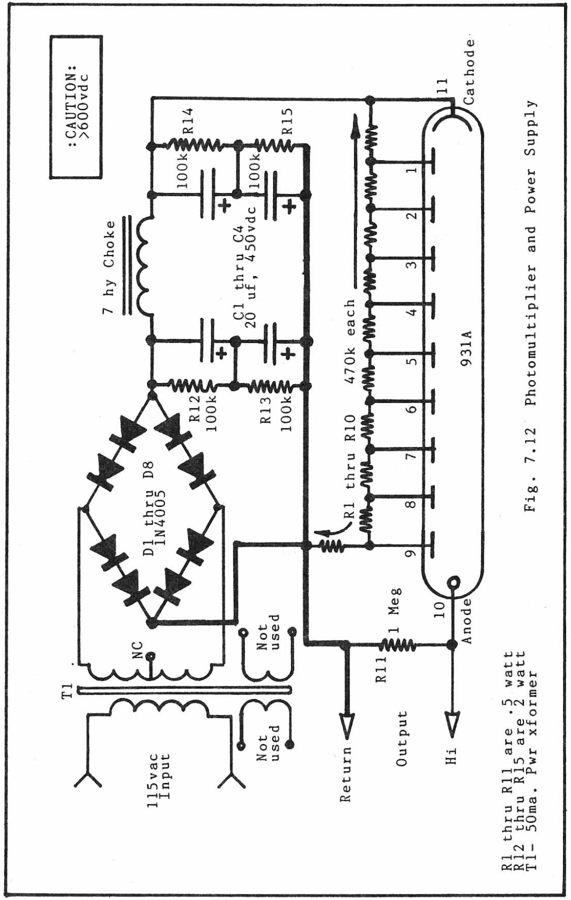


Fig. 7.12 Photomultiplier and Power Supply

R1 thru R11 are .5 watt
R12 thru R15 are 2 watt
T1- 50ma. Pwr xformer

The negative going output signal can be inverted by following the photomultiplier with an inverting type video amplifier. Fig 7.13 shows an FET amplifier that attaches directly to the output of the photomultiplier in Fig. 7.12. The stage also provides a voltage gain of 5 or more, depending on the setting of trimpot in the FET drain connection. The output of the FET can be connected directly or through a low leakage 2uf, 50 volt capacitor, to the input of the amplifier shown in Fig. 7.15.

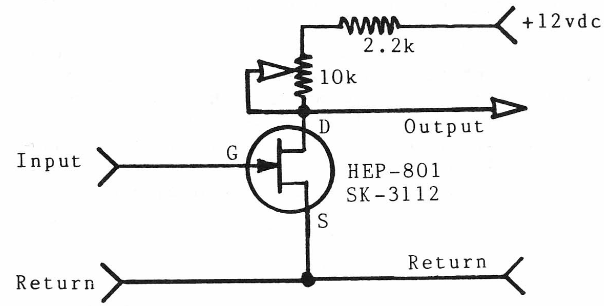


Fig. 7.13 FET Video Amplifier

VIDEO AMPLIFIERS

Video signals are complex waveforms that contain a mix of high and low frequencies that also include a DC component. The DC component is the average of all of the signal frequencies contained in a scene, and has the greatest importance in scenes with light or dark backgrounds.

Video amplifiers may be AC or DC coupled. A DC coupled amplifier, referred to as a direct coupled amplifier, will have a frequency response that begins at zero hertz and extends to higher frequencies depending on various circuit elements. Any signal input within the frequency range and its DC component, will be reproduced in the output.

An AC amplifier has one or more coupling capacitors in the signal path; at the input, the output, or between stages. This is done to improve the temperature stability of an "open loop" amplifier that has no DC feedback. Its frequency range will not include zero hertz, therefore DC signal components do not appear in the output. Scenes having light or dark backgrounds may tend to "gray out", in this type of amplifier because the signal is averaged to zero by the coupling capacitors. This effect has proved to be a minor one, as all of the early amplifiers and receivers were ac coupled and provided satisfactory results.

The range of video frequencies necessary to reproduce an image in a mechanical television system depends on the number of lines in the picture and the number pictures or frames, scanned per second. The lowest frequency is actually the frame rate, but in order to retain the DC component of the signal, It is necessary to pass DC. The bandwidth requirement for the three most common formats is:

No. lines	No. frames/sec	Bandwidth
24	15	4320 Hz
48	15	8640 Hz
60	20	36000 Hz

The frequency requirements for the above listed formats, are well within the range of simple tube or transistor amplifiers and many of the integrated types of operational amplifiers. An example of an early 24 line, tube type television transmitting system is shown in Fig. 7.14. The circuit uses cascaded high gain tetrodes, followed by a three stage triode amplifier. The output drives the transmitter modulator stage, which can also accept an input from a microphone, for voice communications. The RF output is supplied by a self excited oscillator.

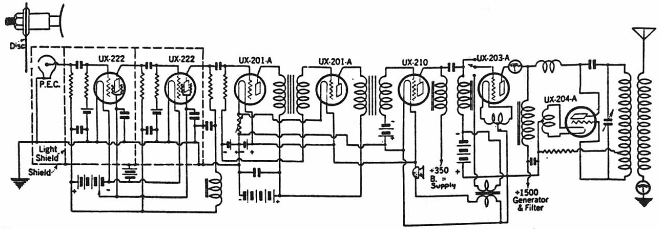


FIG. 7.14 *A complete schematic diagram of the apparatus used in the amateur television experiments*

The photocell output from the early systems was very low, requiring extremely high gain in the signal path. This called for careful shielding of the input circuits, to prevent oscillation and to minimize the entry of hum or noise into the system. Notice the extensive use of batteries in the video amplifier (there are nine), to help accomplish this. Although this circuit shows two tetrodes, sometimes three were used, when light levels were especially low.

All of the low level signal circuitry in Fig 7.14, could be readily converted to transistor operation. This could reduce the cost and complexity of those circuits, as well as improve performance. Integrated operational amplifiers could also be incorporated and would lead to even further reductions in cost and complexity. Because the operational amplifier offers numerous advantages over discrete transistor circuits, they will be considered here.

The operational amplifier originated in the 1940's, in the field of analog computers. The name "Operational Amplifier" derives from the concept of a very high gain, differential input DC amplifier, the operating characteristics of which are determined by the feedback elements used with it, rather than the amplifying device itself.

The op-amp has a differential input and signal may be applied to either input. This makes it possible to connect it as an inverting or a non-inverting amplifier. Two of the most common configurations for operational amplifiers are shown in Fig. 7.15. The circuit on the left, inverts the input signal, be it AC or DC, as it passes through the amplifier. The gain characteristic of the amplifier is controlled by the ratio of the feedback resistor (Rf), to the input resistor (R1). The circuit on the right has the same characteristics as the first, except that the output signal has the same phase as the input. The two inputs of the op-amp are usually marked positive (+) and negative (-), to denote the non-inverting and inverting inputs.

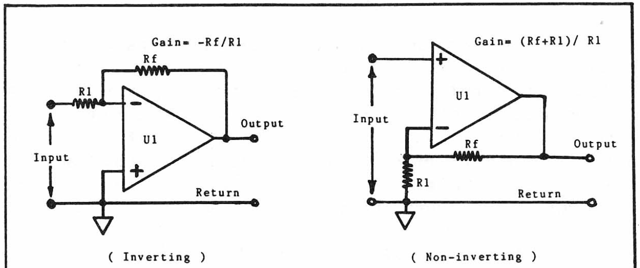


FIG. 7.15 Operational Amplifier Configuration

Fig. 7.16 shows a complete amplifier with an output adequate for driving up to six or more LED's. The amplifier consists of operational amplifiers and transistors configured as a amplifier followed by a voltage to current converter suitable for driving high current loads. The input to the amplifier should be by way of a shielded wire or cable from a silicon photodiode such as a Vactec VTS4085S, with its anode connected to the shield and return. A positive going signal from the photodiode will cause an increase in light from the LED array. The circuit operation is as follows.

The first stage, (U1) is connected as a non-inverting DC amplifier. Its gain is adjustable with a trimpot (RV1) over a wide range because of the manner in which it controls the signal to the feedback resistor. The minimum gain of this stage is eleven. The inverting input to the amplifier is

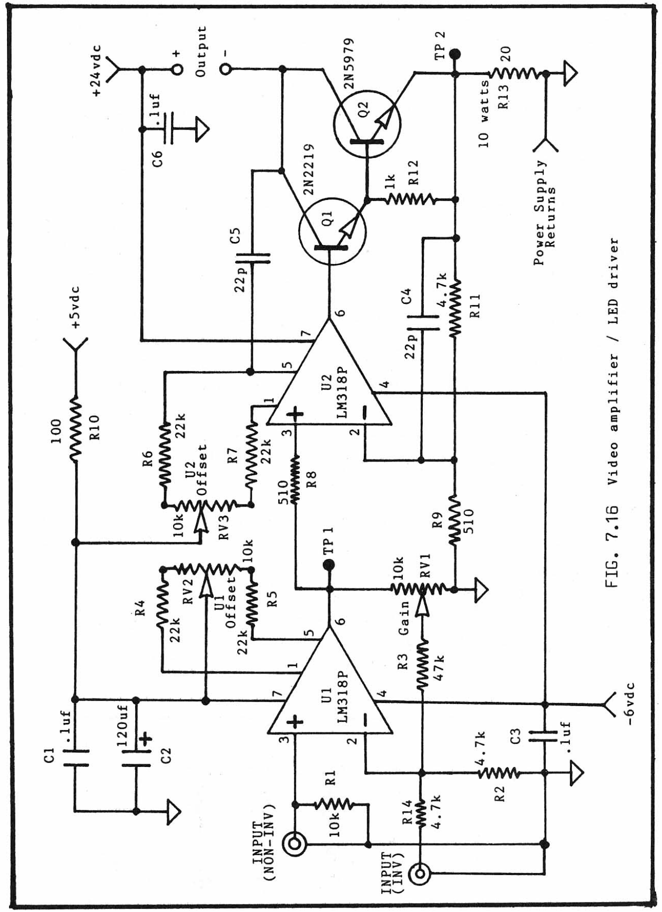


FIG. 7.16 Video amplifier / LED driver

also provided. Only one of the inputs should be used at a time. Either input will accept a low level signal from a tape recorder.The LM318 includes connections for adjusting out the effects of its internal or an external offset. The adjustment is made with RV2, for zero volts at TP1 in reference to ground, with RV1 at the center of its range and the input connected, but no signal in (black screen).

The output of U1 is coupled directly to the converter stage consisting of U2, Q1 and Q2. U2 is a non-inverting amplifier, driving Q1 and Q2, configured as a Darlington amplifier, which inverts the signal and supplies feedback to U2. The scale factor is set by R13 and with 20 ohms, is 460 milliamps per volt. Increasing the value of R13 will reduce the current to the LED's. If less than four are used, R13 should be increased to 40 ohms. U2 includes an offset adjustment (RV3), which is set after proper adjustment of RV2 and under the same input conditions. Adjust RV3 to produce 100mV at the TP2 on R13 in reference to return. RV1 is adjusted finally to produce the proper image contrast and tonal range.

The load for this amplifier should consist of four to six or more LED's, each with a series one half watt resistor, the value of which depends on the number of LED's used. The load impedance for the amplifier should be approximately 17 ohms, into which it can supply 600 milliamps. The series resistor value is determined by multiplying the number of LED's by 17 and selecting the resistor value closest to that

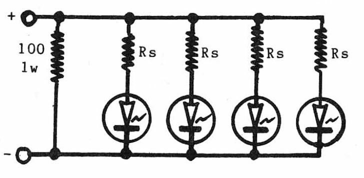


Fig. 7.17 LED Array

number. For three or less LED's, use 51 ohms (and increase R13 to 40 ohms); for 4, use 68 ohms; for 5, use 82 ohms and for 6, use 100 ohms. Each of the resistor diode combinations are connected in parallel and a 100 ohm, 1watt resistor is connected across the group, see Fig. 7.17. The purpose of the parallel resistor, is to stabilize the amplifier at low current levels, when LED's are about to turn off. The resistor assures that the amplifier will always have a load.

The amplifier requires three regulated DC voltages, which are supplied by the circuit shown in Fig. 7.18. The +24vdc and +5vdc are controlled by integrated circuit regulators and the -6vdc is zener regulated.

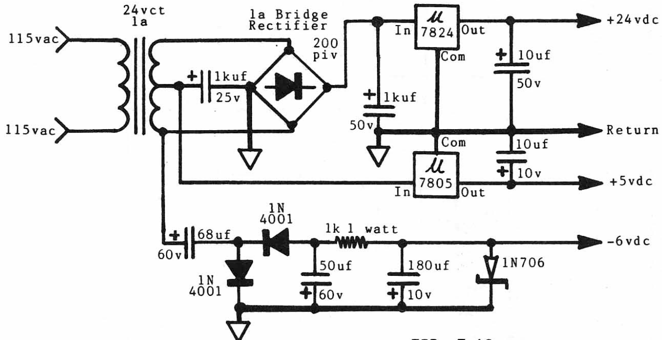


FIG. 7.18 Power Supply

HI-LEVEL AMPLIFIER

The amplifier previously discussed can supply a maximum output current of approximately 600 milliamperes into a load of seventeen ohms. Neons lamps however, present a much higher load impedance (approx. 5000 ohms), than the LED's and the output stage of the amplifier must be changed to accommodate this. Fig. 7.19 shows the schematic for a video amplifier and driver for either flat plate or crater neon lamps. The output stage has a scale factor of 51 milliamps per volt and is controlled the by the value of resistance in the emitter to return circuit of the output transistor. Circuit operation and adjustment is similar to the previous

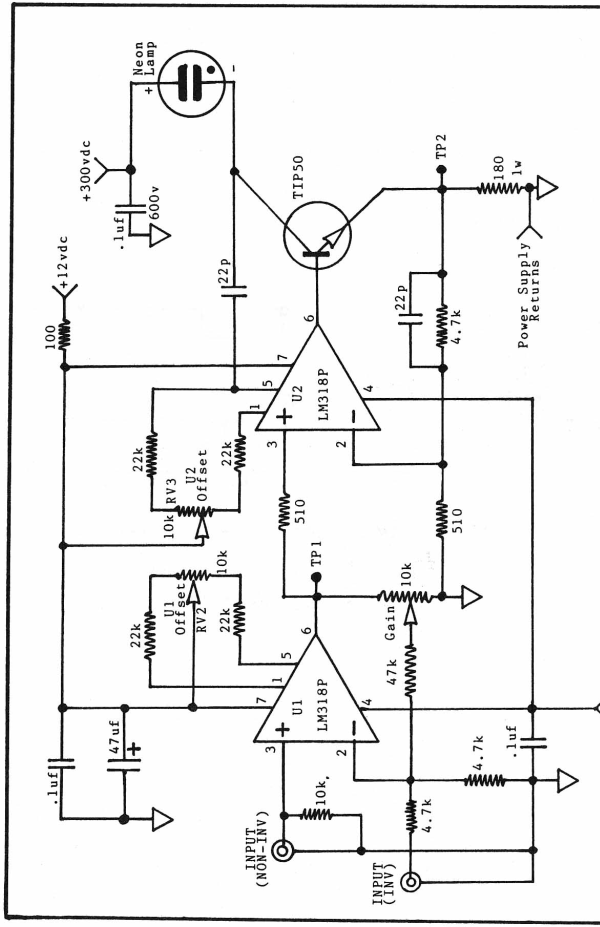


Fig. 7.19 Video Amp / Neon Lamp Driver

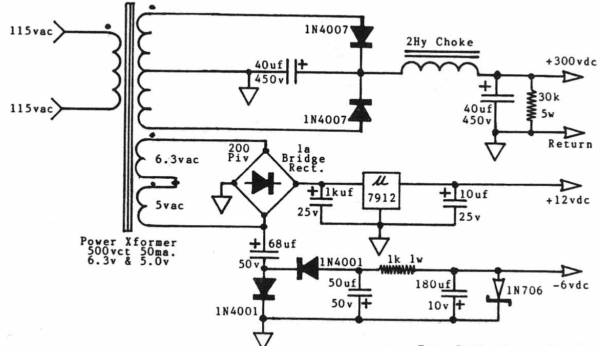


Fig. 7.20 Power Supply

amplifier. When RV3 is adjusted, it can be set so that the lamp just barely lights, with no signal input.

Fig. 7.20 shows the power supply for the hi-level amplifier. The power transformer is the type commonly used for small tube type radios. Its filament windings are connected in series to produce an output of nearly 12 volts which is used to provide both +12vdc and -6vdc. If the windings are not phased properly when they are connected, the output will be less than 2 volts. The connections to either winding should be reversed if this occurs.

If a crater lamp is used with this amplifier and the glow in the lamp occurs around the elements instead of in the crater, connections to the lamp should be reversed.

AUDIBLE VIDEO SIGNALS

When television receivers were being tuned to stations in the broadcast or shortwave bands, it was standard practice for the operator to connect the radio speaker and listen for the characteristic sounds of a television broadcast. Once a station was tuned in, the volume control was positioned to an appropriate setting and the speaker was switched out and the neon lamp in.

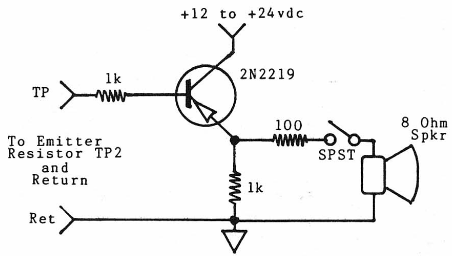


Fig. 7.21 Speaker Driver

The unique sound comes from a combination of a steady but rough sounding tone, due to the image lines being generated at a constant rate, and the modulation of the image video, which tends to repeat at the frame rate. Finally, any motion in the image causes all of these sounds in pitch and amplitude, to change in a most unpredictable and unusual manner. Its been said that some could recognize who or what was on the screen, by the sounds coming out of the speaker.

Fig. 7.21 is a schematic to a simple addition for either of the video amplifiers, that will allow audible reproduction of the video signal. It consists of an emitter follower stage, driving a small speaker. Closing the switch activates the speaker. The image lamp operates at all times.

The audio output can be recorded on any tape recorder of good quality, using a synchronous motor capstan drive.

MISCELLANEOUS USEFUL CIRCUITS

The circuits discussed up to this point, include all that are necessary for constructing and duplicating a closed circuit mechanical system, similar to those used in the late 1920's. In addition to these, there are some of more recent development, that introduce new or different techniques and advantages in the operation or performance of the system. These are presented here for your consideration.

OPTICAL SENSOR

There are applications where it is important to know the exact position of the disk as it rotates. An optical sensor can accomplish this with a minimum of hardware. The sensor contains an infra-red LED and a phototransistor mounted in such a manner, that only by reflection can light from the LED reach the photocell. They are produced by various manufacturers including Texas Instruments (P/N TIL139). This device in conjunction with an amplifier, will sense one or more small squares of white adhesive tape on a dark colored, non-reflecting scanning disk, as it rotates.

This is done by mounting the sensor approximately one-eighth inch from the surface of the disk, in an area just inside the scanning hole pattern and connecting it to the circuit shown in Fig. 7.22. This circuit is commonly referred to as a Schmitt trigger and its output interfaces with 5 volt logic families such as TTL. The output is normally at a low level, going high (positive) at the sensing point.

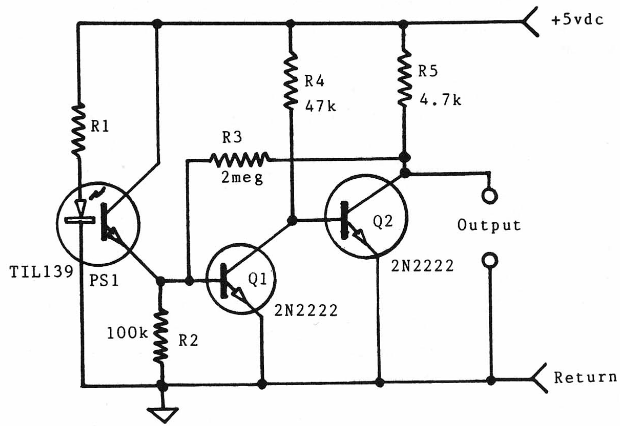


Fig. 7.22 Photo-switch sensor amplifier

Applications for this sensor include a means of providing some illumination for the operator of a flying spot camera, in an otherwise totally dark space. This sensor could also show when two disks are exactly together, through the use of a coincidence circuit. Finally, there are opportunities for improving on the techniques used in the 1920's and one example of the possibilities is presented in Appendix A. It shows a method for enlarging the receiver image by a factor of two, without the use of lenses or mechanisms.

SPECIAL LIGHTING

The flying spot scanner must operate in a totally dark area. Only the light reflecting off the subject as the spot sweeps across it, can be allowed to reach the photocell. Any other light that is picked up by the cell will reduce the contrast of the televised scene. Due to the extreme sensitivity of the photomultiplier, even very small amounts of extraneous light can result in a complete "wash out" of the image. The low light level makes it difficult for the operator to see his cables and equipment or make adjustments. A small amount of lighting would be helpful, if it did not interfere with the camera.

This can be accomplished by having a light turn on and off for a short time at regular intervals and the have the receiver off whenever the light is on. This type of light is referred to as a strobe light.

Refer to Fig.7.23. It shows the schematic of a strobe light. These are familiar to us in the form of electronic camera flashes and automotive timing lights. This particular circuit closely resembles the timing light variety. If one has an operating timing light for the purpose, it could be modified by adding the silicon controlled rectifier (SCR), as shown in the schematic.

Referring to the schematic, the transformer and rectifier, charge the 1uf capacitor to approximately 700 volts. This voltage is present across the end terminals of the lamp, but

it is insufficient to ionize the Xenon gas. The .02uf capacitor is also charged to approximately 300 volts through a resistive divider. When a positive input pulse triggers the SCR "on", it connects the .02uf capacitor to the primary of the trigger transformer. The output of the trigger transformer connects to a few wraps of wire, around the glass tubing of the lamp. When the .02uf capacitor discharges into the primary of the transformer, it ouputs a 6kv to 10kv pulse to the wire wrapped on the lamp. This ionizes the gas and allows the main charge from the 1uf capacitor to pass through, completely discharging it and giving a very bright flash of light for approximately 5 microseconds. In 10 to 15 milliseconds, the capacitor will recharge and the lamp is ready to trigger again. This strobe light can be triggered up to 50 times per second.

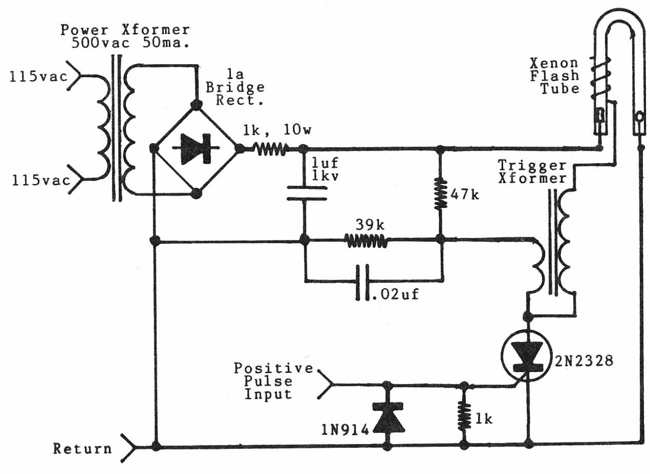


Fig. 7.23 Strobe Light

This strobe light can be triggered by the optical sensor circuit in Fig. 7.22, by connecting the output of the sensor circuit directly to its input. Controlling when and where the the light comes on, is accomplished at the camera disk, by placing a one-forth inch square of white vinyl tape on the disk. Place it at a location where it crosses or passes the sensor just as the first hole in the spiral or last hole goes through the image mask. At the receiver disk, tape over the same hole, so that no light can pass through, on that hole only.

Now when the system is operated, the strobe lamp will be flashing at the frame rate. The receiver will not show an output or bright line, because that particular line is "blanked" by the taped hole.

Since the strobe is flashing at the frame rate, any motion on the part of the operator or spectators, will appear to be in the form of short steps and may appear very strange at first. This could be upsetting to some and should only be used with their consent.

ZIRCONIUM ARC LAMP SOURCE

The Zirconium arc lamp is a point source lamp, giving off white light, similar in color to a tungsten lamp. It has an extremely small spot size and in combination with a lens type disk, can be used as the light source for a flying spot scanner. It is available in a ten watt size, which is adequate for small scanned areas. It requires a special power supply for operation, such as one shown in Fig 7.24. The lamp operates with approximately 20 to 25 volts DC, but requires over 1000 volts, for starting. The transformer is only used for starting and therefore can be of minimal size. The power supply consists of both a high voltage section, producing 1100 volts and a low voltage section that rectifies the line voltage and produces 130 volts. A momentary switch controls the high voltage section.

When the momentary switch switch is depressed, approximately 1200 volts DC is applied to the lamp. During starting, the

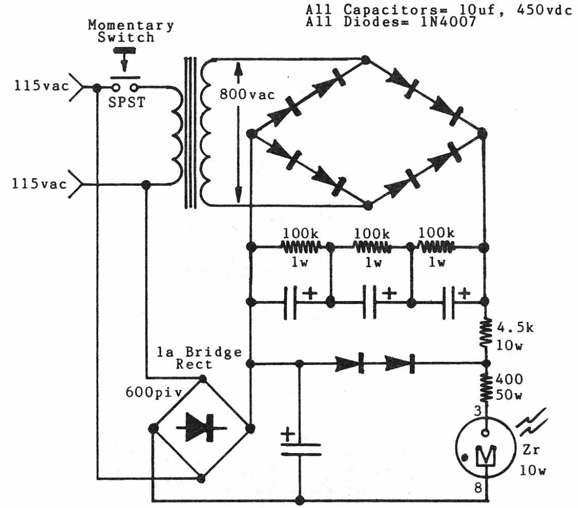


Fig. 7.23 Zirconium Arc Lamp and Power Supply

high and low voltage sections are connected in series. The gas in the lamp immediately ionizes and a small arc begins across its electrodes. When the arc begins, the switch should be released, turning off the high voltage and allowing the low voltage section of the supply to operate the lamp.

DC LAMP SUPPLY

The small 6 volt and 12 volt automotive lamps are often adequate for lighting a small area subject, such as 35mm film. These lamps use a very small filament, which is desirable, because it will produce a sharper image in the optical system. However, the small filaments have small mass and little thermal inertia. When these lamps operate on 60Hz AC power, the light contains a 120Hz modulation, which can appear in the camera signal output. This can be corrected by operating the lamp on filtered direct current. Fig. 7.25 shows a power supply, suitable for this purpose. The capacitor is one of the familiar "computer grade" variety, with a capacitance value of at least 10,000 uf per ampere of lamp current. Its voltage rating should be approximately 20% higher than lamp voltage.

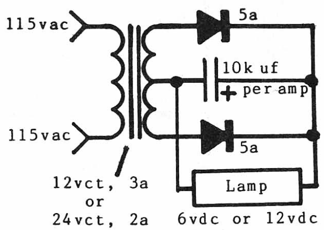


FIG. 7.25 DC Lamp Supply, 6/12 volt

Silhouette as broadcast by the Jenkins Laboratories in 1928. The image size shown here is the approximate size of the image seen by "lookers in."

TELEVISION CAMERAS AND RECEIVERS — CHAPTER 8

CAMERAS

There have been four basic forms of cameras developed and used for mechanical television. The most common type was the flying spot variety, followed by the motion picture film camera. For use outside the studio, the camera depicted in Fig. 4.17 (page 41) was used. Cameras of this type saw limited use in the studio because of high level of illumination required.

Fig 4.18 (page 41) shows a type of camera that operates with a lens disk. The photocell is located in a light tight enclosure, equipped with pinhole facing the disk and located at the focus point of the lenses. The action of the disk causes the entire image to scan across the pinhole, effectively scanning the image. If a photomultiplier is used, the amount of lighting required is greatly reduced.

The theater slide or 35mm slide camera is a more recent development and is ideal for demonstrations and for showing test patterns of various types. This camera presents the least number of optical and mechanical problems to the constructor. It is strongly recommended for those planning to develop their first system.

FLYING SPOT SCANNER

The most popular type of camera for studio pickup was the flying spot scanner. It was most often used for close ups of persons heads or upper body. In the flying spot system, the subject is scanned by a moving spot of light and a bank of photocells was used to pick up the light reflected from the subject. Since the photocells will respond to light from any source, the camera and subject had to be operated in totally dark space except for the light from the scanner. Sometimes, the scanner and operator were placed in a separate room, similar to a projection booth, while the subject along with banks of photocells was in a room adjoining. A small porthole was in the wall between the rooms and the scanner beam passed through the opening. Here too, the scanning beam was the only light allowed to enter the room with the subject, but camera room could have low level lighting for the operators benefit, without affecting the operation of the camera.

Fig. 8.1 shows the structure of an early flying spot scanning system, with an exposed scanning disk being illuminated from the rear. Illumination was supplied by a 300 to 1000 watt hi-intensity arc, tungsten lamp or other powerful light source. The light passed through the holes in the disk and formed a small, intense moving beam, scanning the subject. An image mask was positioned near the rotating disk, but not touching it. It prevented light from escaping from more than one scanning hole at a time.

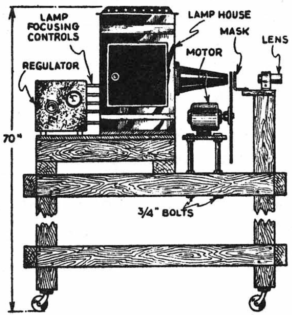
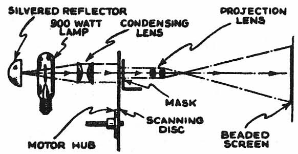


FIG. 8.1 *Side view of lamp house, scanning motor and disc, mask and lens.*



line-up of reflector, lamp, lenses and scanning disc; subject poses before the beaded screen.

In order to achieve even illumination over the entire frame, one or two convex condenser lenses were located between the disk and light source. Lens diameter was approximately twenty-five per cent larger than the diagonal of the image. A small condenser lens would result in an image with dark edges and corners. A large one would spread the available light over a larger than required area, reducing the intensity of the scanning beam. None of the light illuminating the disk could be allowed to escape into the

space occupied by the subject. This required the lamp, lenses, mask and possibly a portion of the disk, to be located in some sort of housing, that allowed cooling air to enter and exit, but prevented light from escaping.

The condenser lens was located approximately one-half inch from the disk and one focal length from the light source. If two plano-convex lenses were used, in order to reduce their focal length, they were mounted with their curved surfaces facing and almost in contact with each other. A small range of adjustment, back and forth, up, down, left and right, was available for both the lens and the light source. These adjustments allowed optimizing the evenness of illumination on the disk.

The beam of light emerging from the disk must be focused on the subject. A camera or projection lens will serve this purpose. These lenses have three important characteristics;

(1) Image format...circular size of image the lens can form.
(2) focal length...affects subject distance and image size.
(3) f-number......"speed" of lens or light gathering power.

Lenses are designed to be used with certain image formats or sizes. The common sizes are 8mm, 16mm, 35mm and two and a quarter inch, square. Larger format lenses may always be used for smaller formats without difficulty, but not the other way around. The 8mm and 16mm lenses are not suitable, except for cameras having very small images.

Because a camera lens will invert and reverse the scene that appears on the disk , it is necessary to correct the image at the receiver, or compensate for it at the camera. This can be accomplished by locating the entire optical assembly at the bottom of the camera disk (the 6 o'clock position).

If the disk image size is approximately one and one-half inches or less, in the longest dimension, lenses designed for use with 35mm cameras are recommended. Because of the popularity of 35mm single lens reflex cameras, there is a large variety of low cost lenses available. Many are equipped with focusing mounts. Suitable lenses have focal lengths from 50 to 100mm, and f-numbers between 1.2 and 3.5, when set to their maximum opening. The mounting surface of these lenses is approximately one and three-forths inches from the disk, but the exact location can be found by experiment. During operation, the lens diaphragm is normally set to its maximum opening and focusing is accomplished by adjustment of the lens.

From the scanner, the beam passed through a photocell mount similar to Fig. 8.2 and onto the subject. The mount contained four or more large reflectors with photocells at their focal points. The cells were operated in parallel and connected to a pre-amplifier, located on a shelf behind the reflectors.

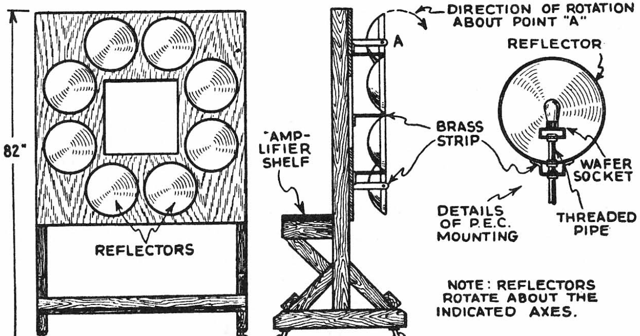


FIG. 8.2

A variation of the flying spot scanner uses a lens disk instead of the aperture disk. Lenses have greater surface area than the apertures and consequently provide more efficient use of the light source. Each of the lenses is a short focal length, large aperture micro-projector, operating in conjunction with a hi-intensity point source lamp. No camera type lens is used with this camera. Focusing is accomplished by varying the position of the light source in respect to the disk. As before, the subject must be in total darkness.

Working in total darkness can be very awkward for an operator of the equipment, who may be attempting to arrange or adjust the equipment while it is in operation. This situation can be improved by a modification to the camera and the addition of strobe lamp, as described in chapter 7.

The modification to the camera consists of adding a disk position sensor to provide an output when the first or last disk aperture is in the frame. The sensor signal is used to trigger an electronic flash lamp which is positioned to illuminate the subject area. The signal can also used to clamp or turn off the video signal at this time, so that the receiver does not show a bright spot or line when the lamp operates. The bright spot can also be eliminated by placing a small piece of plastic tape over the hole. If this is the first or last hole in the spiral, it will not be noticed.

TELEVISION MOVIES

The first "Radio Movies" transmitted from the Jenkins laboratories were only silhouettes in order to confine the frequency within a ten kilohertz band. The original camera operated with 35mm film, especially prepared for television. The films consisted of moving black and white subjects such as a small boy bouncing a ball and dancing and kicking into the air (see Fig. 8.3). Sometime later a wider band was granted and the transmissions were converted to a half-tone basis.

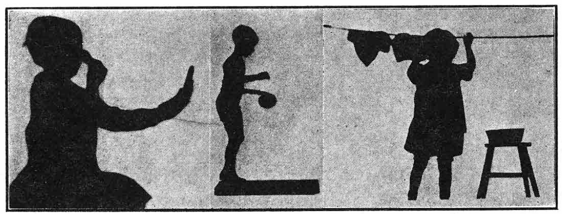


FIG. 331. Silhouettes as Broadcast by the Jenkins Laboratories.

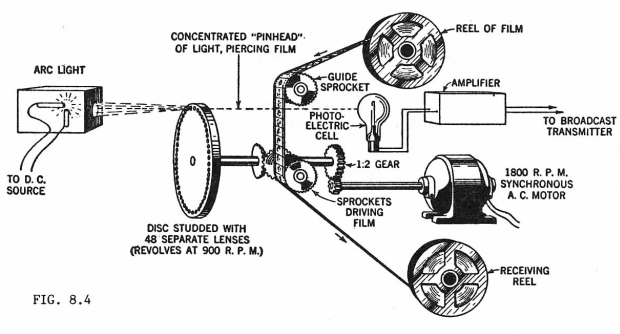


FIG. 8.4

General layout of the radio-movie transmitter, showing the essential parts without the supporting frameworks, etc. The leads marked "to broadcast transmitter" run to the regular input amplifier of the broadcast station through which the pictures are being sent out.

In Fig. 8.4, the essential parts of the camera are shown in the same positions they occupy in relation to each other. The film reels are arranged one above and the film is pulled downward by a set of sprockets. The sprockets are driven at a constant speed through gears by a synchronous motor, which also drives a lens disk at 900 rpm or fifteen revolutions per second. The gear ratio to the sprockets is selected to cause fifteen film frames to pass a given point each second, while the disk rotates once for each frame. Instead of a spiral, this disk has its 48 lenses arranged in a circle. With each turn, the same line on the film is scanned 48 times. But since the film moves one frame during this time, the 48 scan lines are spread evenly over the entire frame. Because the film is loaded into the camera upside down, the scanning progresses from the top of each frame, to the bottom. Because the disk has a circular pattern of holes and always scans the same line, some cameras were equipped with smaller disks containing half the number of lenses (24) and rotating at twice the RPM. The result was the same.

A variation of this movie camera uses an aperture disk and a modified 35mm, 16mm or 8mm movie projector. The projector modifications consist of removing the blower, shutter, claw or shuttle mechanism, adding a new film guide pulley between

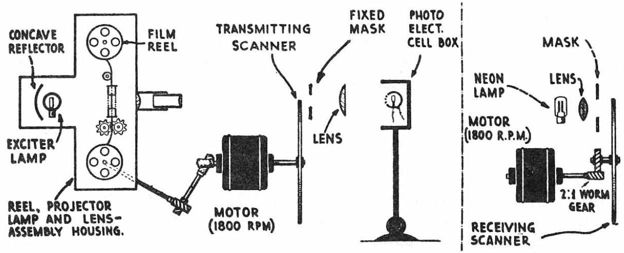


FIG. 8.5 *Arrangement of "movie" television projector at left; receiver at right.*

the light gate and lower sprocket and modifying the motor drive so the mechanism can be driven by an external synchronous motor. The lamp is changed to a lower wattage lamp.

The image from the projector is focused on the disk containing the circular hole pattern (see Fig. 8.5). Light passing through the disk is collected by a condenser lens and large area silicon photocell, similar to the type used in the slide camera, described later in this chapter.

The width of the image focused on the disk, should be the same as the distance between the apertures and the ratio between the disk and sprockets should be such that, 48 horizontal scans of the image occur on each frame. At the disk, the frames will appear to move upward, so the scanning should be from left to right.

The image area on movie film, is always wider than it is high, with an aspect ratio around 4 to 3. Television cameras developed for the live pickup of scenes or actors, produced an image that was either square or taller than it was wide. Aspect ratios ranged from 1 to 1, to 1 to 1.5. This was done to increase the picture area on a given size disk. It was a simple matter to increase the pitch of the spiral on the disk, which made the picture taller, compared to increasing the space between the holes in the spiral, which would have made the picture wider. That would have required a larger disk.

As was mentioned in chapter 2, whatever the image aspect ratio is at the camera, it should be the same in the receiver, or image distortion will result. Therefore, a camera and receiver used with movie film should have disks designed to operate with the aspect ratio of film.

35mm SLIDE CAMERA

Another form of camera, is one using 35mm or 2" by 2" super slides as the subject matter. This camera ideal for generating test patterns. Fig. 8.6 shows the optical construction for the slide camera.

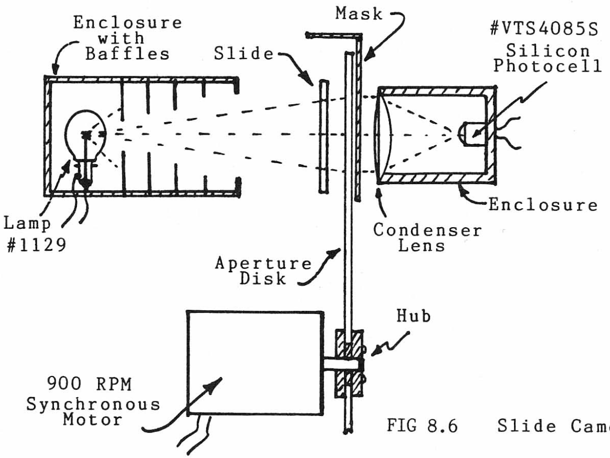


FIG 8.6 Slide Camera

The light source is a small filament, 6 volt, 21cp lamp. It is mounted in an enclosure with light baffles, so that only the direct rays are able to reach the slide. The direct rays passing through the slide will cast a sharp shadow on the disk. Light that penetrates the disk, passes through the mask, which prevents more than one hole from passing light to the condenser lens and photocell. The cell is in an enclosure, along with a condenser lens. The enclosure allows

only light from the disk to activate the cell. The disk is a standard type with a single spiral of holes. In a 24 line system, a 12 inch diameter disk is adequate. With 48 lines, a 16 or 18 inch diameter disk is required.

TEST SLIDES

The slide camera will require one or more test slides, for the purpose of testing or demonstration. A good subject for a 24 or 48 line system, is one of a character that is easily recognized and has very high contrast. The coloring is preferably black and white with no in between shades. One of the most suitable is "Felix the Cat". Felix also has a historic significance, in that he was the first television star. He served as the RCA test pattern, during the early years of scanning disk television at RCA.

Fig. 8.7 is suitable for copying, using a duplicating machine that can produce clear slides or viewgraphs. The image can be cut out and mounted in a 35MM slide mount.

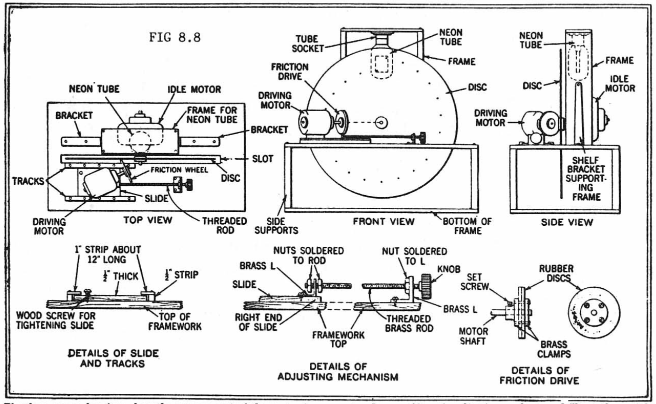
MOVING IMAGES

This 35mm camera can also provide moving images. A method for accomplishing this is to locate a small, low speed (approx. 6 RPM) clock motor in the same area as the slide and have the motor shaft rotate a small figure or device that will cast its shadow on the disk in the image area. As it slowly rotates, the motion will be seen at the receiver.

FIG. 8.7

RECEIVERS

Two types of home receivers were popular. At first all of the receivers used an aperture disk or drum, with a large plate neon lamp. Both kits and complete receivers were available from companies like Jenkins, Baird, Daven and others. Many of the popular magazines ran "how to " articles for building your own. And many people did. Fig. 8.8 shows a drawing from a typical article of this time. Fig. 8.9 shows another home made set, that might be called a "bare bones" set, since it had no provision for synchronizing the motor (an external reostat was used), nor has it a cabinet. In spite of its simplicity, it did work.



The three upper drawings show the arrangement of the parts of an excellent television or "radio-movie" receiver; the support for the disc may be an idle motor or a small polishing head. Mount the neon tube so that it is not affected by the vibration of the driving motor. In assembling the adjusting mechanism, drill out the upright arms of the L-shaped brackets so that the threaded brass rod will revolve in them easily. Once the proper position for the slide has been found, turn in the wood-screw, so that the motor will not "walk."

Fig. 8.10 shows a more elaborate kit type of receiver, sold under the "Pioneer" label. The receiver includes two motors, one of them synchronous, a double spiral disk with an adjustable neon lamp for framing adjustment and a six inch magnifying lens. The disk featured square holes.

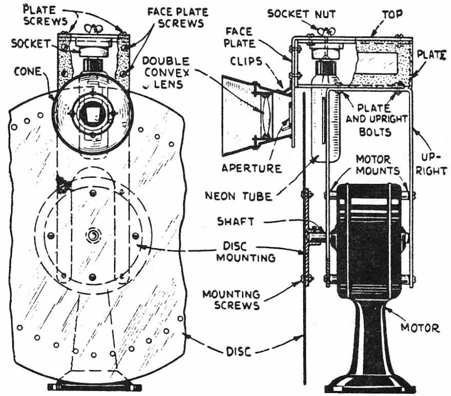


FIG.8.9

Simple home-made televisor built around an ordinary fan motor

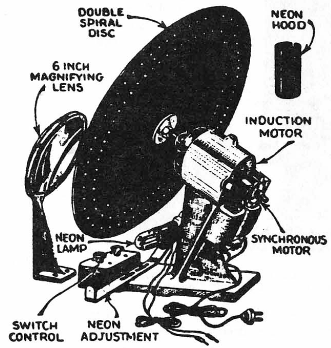


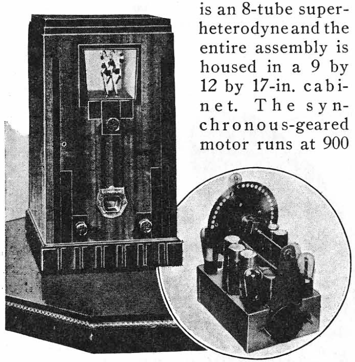
FIG.8.10

The Pioneer scanner, fitted with accelerating and synchronous motors. The image is viewed through the lens at the left.

In order to increase the picture size and brightness, the lens type disk and crater lamps came into use. This made the set into a form of projector and small disk images could be magnified to produce reasonable sized pictures. Disks using mirrors instead of lenses also became popular about this time. Fig 8.11 shows a "Western" brand, table model television set. It is equipped with a crater lamp and an eight inch diameter lens disk, containing 45 lenses arranged in three spirals. The picture size was approximately four inches square and the brightness was adequate for use in low to medium light levels. The disk rotates at 900 RPM and the cabinet includes an eight tube superheterodyne receiver.

Television Receiver with Scanning Disk

The triple-spiral scanning disk used in this television set is only 8 in. in diameter and contains 45 small lenses. The receiver is an 8-tube superheterodyne and the entire assembly is housed in a 9 by 12 by 17-in. cabinet. The synchronous-geared motor runs at 900



Television Receiver Showing Projected Picture and Tuning Controls; Insert, Compact Chassis Assembly

revolutions per minute in step with the various stations in the middle west which are operating on daily schedules with the 45-line 3-spiral system. The received picture is 4 by 3⅞ in., and the new crater-type lamp behind the disk produces sufficient light to show the pictures in a fairly well-lighted room from various angles.

FIG. 8.11

Up to now, we have been discussing the history, theory and component parts of mechanical television systems. Now we will go into the actual construction of the key elements of an operating camera and receiver. This is not intended to be a step by step instruction, so that the builder can better utilize his own skills and ingenuity. Building a closed circuit mechanical television system will be a very demanding project, but it will also be a very rewarding one.

Before construction can begin, one must decide on the basic characteristics of the system. As with most decisions of this sort, there are the usual trade offs concerning cost, complexity and performance. If this is your first attempt on a project of this nature, there are also the factors of experience, confidence and capability. For this discussion, it will be assumed that the system to be built must use a standard scanning format, be low in cost and suitable for effective demonstrations of the operation and performance of mechanical television.

The standard formats for single spiral (non-interlaced) disks were 24, 48 and 60. The 24 hole system represents the earlier equipment used by Jenkins and Baird and is the one selected here for a first attempt at producing disks. These disks are easy to build and produce relatively large pictures. This system will provide recognizable pictures of a range of subjects. There is much to be learned by developing this 24 line system to a high degree.

PROPOSED SYSTEM SPECIFICATIONS

Wired, closed circuit camera and receiver.
Camera subject matter: 35mm double frame or super slides.
Scanning format: 24 lines, 15 frames per second, non-interlaced.
Disk: 12.0" diameter, aperture type (Camera and Receiver).
Image Aspect Ratio: 1 to 1.2

The system will consist of two packages: the camera and the receiver. The camera will contain an optical assembly, mechanical assembly and the electronics assembly. The receiver will contain an optical and mechanical assembly.

The camera will be discussed first and then the receiver. The disks should be constructed together, as a matched pair, to provide improved performance, as compared to making them separately.

BUILDING AN APERTURE SCANNING DISK

The 12 inch diameter disks were selected because, in a 24 line system, the image area is well suited for use with 35mm or 2 x 2 superslides. Aluminum is the best choice for disk material and the only one recommended, although many other opaque materials such as bakelite, brass, steel and even cardboard have been used. The alloy should preferably be one of the hard varieties, such as types 6061, 2024, or 7075 , in T4 or T6 condition. These materials have a springiness or stiffness that ordinary aluminum lacks. Sheet aluminum is available in circles, squares or sheets. Acquire two 12 inch round or 12.5 inch square pieces of .025 to .040 thick aluminum. The material should lie flat without any force applied to it.

LAYOUT OF THE DISK

Whatever the shape of the material when you receive it, you must locate its center. If the material is square, scribe both pieces with two short diagonal lines, near the center of the disks, directly on the aluminum surface. If you have difficulty seeing the lines, coat the area with a layout ink such as "Dykem", which is available from most machine shop supply companies. Where the lines cross, center punch the material very carefully. A magnifying glass is recommended for all center punching done on the disk. Examine the mark with the glass. If the mark is located correctly, center punch it again. From the center, scribe a 6 inch radius circle and cut the circle out of the square. Use a jig saw or band saw rather than tin snips, because there will be

less chance of bending the disk. Repeat this on the second piece of material. Place the disks together and see that they are the same diameter. Trim the larger disk if necessary. The outer dimension is not critical, but the disks should be at least 12 inches in diameter.

If you received the material in the form of a 12 inch circle, the disk centers can be located by using dividers set to the radius of the circle (6 inches), and scribing three arcs through the center area of the material. The arcs should be approximately 120 degrees apart (see Fig. 9.1). Where the arcs cross, center punch each disk very carefully.

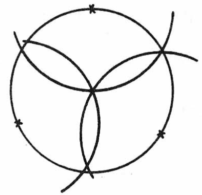


FIG 9.1

LOCATING THE CENTER OF A LARGE CIRCLE

It might well to point out at this time, that the following steps must be carefully done. The quality of the final picture will depend on the accuracy of the layout and drilling of the disks. Use the magnifying glass on every hole. Layout of the holes can be performed on one of the disks, but when the center hole and scanning holes are drilled, the disks should be clamped together, so that the holes drilled in one disk are matched with those in the other.

On each disk, scribe a .250 inch, a .375 inch, a .500 inch, and a 1.0 inch circle around the center (these circles will look like a bullseye). Do not drill any holes in either disk at this time. The extra scribed circles will be used later to help locate the 1.0 inch hole accurately.

On one of the disks, scribe a line across the disk and through the center mark. Scribe a second line in a similar manner, only rotated exactly 90 degrees from the first. This divides the circle into four quadrants and each eventually will contain 6 holes. Scribe a 5.75 inch radius circle on disk. This is the radius to the first hole in the spiral and is .25 inches from the edge of the disk. The space at the edge is necessary to prevent spillover of the light source, around the disk into the viewing area. The circle intersects with the straight lines through the center, in four places. These four intersects are the angular positions of holes No. 1, 7, 13 and 19. Choose one of them and lightly mark the disk, "Hole # 1". Using dividers or a protractor, divide each quadrant into six equal 15 degree segments. Check that all segments have the same width where they intersect with the outer circle. Perform this step carefully because if a scanning hole is angularly out of place, the line formed by this hole will be shifted to one side, as illustrated in Fig. 9.2.

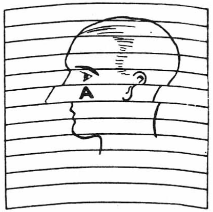


FIG. 9.2

IF ONE SCANNING HOLE IS ANGULARLY OUT OF PLACE THE PICTURE LINE A FORMED BY THIS HOLE WILL BE SHIFTED TO ONE SIDE.

There should be 24 intersections on the outer circle. Scribe a line through each of these intersects into the center of the disk. Carefully and lightly center punch the intersect marked "Hole # 1". Inspect it with the glass and if not satisfied with its location, center punch it again with the punch at an appropriate angle and move the mark to the correct location.

The disks should now be placed together and the outer edges aligned. Lightly clamp the disks (with the scribed disk on top) using three or four small "C" clamps around the periphery of the disks.

THE CENTER HOLE

Set the speed of a good drill press to approximately 700-900 RPM and using a No.3 center drill, drill out the center hole. Use the scribed circles to help locate the center hole accurately. When satisfied that the hole is in the correct position, pass the center drill all of the way through both disks. Follow through on the center hole with progressively larger drills until the hole is .375 inches in diameter.

A good method for laying out the spiral hole pattern, is to temporarily locate a 2 inch long, .375 inch metal stud or post, in the center of the disk. The post is threaded over a portion of its length and mounted in the .375" hole in the center of the disks, using washers and lock nuts. Once it is securely in place, care should be taken to see that it is in fact centered. See Fig. 9.3.

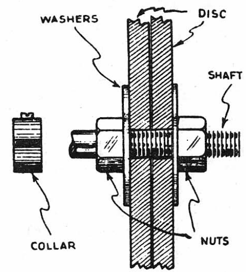
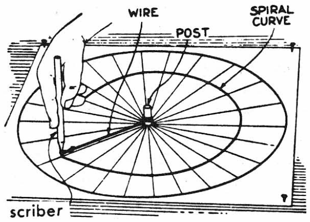


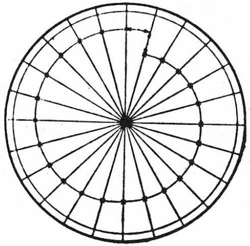
FIG. 9.3 Center Stud and Collar

The circumference of the post must be the same as the height of the image, therefore the diameter of this post will be increased to the correct size by attaching an appropriate set screw collar. This disk will require a collar with an inside diameter of .375 inches and a .576 inch outside diameter. This collar could start out with a larger outside diameter, reducing it to the correct size in a lathe or drill press.



Divide a circle on a metal disk into 24 equal sectors and scribe a spiral

FIG 9.4



mark holes at intersections

FIG. 9.5

By attaching a wire to the set screw in the collar and winding the wire around the post for one revolution while holding a sharp scriber in a loop at the other end of the wire, it is possible to generate a good spiral (see Fig. 9.4). As the wire winds around the post in a counterclockwise direction, it will shorten the radius and pull the scriber towards the center. A suitable wire is available from music stores as an "E" string for a mandolin. The wire has a loop on one end that is just the thing for the scriber point.

Begin with the wire length and scriber set to place the scriber point in the mark for Hole # 1. Move the scriber through one complete revolution, being sure to hold the scriber vertical as you move around the disk. Carefully center punch each of the intersections on the spiral curve and remaining 23 angular lines (see Fig. 9.5).

Another way to lay out the disk is to mark the radius for each hole, on the 24 angular lines. Begin with Hole #1. It is located on a 5.75 inch radius. Hole # 2, is positioned 15 degrees counterclockwise from hole # 1 and is located inward from the 11.5 inch circle, by the width of one hole. The hole diameter for a 12 inch, 24 hole disk with an aspect ratio of 1.2, is .0753 inches. Therefore, the radius to hole # 2 is 5.75" minus .0753" or 5.68 inches (rounded off to two place accuracy). Set the dividers to this dimension and mark

the location of hole # 2 on the 15 degree mark. Center punch the mark and go on to hole # 3. Reduce the radius by .0753 inches as before and mark and center punch the 30 degree line. Continue this until all 24 hole locations are marked and center punched. Appendix B includes a printout that provides all of the radii and other information necessary for this 24 hole disk.

DRILLING THE HOLES

At this point, you should have two disks, clamped together with all scanning holes marked and ready for drilling. Using a drill press that is in good condition and preferably with a new No. 48 drill bit, drill the 24 holes in the spiral through both disks. Remove the clamps and separate the disks. Deburr the holes with fine emery paper.

THE HUB

Each disk will require a hub to allow it to be attached to a motor shaft. The hub should center the disk in respect to the shaft without causing any bending or distortion at the center of the disk. If there is nothing on hand, use Figure 9.6 as a guide for producing a hub. Hubs must be precisely made and are a job for a machinist. Sometimes, a gear with similar dimensions can be modified for this purpose. Some of the hubs used on early systems included a means of spring

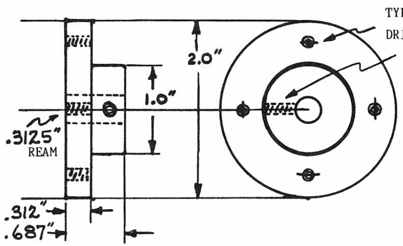


FIG 9.6 SCANNING DISK HUB MAT. 6061-T6 ALUM.

coupling between the disk and motor shaft (see Fig. 9.7). The spring decoupled the "cogging" effect of the motor and also improved its starting characteristics. However, modern synchronous hysteresis motors do not suffer from these effects and direct drive to the disk is acceptable.

The hub mounts in a 1.0 inch diameter hole in the center of each disk and is held in place with four 8-32 screws. Using a 1.0 inch socket hole punch, cut a 1.0 inch hole in the center of each disk, being careful that the male part of the punch is properly located during the punching action.

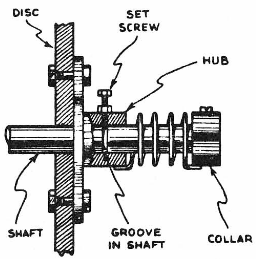
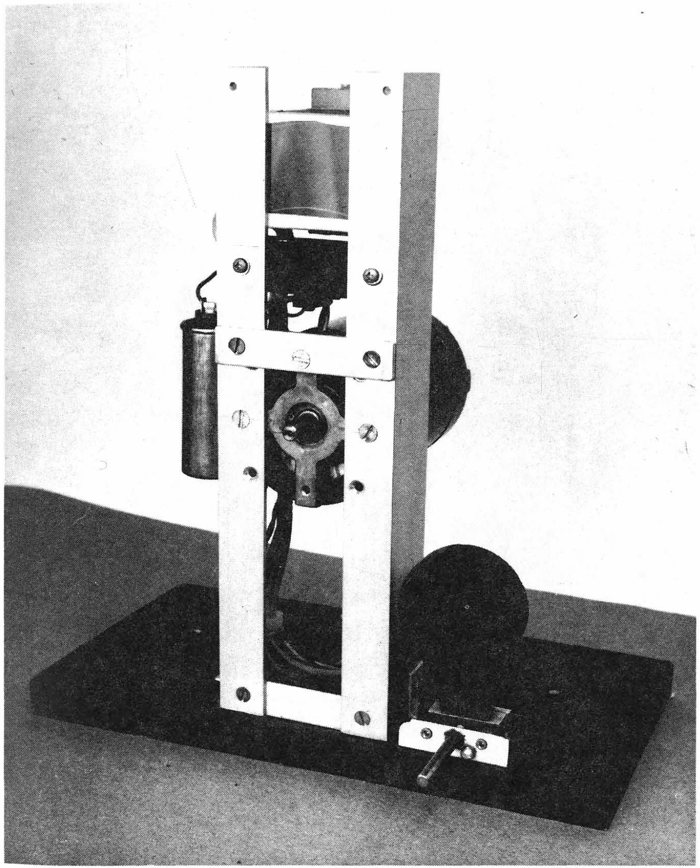


FIG. 9.7

Locate a hub on each disk and use it as a template for drilling the four mounting holes with a No. 28 drill. Remove the hubs and enlarge the holes in each disk with a No. 19 drill and deburr.
Clean the disks with a solvent that will remove any grease or oil that may be on the surface. Paint both sides of each disk with a flat black, spray paint. The epoxy variety work best. Give each side one light coat, being careful not to clog the holes with paint. If necessary, clean out the holes with a No. 48 drill in a hand vise. This completes the disks.

THE MECHANICAL ASSEMBLY

The mechanical assembly consists of the various parts, relating to the scanning disk, the motor and the associated structure. The choice of materials is generally not critical, in that most of the parts can be made from wood or metal, which ever you feel more comfortable with.



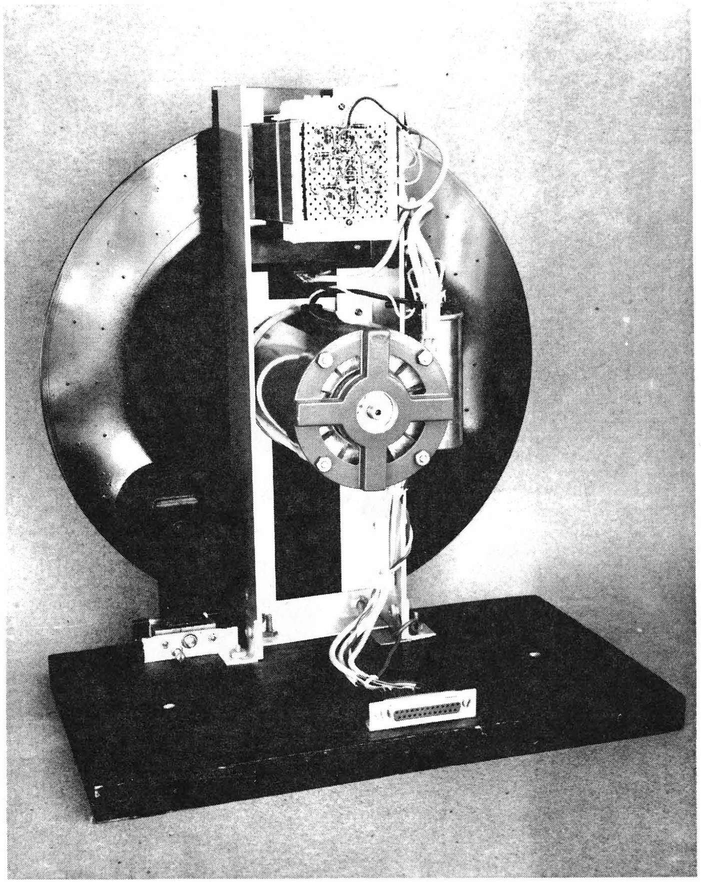


FIG. 9.9

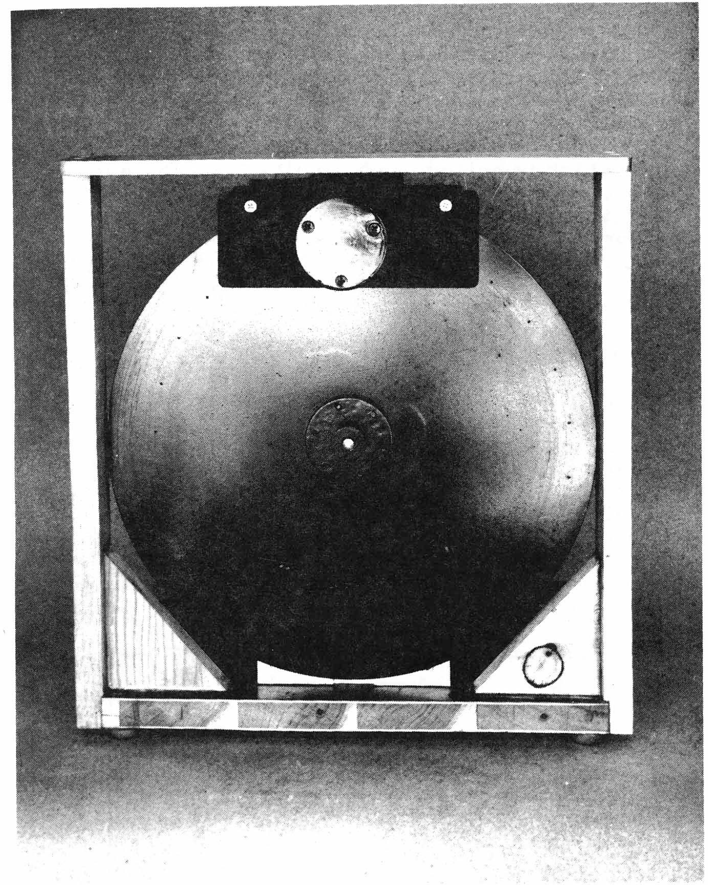
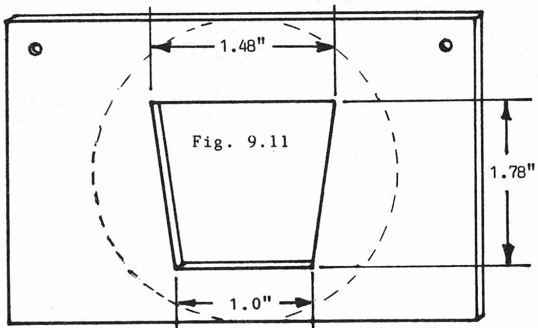


FIG. 9.10

Fig. 9.8 shows the mechanical assembly used in the receiver. This structure is the same as one used for the 2X system described in the Appendix. The disk has been removed to show overall construction and the means of supporting the motor. The structure consists of two vertical extruded aluminum angles, connected together at the base with another smaller angle, which is bolted to the wooden base. Two additional small angles support the structure on the base. This supporting structure is identical to one used in the camera. The motor is located at the approximate center of the structure, but high enough so that the disk clears the base by .025 inch. The upper end of the structure should extend above the edge of the disk, approximately .750 inches, in order to support the mask and photocell housing. Fig. 9.9 shows a view of the structure from the rear.

Fig. 9.10 shows a front view of a 24 line slide camera. The disk has a wood frame built around it, as protection to both the equipment and the operator. There is an eighth of an inch clearance between the frame and the disk. This frame is recommended in lieu of a cabinet. The mask and photocell assembly are located at the top of the disk and are supported with two screws into the aluminum structure behind the disk. The mask will operate equally well on either side of the disk, but by mounting it as shown, it provides a means for mounting the photocell sub-assembly.



24 Line Image Mask

THE IMAGE MASK

Fig. 9.11 shows the mask with its keystone opening. The opening is slightly undersize, to be certain that there is never more than one hole showing in the opening at a time. The mask can be made from .040 to .090 aluminum and painted flat black on the side facing the disk, to minimize reflections.

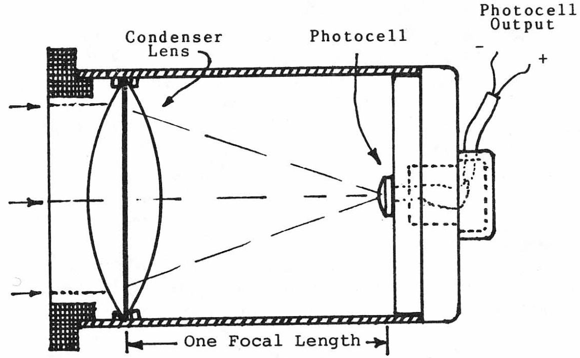


Fig. 9.12 Photocell sub-assembly

THE PHOTOCELL HOUSING

Fig. 9.12 is the photocell sub-assembly which attaches to the mask. It consists of a housing made from round cardboard or metal tubing, a condenser lens and a silicon photocell. The ends of the housing can be made of wood, pressed into the tube. The photocell is cemented to the wood block, which has a small cavity in which the two photocell wires are connected to a shielded cable. A small wood cup covers the cavity and wire terminations.

The distance from the photocell to condenser lens is one focal length of the lens. This is usually from 2.0 to 4.0 inches. The lens diameter should be 2.0 to 2.5 inches and its thickness at the center should be .50 inches or more. If less, two lenses can be mounted in close proximity to each other and will accomplish the same result. A good source for these is obsolete 35mm slide projectors. The focal length of the lens can be determined by focusing the image of a light source located twenty or more feet away, onto the surface of a sheet of paper and measuring the distance from the lens to the paper.

The distance from the lens to the mask is approximately .50 to 1.0 inches and is not critical. It is supported in the tube with cement or small tabs glued in place. Another technique is to insert thumb tacks, from the outside of the tube, on both sides of the lens. Two rows of four each around the housing is sufficient. A wrap of tape over the tacks, keeps them in place.

The housing is mounted to the mask by way of a wooden cap, pressed a short distance into the tube. The cap must have an opening as large as the diagonal of the image, so that the image can pass to the condenser lens, without restriction. The actual mounting of the photocell sub-assembly to the mask is done with screws from the mask into the housing. Three small flat head wood screws are sufficient.

Fig. 9.13 shows a view of a photocell and mask . The wooden cup covering the wire terminations, is the same diameter as the housing.

Another view of the mounting method used to support the mask on the receiver is shown in Fig. 9.14. This is done exactly the same on the camera.

THE LIGHT SOURCE

Fig. 9.15 is a view of the camera from the left rear side. The protective frame and disk are visible, as is the motor driving it. Below the motor, is its running capacitor. The 8 volt, 50 watt projector lamp , socket and associated step down transformer are mounted on the baseboard.

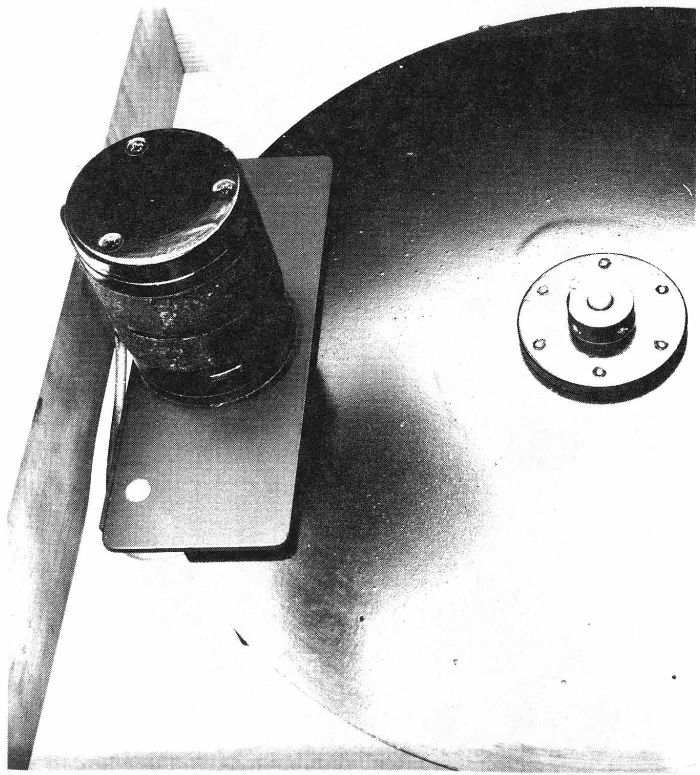


FIG. 9.13

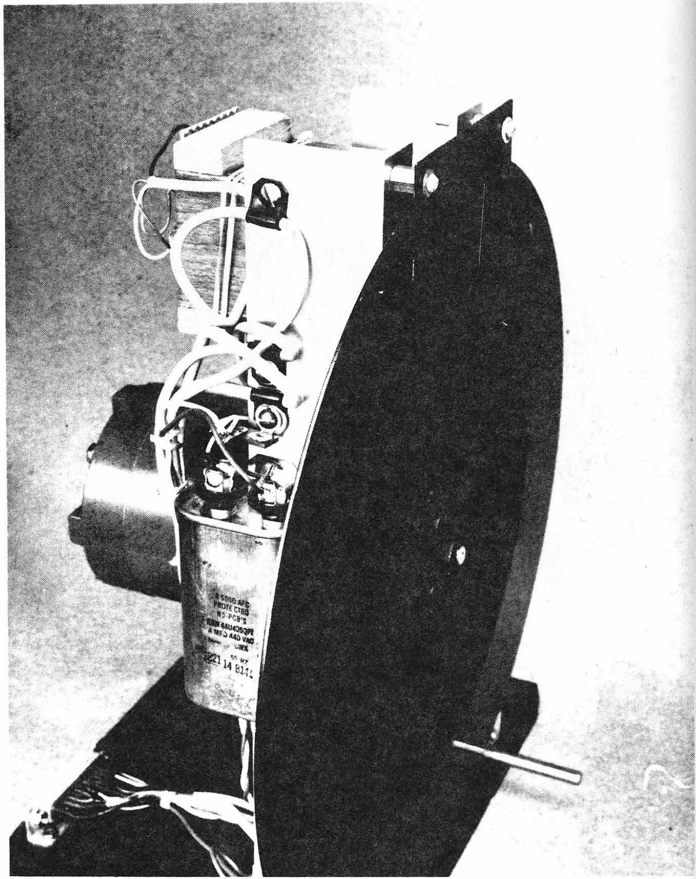


FIG. 9.14

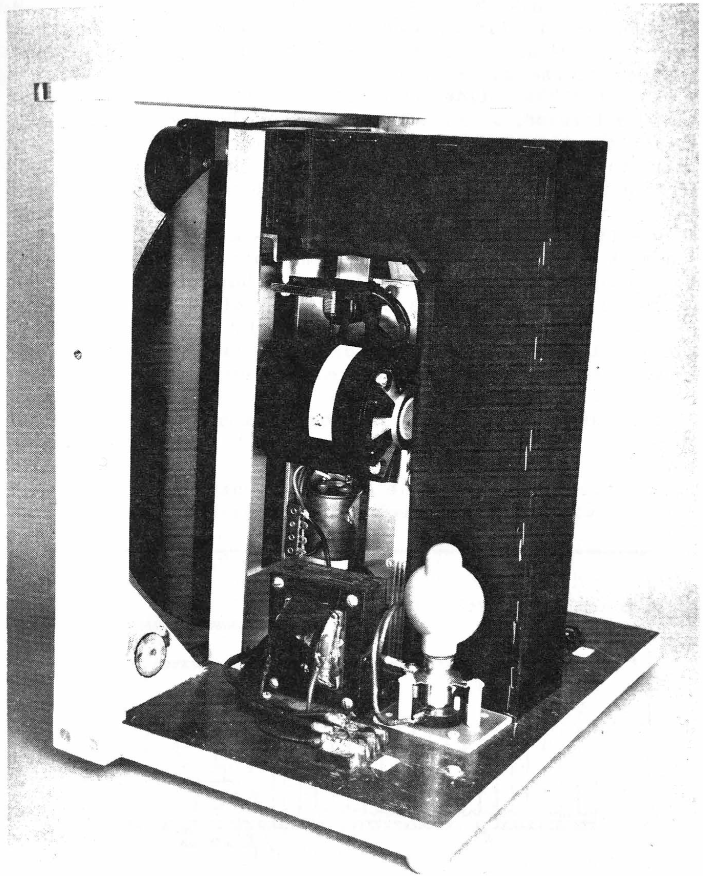


FIG. 9.15

The large black "inverted L" shaped box is hollow and constructed similar to a child's periscope. It contains two mirrors, one at the lamp, to direct the light upward and another at the upper corner, where the light is directed towards the 35mm slide and disk. Although the light from the lamp is intense, it is not a good point source. In fact, due to its shape and construction, the lamp effectively has a built in reflector and condenser lens. The lamp was designed for 8mm film and the bundle of parallel rays from it are too small for a 35mm slide. To overcome this , it was decided to use the lamp as a point source. This made it necessary to separate the lamp and slide by a sizable distance, in order to achieve a good sharp shadow. The idea behind the periscope, was to increase the length of the light path to the slide without adding considerable depth to the assembly. The light path in this camera is approximately 16 inches long. This lamp does not require a DC source.

Another point light source that can be used in the camera is shown in Fig 9.16. This type is used in the 2X system described in the Appendix. It uses a 6 volt, 10 watt lamp with a small filament. The lamp is mounted at one end of a 2.0 inch wide, 1.5 inch high rectangular housing made from

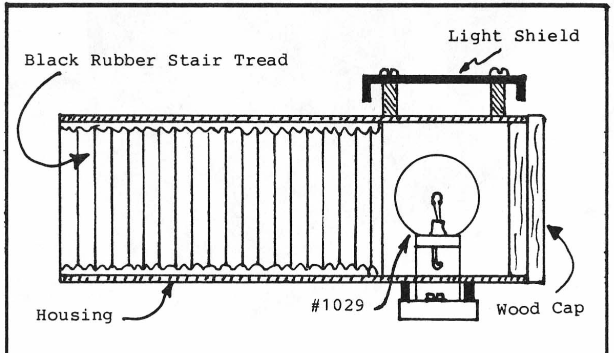


Fig. 9.16 Point Light Source

aluminum or wood. The housing is 5.0 inches long and one end is closed with a wood or metal cap. Two 1.125 inch holes, one above the other, are punched in the housing near the capped end. These provide clearance and cooling air for the lamp. To reduce stray light which may interfere with camera operation, a shield is mounted over upper hole. The lamp socket is mounted in the lower hole, so that the lamp filament is located in the approximate center of the housing.

The lamp filament is in the shape of an inverted "V". Mount the socket so that the broadside of the filament faces the slide. The inner surface of the end cap should be painted with a flat black paint.

The inside of the housing is lined with corrugated, black rubber stair tread material, that acts as a light baffle. It nearly eliminates reflected light from the walls of the housing. The rubber can be attached with contact cement or one of the various "super glues".

The open end of the housing is located approximately 2.0 inches from the 35mm slide. Because the lamp filament has very small mass, it is likely that "hum bars" with appear in the receiver image, because of 60 cycle modulation in the light from the lamp. It is recommended that the lamp be operated on direct current. Refer to Chapter 7 for a suitable power supply.

THE OPTICAL STRUCTURE

Fig. 9.17 is a photograph taken from the left side of the 2X camera. It shows the relative positions of the component parts of the optical structure in a slide camera. The 35mm slide is located approximately .125 inches from the disk and can be seen extending slightly above the bracket supporting the mask and photocell housing.

Fig. 9.18 is a photograph showing the "stage" area in the 24 line camera. The slide is located so that the image is centered over the area occupied by holes in the disk, and

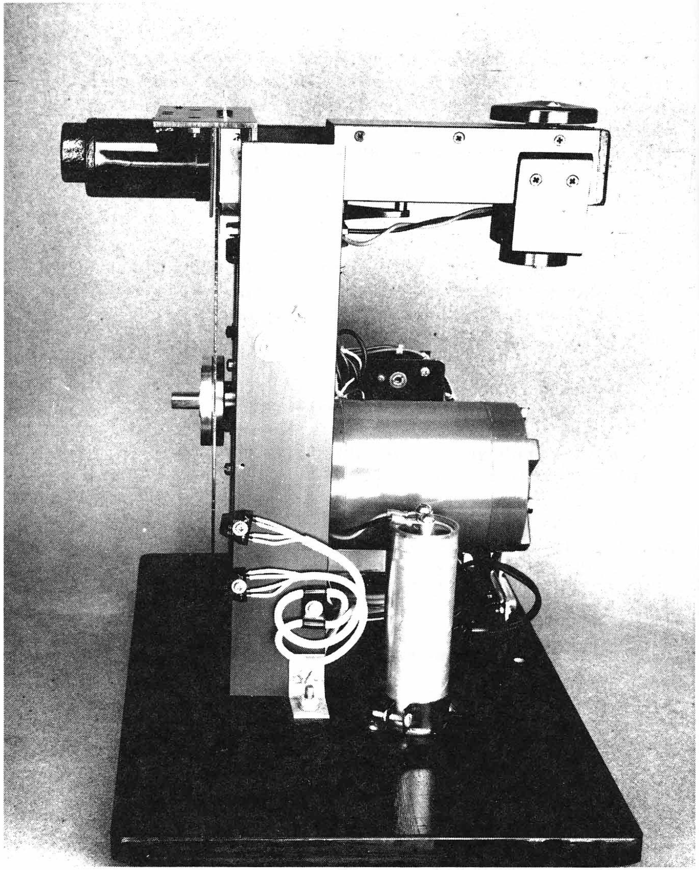


FIG. 9.17

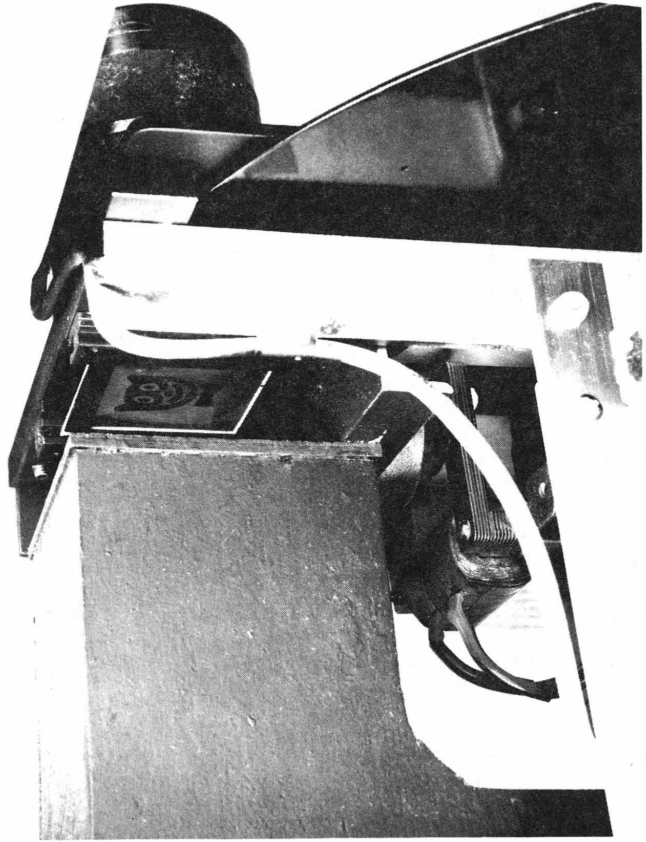


FIG. 9.18

directly in line with the condenser lens and photocell, located in the photocell housing. Light from the periscope , illuminates the slide evenly over its surface. The photograph shows that the slide is supported by two grooved metal guides that hold the slide in the correct position , but allow slides to be changed easily . The slide should be located as near to the disk as is practical, in order to achieve good resolution. In this camera, the distance is approximately .312 inches and is the maximum that should be considered.

THE MOVING IMAGE

The photograph shows a small shielded signal cable from the photocell passing through its center. Also visible, is the coil of a small 6 RPM, 115vac clock motor, with its shaft mounted vertical. The shaft is located in the center of the stage, directly under the center of the slide.
The shaft is a hollow plastic tube with a .125 inch hole. If the slide is removed, a small opaque plastic or metal figure, mounted on a .125 inch pin, can be inserted in the plastic tube, where it will rotate and cast a moving shadow on the disk. This motion, of course appears in the receiver. The motor can be switched off when it is not in use.

THE ELECTRONICS

The electronics for this camera was covered in Chapter 7 and the amplifier schematic is shown in Fig. 7.16. The power supply schematic is shown in Fig. 7.18. The amplifier requires a positive going signal input.

The polarity of the photocell wires can be determined with a small milliammeter. Expose the cell to a strong light and measure an output current with the meter. By the direction of the meter needle, determine the polarity of the cell. (A positive reading indicates the polarity is the same as the meter polarity). The negative wire of the cell will connect to the power supply return and the positive wire will connect to the input of U1. The power supply returns should also connect to the metal framework of the optical and

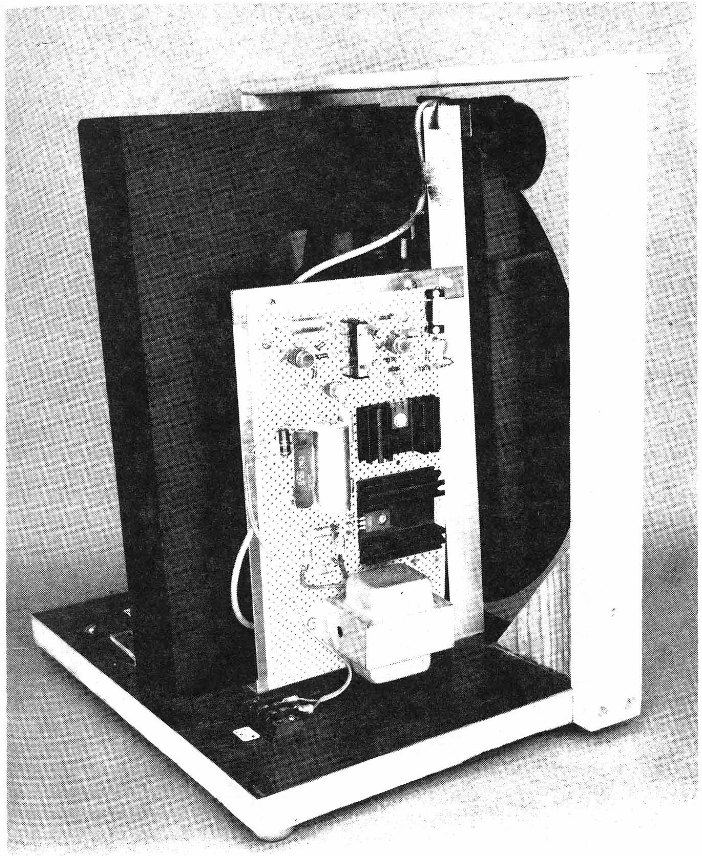


FIG. 9.19

mechanical assemblies. A three wire AC power cord should be used, with the ground wire also connected to the metal framework.

The electronics board can be mounted on the baseboard, or the mechanical structure. Fig. 9.19 is a view of the right side of the camera with the board in an upright position. The board in this photo contains both the amplifier and the power supply. It is mounted on a .060 aluminum plate, which is in turn mounted to the baseboard with a small angle bracket and also supported at the top by a bolt through the upright angle. The plate acts as a shield and also a support for the board. The LED output from the board it connected to a screw terminal strip on the baseboard. All terminals should be identified.

CAMERA WIRING

Fig. 9.20 shows a wiring diagram for the camera. The camera is connected to the receiver by way of a five conductor cable. AC power is supplied to the camera and through three wires of the cable, to the receiver. A main power switch can be added in the line and mounted on the baseboard.The other

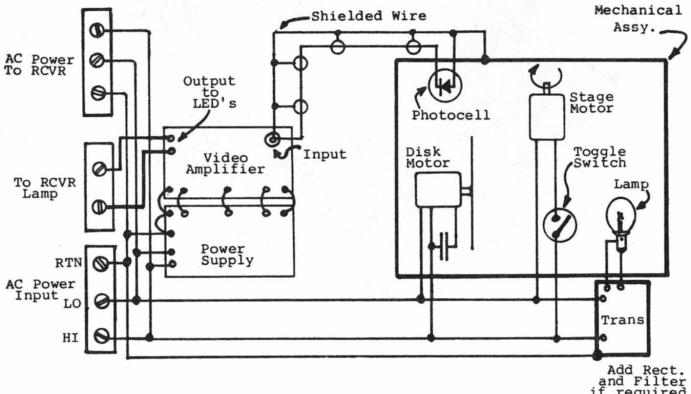


Fig. 9.20 Camera Wiring Schematic

two wires in the cable carry the LED lamp current. Up to 25 feet of cable have been used with out special shielding.

THE RECEIVER

The receiver for the 24 line system will contain an optical and mechanical assembly, made up of the scanning disk, motor and associated structure. The structure will also support the LED light source and image mask. Some of the photographs used to show details of the camera construction, were in fact receiver photos. These will be used again to show the receiver requirements. The construction practices are the same as those for the camera.

Fig 9.8 was used to show the basic mechanical structure for the camera. The same construction is used in the receiver. Since the scanning disks for the receiver and camera are identical, much of the structure can be the same. Fig. 9.8 shows the LED light source, mounted near the top, in the center of the structure.

THE LED LIGHT SOURCE

The light source consists of a 2 inch square tube, with a ground glass mounted at one end and four to six LED's at the other end. A suitable material is .060 plywood, available from your local hobby shop. Fig. 9.21 shows the construction of a unit, similar to one used in Fig. 9.8. It is mounted in

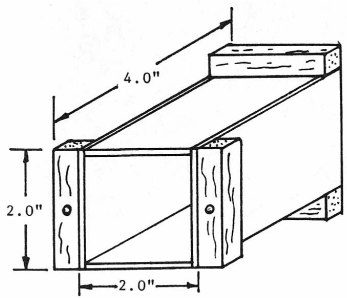


FIG. 9.21

LED Light Source Housing

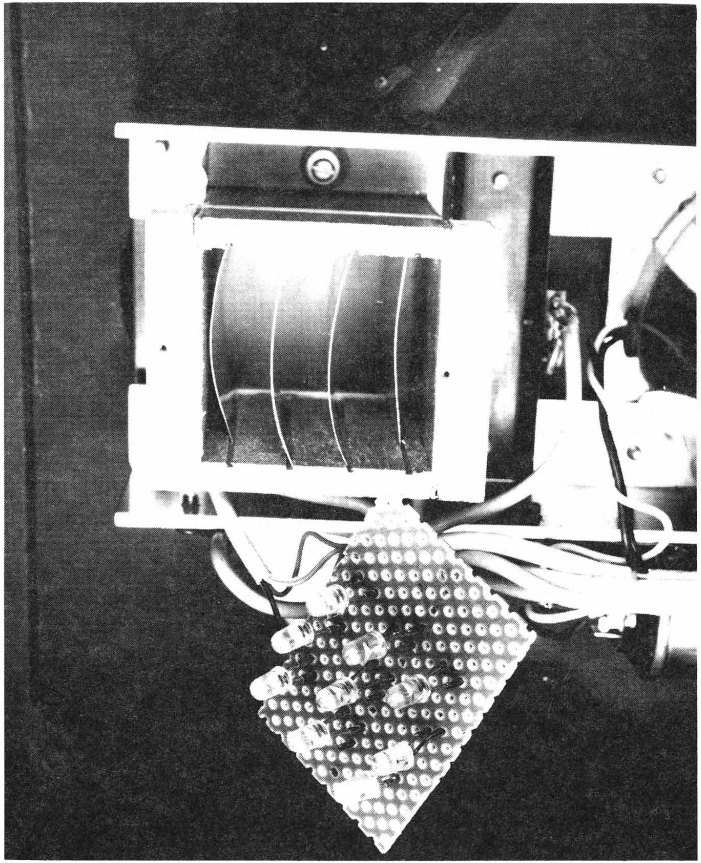


FIG. 9.22

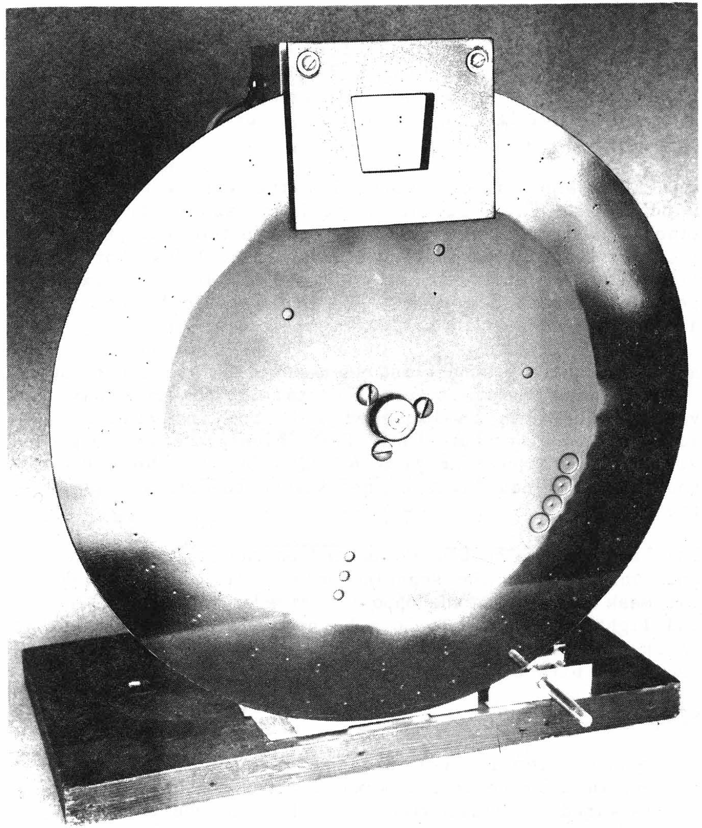


FIG. 9.23

the structure with two 6-32, flat head screws. The LED's are mounted on vector board with flea clips, along with their associated resistors. Fig. 7.17 shows a schematic for the LED assembly. The series one half watt resistors are each 68 ohms when four LEDs are used and 82 or 100 ohms if 5 or 6 are used.

The LED assembly is then mounted on the rear, with two small wood screws. Fig 9.22 shows the light source from the 48 line 2X system. It has the same construction except that it includes four curved baffles and uses nine LED's. For the 24 line receiver, baffles are not used and four to six LED's provide adequate brightness. The LED's should be mounted in a square or some other symmetrical pattern.

A 2 inch square ground glass is mounted at the other end of the tube using contact cement or tape. After assembly, the vector board can be loosened and the individual LED's adjusted, to distribute their light evenly across the ground glass. Apply approximately 4 volts DC to the LED's and bend the LED lead wires as necessary, to evenly illuminate the glass

The light source should be located on the structure, in line and centered with the scanning hole pattern in the disk and the mask located on the opposite side of the disk. The mask and light source should both be approximately an eighth of an inch from the disk. Fig. 9.23 shows a front view of the receiver, with the disk in place.

SYNCHRONIZING

Synchronization is accomplished by interrupting the motor current in the receiver. A momentary switch that is normally on, is wired in series with the disk motor and the switch is mounted so it is accessible to the operator.

Fig 9.8 and 9.9 show another method, a magnetic brake, using the large magnet found on certain automotive radio speakers. It provides a very sensitive means for synchronizing and adjusting the image framing. It is described further in the appendix.

RECEIVER WIRING

Fig. 9.24 shows the wiring diagram for the receiver. Mark the LED polarity on the terminal and be sure to connect the return wire from the camera cable, to the mechanical structure. Mark the terminals on the AC power connector , so there is no confusion when connecting the cable.

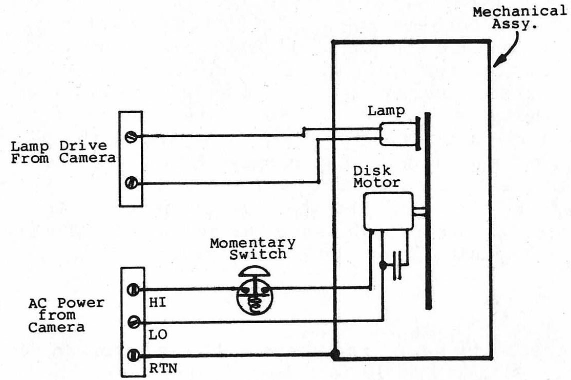


Fig 9.25 Receiver Wiring Schematic

SET UP

Actually, the camera and receiver could be connected together at this point, and if all of the adjustments were correctly made, it would work. Prior to attempting this however, a few checks might save some time later on.

RECEIVER TESTS

Before applying power to the receiver, check that the screw terminals are properly marked and that the return wire is connected to the mechanical structure. Apply AC power and 4 volts DC to the lamp. Facing the motor shaft, it should be turning clockwise and the scanning should be from left to right and from the top, down. Check if the disk is rubbing on any part of the assembly. The lamp should be on and when looking into the mask, the image area should appear to be evenly illuminated. See that the momentary motor switch functions properly.

CAMERA TESTS

Before applying power to the camera, verify that the connections between the amplifier and power supply are correct. See that the photocell is properly connected. Check that the screw terminals are all correctly marked. Apply AC power and see that the motor is running clockwise and that the scanning is from left to right and from the top, down. See that the disk does not rub on any part of the assembly. Check that the lamp is operating and that the stage motor rotates when the motor switch is turned on. If a DC supply is used for the lamp, see that the polarity on the filter capacitor is correct. Measure the voltage to the lamp. It should be within 15% of the correct value.

SYSTEM TESTING

Disconnect all power and connect the camera and receiver together with a 5 to 10 foot long 5 wire cable. Apply power to the camera. The motors should begin running and the LED's should illuminate. See if there is a response from the LED's when the light to the disk is blocked. If not, check adjustments on the amplifier. If there is a response, place a test slide in the stage and synchronize the disks. Touch up the adjustments in the amplifier and set gain for best contrast.

CABINETS

For appearance sake and protection of the equipment and operators, it is recommended that cabinets be considered for the camera and receiver. A cabinet for the receiver also provides a convenient mounting point for a magnifying lens that can enlarge the image to a more impressive size.

A typical receiver cabinet, suitable for home construction

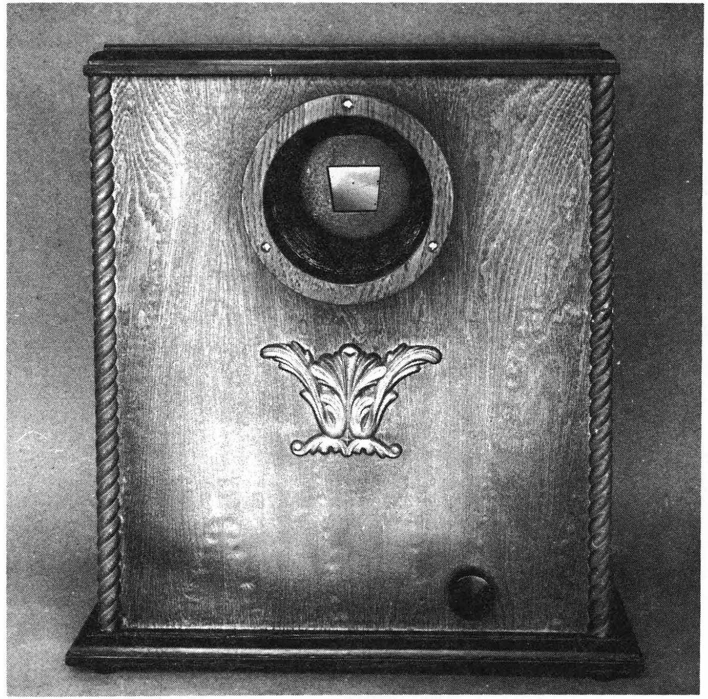


FIG. 9.24

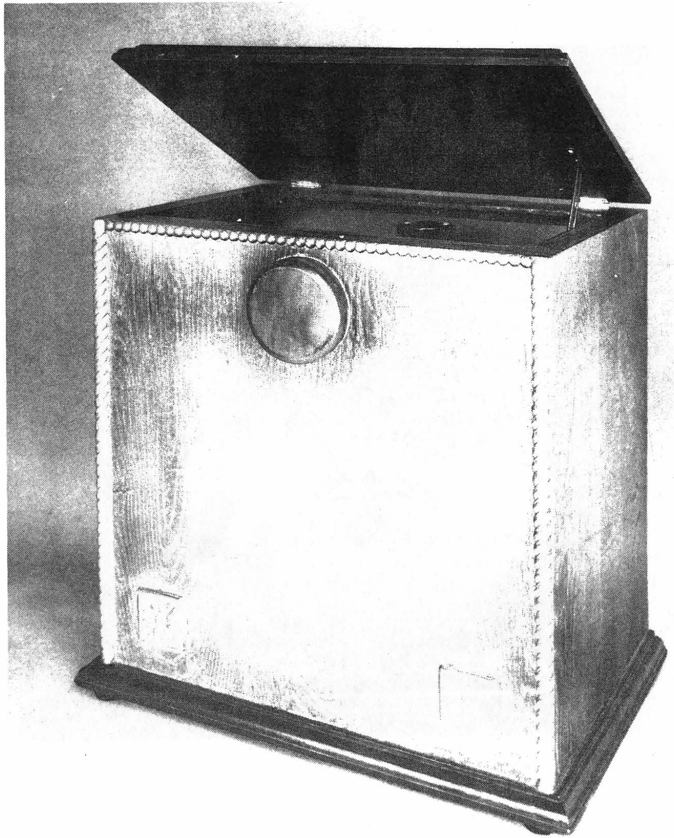


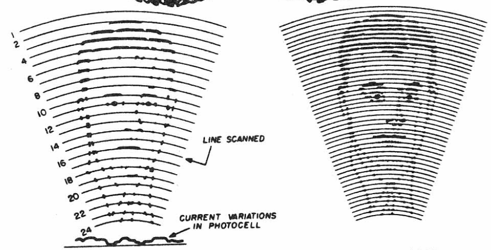
FIG. 9.25

is shown in Fig. 9.25. It consists of a simple box frame, covered with .025 inch ash furniture grade plywood. The top is .75 thick pine, with its edges molded and covered with a thin veneer on its top surface. The bottom is a similar piece of pine with its edges molded. The seams of the plywood on the front corners are covered with carved wood in the shape of rope. Another carving is cemented to front to add interest. The area around the image has a 2 inch thick oak, lathe turning cemented in place. This turning can accept a 4 inch diameter convex lens, that provides a magnification of two times. The knob on the cabinet front is used for synchronizing the disks.

Fig. 9.26 shows a cabinet for a camera. Its construction is similar to the receiver cabinet except for the hinged top. This is done to allow access to the stage. The projection on the front is hollow and provides space for the photocell housing. Without this, the cabinet would be an inch deeper.

This completes the necessary construction for a complete 24 line mechanical television system. Should you be unable to achieve satisfactory operation, it is suggested that you first read over the chapters that apply and isolate and test the component parts of the system individually, until you locate the problem.

Enjoy, Enjoy.



24-LINE SCAN

48-LINE SCAN

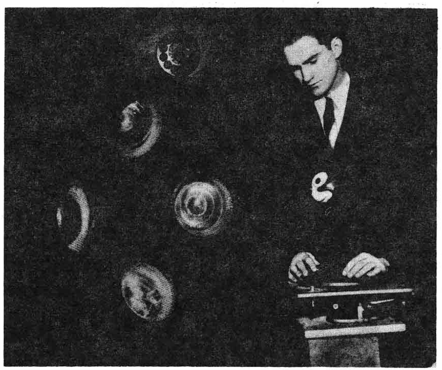
Index

aberrations 62
amplifier 6, 8, 64-65, 67-68, 71-72, 76-84, 86, 95, 125, 127, 133
analyzer 5, 40
aperture 3, 12, 19, 21, 34, 40-41, 95, 97, 101, 104
arc 38-39, 52-53, 68, 89-90
arc light 5
aspect ratio 16, 98-99, 104
Bain 2
Baird 6-7, 13, 23, 101, 104
baffle 122, 131
Bakewell 2
balance 18
bandwidth 14, 44, 65, 77
beam 36-37, 93-95
belts 18, 30
Bidwell 3-4
cabinet 18, 115, 133
camera 6, 11-12, 16, 22, 24, 26-27, 39-42, 50, 54, 69, 73, 87, 89-90, 92-97, 99-100, 104-105, 115, 125, 127, 132, 133, 136
capacitor 29, 42, 76-77, 87-88, 91
cathode ray 8-9
cell 3, 6, 10, 46-47, 67, 71, 73, 87, 100, 125
cement 20-21, 62, 117, 122, 131
centrifugal 20-21
cleaning 21
cogging 111
collar 108, 111
condenser lens 5, 36, 41, 55, 60, 93-94, 98-99 116, 117, 121, 123, 125
convex 60, 93, 136
counterbore 21
crater 8, 33-34, 53, 68, 84, 103
Darlington 47, 81
Daven 101
DC coupled 76-77
DeForest 6
detail 12, 16, 19
diode 35-36, 73-74, 82
disk 5-6, 8, 10-14, 17-25, 27, 30, 34, 36, 38, 40-41, 50, 55, 61, 68, 86-87, 89, 92-93, 95-98, 100-101, 103, 106, 111, 115-117, 121-122, 125, 127, 131-132
double-convex 55
drums 18, 61, 101
dynodes 44-45
element 11-12, 22, 62
Elster 6
equa convex 21
feedback 78-79, 81
Felix 9, 100
FET 76
film 7, 16, 22, 40, 55, 61, 73, 92, 96-98
filter 42, 74, 127, 133
flash 42, 88, 96
flea clips 131
flexible 17-18, 30

flicker 14, 65
flying spot 38, 41, 73-74, 87, 89, 92-95
focal length 21-22, 55, 60, 94-95, 116
format 12-14, 23, 77, 94
frame 15-16, 22, 77, 85, 89, 93, 97-98, 104
framing 26-28, 131
fresnel 55
GaAs 35-36
gearing 30-31
Geitel 6
glow 33-34
ground glass 3, 19, 37-38, 50
gyroscopic 18
halogen 40-41, 53
heatsinking 35
Hertz 43
hole 12-13, 15-16-17, 19, 22-23, 27, 34, 40, 50, 89, 93, 96, 98, 100, 107, 109
housing 27-28, 94, 117, 121-122, 125, 128
hub 21, 110
Huygens 50
image 3-5, 8, 10-11, 13, 15-16, 19, 22, 24, 27, 32, 54-55, 61, 64, 70-71, 81, 85, 89-90, 93-94, 98-100, 105, 116, 122, 125, 125, 131, 133, 136
incandescent 32, 52-53, 74
infra red 6, 49-50, 86
Insuline 27, 65-66
interlaced 14
inverse square 52
Jenkins 6-8, 23, 27, 65, 96, 101, 104
Kerr cell 40
keystone 15, 116
lamp 11, 21, 26-27, 32-34, 38-39, 42, 52-53, 61, 70-71, 83-85, 87-88, 90-91, 93-94, 96, 98, 117, 121-122, 127-128, 132-133
LED 35-38, 70, 79-82, 86, 128, 131-132
lens 5-6, 18-22, 38, 40-41, 50, 54-55, 60, 69, 89, 92, 95, 97, 103, 116-117, 121, 125, 133
lenses 16, 19-20, 22, 34, 36-37, 48, 50, 54-55, 62, 94-95, 97, 103
light 43, 46, 49-52, 54-57, 60-62, 71, 73-74, 87, 92-94
light source 18, 89, 99, 107, 117, 121, 128, 131
line 13, 16, 22, 24, 65, 77, 85, 96-97
magnetic brake 26, 131
magnify 8, 50, 101, 106, 133
mask 94, 99, 115-177, 128, 131, 133
mirror 8, 11, 41, 50-51, 61-62, 121
modulate 6, 38, 40, 42, 46
Moore 6
motor 8, 10, 18, 22, 24-31, 41, 69, 85, 97-98, 100-102, 110-111, 115, 117, 125, 131-133
motor starter 29
movie 7, 16, 22, 40, 65, 96-99
neon 4, 8, 10, 26, 31-34, 38, 53, 65, 68-69, 82-84
Nipkow 5-6, 8, 39
nitro-benzol 40
offset 81

operational amplifier 48, 72, 78-79
optical 11, 20, 37, 41, 43, 50, 54, 61-62, 74, 90, 92, 94, 99, 105, 122, 125, 128
optical sensor 86, 89
overlap 14, 16
parabolic 36, 41, 62
peening 20
periscope 121, 125
persistance 9, 13
phase 70-73, 79, 84
phase shift 29
phonic wheel 25-26, 68-69
photocell 6, 40-41, 44, 46, 49, 55, 62, 68-71, 78, 86-87, 92, 95, 99, 115-117, 125, 127, 133
photodiode 47-49, 73, 79
photoelectric 6, 10, 43, 67
photomultiplier 44-46, 49, 68, 74-76, 87
phototransistor 47, 86, 863
phototubes 43-44, 70, 72-74
pinhole 3, 92
plano convex 21-22, 54-55, 58
plastic 21, 30, 46, 54-55, 61-62, 125
plates 16-17
Pockels cell 40
point source 18, 19, 33-34, 36, 42, 52-53, 89, 95, 121
polarizer 5, 40
post 108, 109
power supply 42, 45-46, 75, 82, 84, 89-91, 127, 133
prism 6
projection lens 41
projector 22, 50, 53, 55, 61-62, 95, 97-98, 103, 117
Radio movies 7, 96
receiver 3-5, 8, 11, 13, 16, 18, 24, 27, 32-33, 36, 50, 64-65, 67, 69, 84, 89, 92, 96, 98-99, 101, 103-105, 115, 128, 131-132, 136
rectifier 42, 87
reflected 51, 61
reflector 36, 62, 68, 70, 74, 95, 121
resolution 8, 13, 19
response 36, 40, 44, 46-49, 64, 73, 133
Round 35
safety 18
Sanabria 68
scan 3, 5, 12, 92
scanned 22, 24, 70-71
scanner 41, 73-74, 87, 89, 93, 95, 102
scanning 8, 10-14, 16-19, 21-23, 26, 32, 36, 55, 61, 64, 67-69, 86, 92-93, 97, 100, 104, 107, 110, 128, 132-133
screen 3-4, 19
scribe 106-107, 109
sector 14
selenium 3-6, 43, 47
Senlecq 4
shading 70
shadow 11, 52-53, 100, 121, 125
silhouettes 91, 96
solar cell 46-47
source 18, 37-38, 51, 74, 93-95
speaker 32, 65, 67, 84-85
spiral 10, 12, 15-16, 19-20, 22-23, 27, 30, 34, 97-98, 100-101, 104, 107-109

spot 11, 34, 39, 70, 96
sprockets 22
stage 122, 125, 127, 133
staking 20
stereoscopic 6
streaking 16
strobe light 87-89, 96
structure 18, 111, 115, 122, 127-128
styrene 20-22
sweep 8, 22, 69, 87
Swinton 8
synchronism 5, 24, 68
synchronization 8, 24-25
synchronizing 3, 25, 101, 131
synchronous 8, 22, 24-26, 28-30, 41, 85, 97-98, 111
tape recorder 29, 81, 85
television 5, 7, 10-11, 16, 19, 24, 31-33, 38, 42, 50, 54, 64-65, 67, 69, 77, 84, 92, 96, 98, 103-104, 136
Televisor 5-7
timing belt 30
torque 30-31
transmitter 24, 77
transmitting 2, 24, 65
tungsten 40-42, 49, 53, 89, 93
ultra violet 39, 49-50
video 26, 40, 42, 70, 74, 76, 78, 80, 83-85, 96
wire 109, 125
wobble 18
xenon 39, 42, 52-53, 88
zirconium 38, 53, 89-90



In the early 1930s, Felix the Cat was the first "star" to appear before RCA-NBC experimental television cameras.

NOTES

NOTES

APPENDIX A

IMAGE SCANNING SYSTEM WITH ELECTRONIC MAGNIFICATION

by Peter Yanczer Dec 1985

The 2X system

The purpose of this system is to generate and display video images by means of a mechanical scanning system. However, it departs from the usual system, in that it offers increased image size and brightness without optical magnification or an increase in disk diameters.

The 2X system described here provides an image magnification of two or an increase of 4 times in area, without the corresponding loss in brightness associated with optical magnification. Those of you familiar with early apparatus may detect a resemblance to early Jenkins equipment.

The camera for a 2X system operates in a manner similar to a standard mechanical scanner. As the disk rotates, each hole passes across the image plane in a different location. After one complete revolution of the disk, every element in the image will have been scanned . In the standard system, the receiver and camera disks have the same hole patterns and rotate at the same speed. When disks of the same diameter are used, the receiver image will have the same dimensions as the camera image. A typical 48 line image on a 12 inch diameter disk measures approximately .7 inches square. If one desires to double the height and width of the image, it would be necessary to increase the diameter of the receiver disc to 24 inches. The increased radius provides more space between the holes and a larger image results. However, a 24 inch disk is costly to manufacture, requires four times more motor power and unwieldy to use.

In order to overcome the problems associated with such large disks. I have developed the 2X system, which provides an image magnification of two, without increasing the size of the receiver disk.

To illustrate, the following 2X system will be discussed:

Specifications

	CAMERA	RECEIVER
Disk diameter	12 inches	12 inches
Holes & diameter	48, .0145"	48, .0295"
Spirals	one	two
Angular hole spacing	7.5 degrees	15 degrees
Disk RPM & (direction)	900 (ccw)	1800 (ccw)
Image size (W)x(H)	.7" x .7"	1.4" x 1.4"
Frame rate (per sec)	15	15

THE CAMERA

The camera of the 2X system is similar to one used in a standard system except that two disk position sensors are added. One is used to detect the beginning of line No. 1 and the other performs a similar function on lines 17 and 33. The sensors are photoelectric and require no disk modification other than placing 3 small pieces of white tape on the back side of the disk. First paint the disk with a flat black paint. (If it's not already black, it should have been). Then apply the 3 pieces of tape as shown in Figure 2.

A view of the back of the disk reveals that the three sensor tapes are 120 degrees apart and that the radius to the tape for hole No. 1 (located at 0 degrees on the disk) , is different from the radius to the tape for holes No. 17 & 33 (at 120 & 240 degrees). Therefore, the sensor for hole No. 1 provides one output pulse for each disk rotation. In a like manner, the second sensor provides two output pulses for each rotation. With these sensors it is possible to determine when the camera is scanning the upper third, center third or lower third group of image lines. The three signals formed by the camera are shown in Figure 2.

THE RECEIVER

The receiver for the 2X system differs from the standard type in three ways, i.e. the disk, the light source and the electronics. Each will be discussed in turn.

THE DISK

Notice that the receiver disk has two complete spirals. Since all of the holes are used to form the image, There will always be two lines scanned at a time. When hole No. 1 is scanning, hole No.25 is also in position to scan and when hole No. 46 is scanning, No. 22 is also in position to scan. As will be seen later, the hole that is actually active (1 or 25, or 46 or 22) will be controlled by pulses from the sensors on the camera disk.

THE LIGHT SOURCE

In a standard aperture disk type of scanning system, the light source is a large area type and the illuminated area is generally about 20 % larger than the image. In the 2X system, it is also a large type, except that it is split into three sections. See Figure 3.

Each section has its own group of lamps (led's). They illuminate only that section plus approximately 15% overlap into adjacent section(s). The upper section covers the top 18 or 19 image lines. The center section covers lines 14 or 15 to 33 or 34. Finally, the lower section covers the remaining lines, starting at line 30 or 31. The total area of the light source is the size of the image plus an additional .125", all the way around. A total of 9 lamps are used but any number divisible by three, may be used.

THE ELECTRONICS

In a standard system, the function of the electronic circuitry is to amplify the camera signal to a level suitable for the type of light source that is used. The disks have the same number of holes and they rotate in synchronism. It is relatively straightforward to transfer the video signal developed at the camera, directly to the receiver lamp. In the 2X system, the video will be processed in a different manner.

The camera completes one picture (48 lines) in one rotation of the disk. It completes these at the rate of 15 per second. The receiver disk is rotating at twice the rpm of the camera disk and because the 48 holes are arranged in two spirals, it must rotate twice to complete one picture of 48 lines. Although the disks are not operating synchronous, the holes in one disk are synchronous with those in the other. Since the receiver disk has two complete spirals, two lines are being scanned at all times. Only one of these is the correct one and only that line must appear in the image.

When the camera disk begins to scan line No. 1, the 0 degree sensor will send a signal in the form of a pulse to the receiver, indicating that line No. 1 has started. If hole No.1 on the receiver is in sync with the camera at this point, hole No. 1 in the first spiral will scan to form line No. 1 and hole No. 25 in the second spiral will also scan. Line No. 1 is located at the top of the image and can only be illuminated by the upper third of the light source. Line 25 is located at the center of the image and must be illuminated be the center section of the light source. When the 0 degree sensor signal arrives at the receiver, the electronic circuits respond by illuminating the upper third of the light source. The center and lower sections are off at this time, because the circuits allow only one section to operate at a time. The camera video signal then modulates the light source, a line at a time until line No. 17 is ready to begin.

At this point, the camera disk has rotated one third of a revolution and the receiver disk has rotated two thirds. Line No. 16 is located at the transition of the upper and center sections of the light source and is illuminated by the upper section. In order to compensate for the scan line curvature, the baffles are curved (see Fig. 9.22) and an intentional overlap between sections is designed into the

light source. Lines No. 15, 16, 17, and 18 can be illuminated by either the upper or center sections. This is also true of the second spiral for lines No. 31, 32, 33 and 34. The baffles are made from thin (.010 thk), bright aluminum sheet, set in grooves in the LED array housing. Two additional baffles can be installed, one above, the other below, for a increase in light efficiency.

When line 17 begins, the 120/240 degree sensor sends a signal to the receiver and it responds by turning off the upper section of the light source and turning on the center. At this time, line No. 33 is also scanning, but is located at the center of the lower section of the light source, which is not illuminated because the upper and lower sections are both off. The video signal modulates the center section until line No. 32 is completed.

When line No. 33 begins, the 120/240 degree sensor again operates and the receiver turns on the lower section. Lines No. 33 thru 48 are then formed by the second spiral while the lower section of the light source supplies the illumination. During this time, lines formed in the first spiral, do not appear because the upper and center sections are off.

When line No. 48 is completed, the 0 degree sensor operates again, switching the video back to the upper section and the whole process repeats. See Figure 4 for an overall block diagram of the 2X system.

Conclusion

The 2X system has been prototyped and found to operate in a very acceptable manner. Although it does increase the complexity of the electronics requirement, this represents only a small increase in cost and no measurable decrease in reliability, convenience or performance. The techniques used here are under continuing investigation and it has been determined that a 4X system is also practical. Briefly, the camera would be similar to the 2X system, but the receiver would use a four spiral disk operating a 3600 rpm. The system details are left to the reader as an exercise.

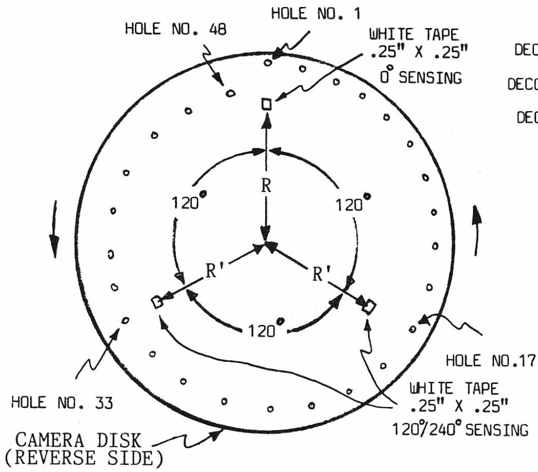
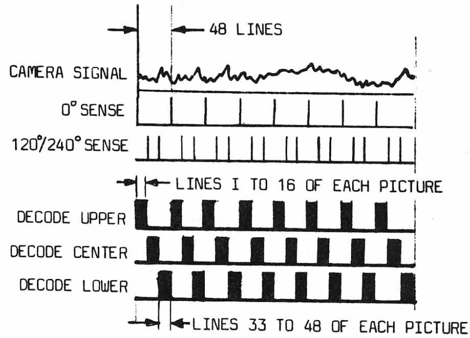
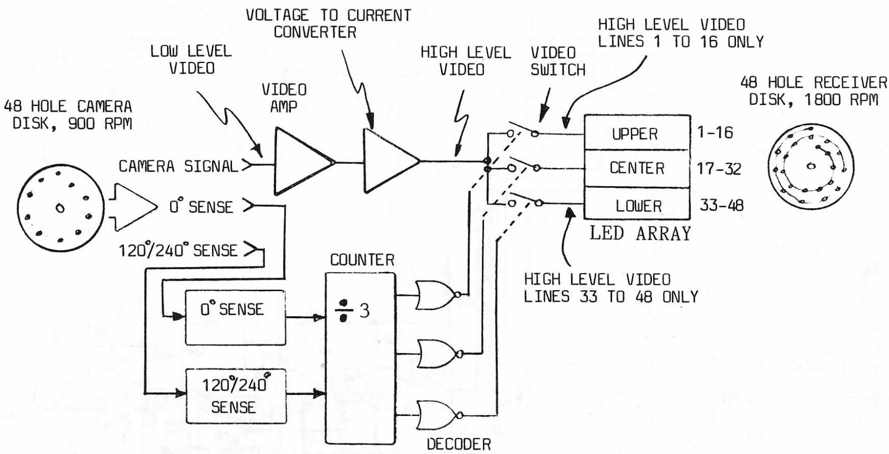


FIG. 1



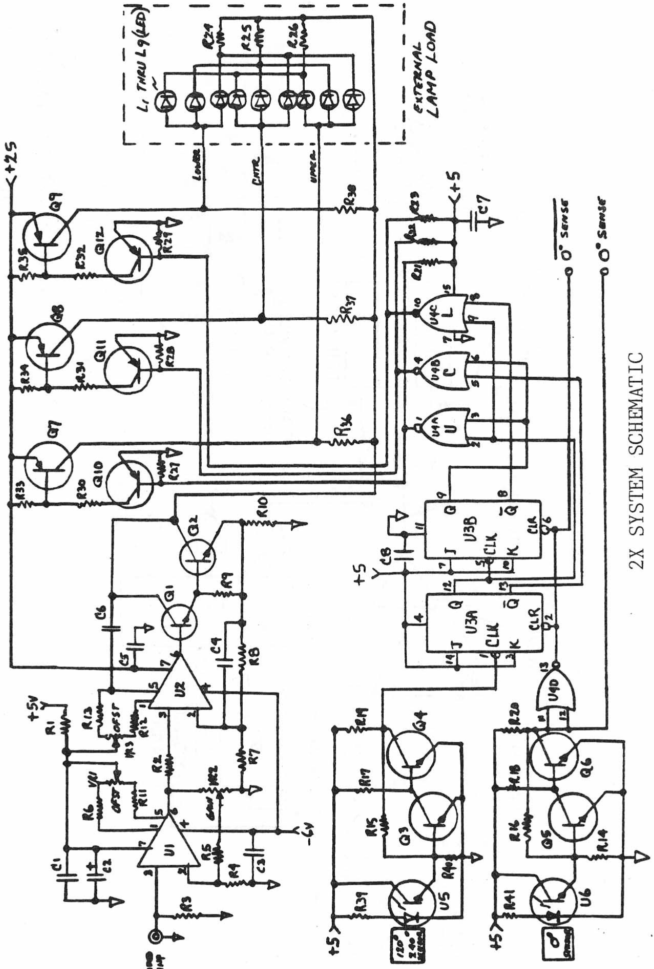
2X SYSTEM TIMING DIAGRAM

FIG. 2



2X SYSTEM BLOCK DIAGRAM

FIG.4



2X SYSTEM SCHEMATIC

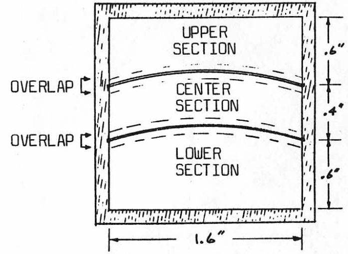
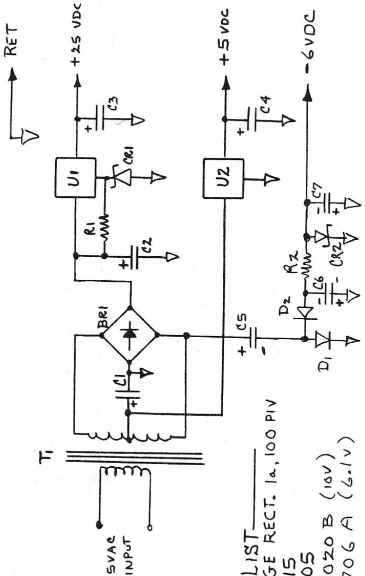


FIG. 3

LED ARRAY

2X SYSTEM PARTS LIST

U1 - LM318P	R5 47KΩ	R28 1KΩ
U2 - LM318P	R6 22KΩ	R29 1KΩ
U3 - SN7473	R7 510Ω	R30 2.2KΩ
U4 - SN7402	R8 4.7K	R31 2.2KΩ
U5 - TIL139	R9 1KΩ	R32 2.2KΩ
U6 - TIL139	R10 20Ω, 10W	R33 1KΩ
Q1 - 2N2219	R11 22KΩ	R34 1KΩ
Q2 2N5979	R12 22KΩ	R35 1KΩ
Q3 2N2222	R13 22KΩ	R36 100Ω, 1W
Q4 2N2222	R14 100KΩ	R37 100Ω, 1W
Q5 2N2222	R15 2MEGΩ	R38 100Ω, 1W
Q6 2N2222	R16 2MEGΩ	R39 180Ω
Q7 MJE371	R17 47KΩ	R40 100KΩ
Q8 MJE371	R18 47KΩ	R41 180Ω
Q9 MJE371	R19 4.7KΩ	ALL RESISTORS ARE .25W UNLESS OTHERWISE NOTED.
Q10 2N2222	R20 4.7KΩ	
Q11 2N2222	R21 4.7KΩ	
Q12 2N2222	R22 4.7KΩ	VR1 - 10KΩ TRIMPOT
	R23 4.7KΩ	VR2 - 10KΩ TRIMPOT
R1 - 100Ω	R24 47Ω	VR3 - 10KΩ TRIMPOT
R2 - 510Ω	R25 47Ω	
R3 - 10KΩ	R26 47Ω	C5 .1, 100V
R4 - 4.7KΩ	R27 1KΩ	C6 22PF, 200V
C1 .1, 100V	C3 .1, 100V	C7 .1, 100V
C2 120uF, 10V	C4 22PF, 200V	C8 .1, 100V



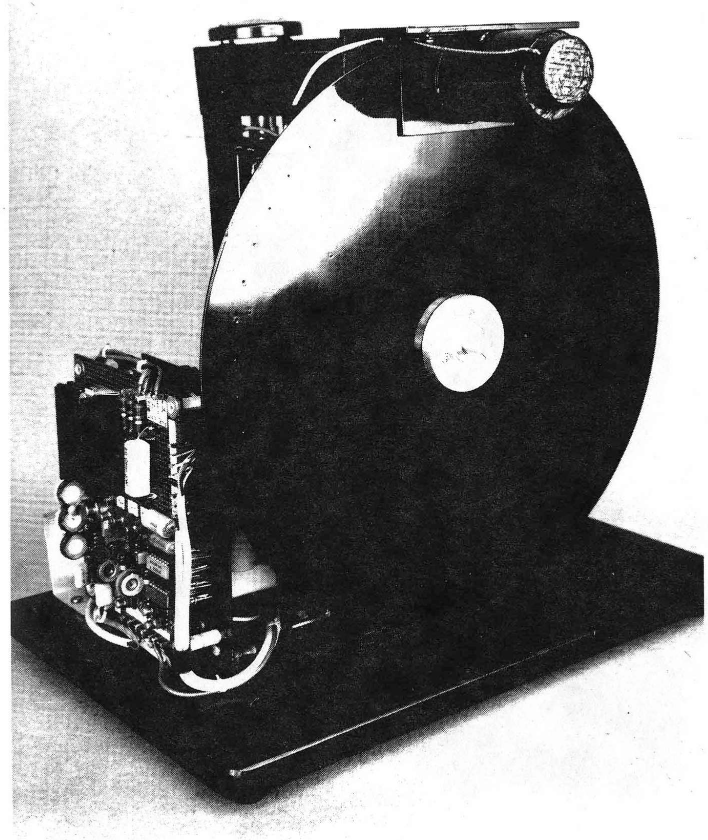
PARTS LIST

BR1 - BRIDGE RECT. 1a, 100 PIV
U1 - μ 7815
U2 - μ 7805
CR1 - 1N 3020 B (10V)
CR2 - 1N 706 A (6.1V)
C1 - 1000 μFD, 25V
C2 - 1000 μFD, 50V
C3 - 10 μFD, 50V
C4 - 10 μFD, 20V
C5 - 68 UFD, 60V
C6 - 50 UFD, 60V
C7 - 180 UFD, 10V

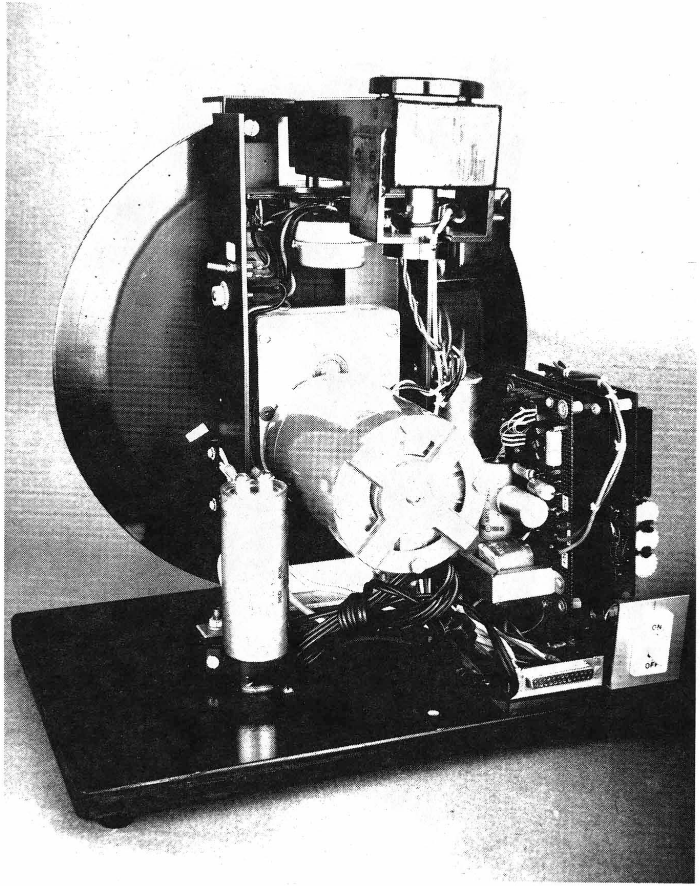
D1 - 1N4001
D2 - 1N4001
R1 - 1.5KΩ, 1 WATT
R2 - 1KΩ, 1 WATT

T1 - 24 V.C.T., 400 MA

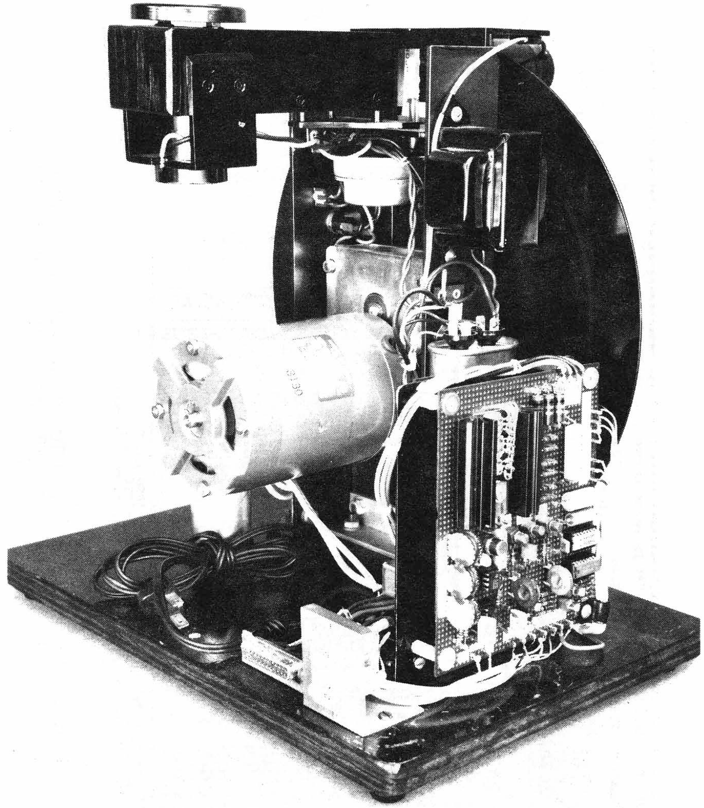
2X SYSTEM POWER SUPPLY



2X SYSTEM CAMERA



2X SYSTEM CAMERA



2X SYSTEM CAMERA

APPENDIX B

```
*******************************************************************************************||
**** SCANNING DISK DESIGN PROGRAM ****** By Peter Yanczer.    (1/27/86)

== MAKE THE FOLLOWING SELECTIONS & INPUTS.==
                                                        THIS DISK IS AVAILABLE FROM TESLA ELECTRONICS CO.
[ 12]  Select DISK DIAMETER. (6 thru 36 inches)                    835 BRICKEN   ST. LOUIS, MO. 63122
[ 24]  Select NUMBER OF HOLES. (16 thru 60)
[  2]  Select LENSES (1), or HOLES (2)
     [    0] Select LENS DIAMETER, in inches.
  [ 1.20] Set ASPECT RATIO, height to width. (.7 to 2.0)
==========================================================================================
| Camera disk hole dia. (Does not apply to lens disks)==[ .07527]
| Receiver disk hole dia. (Does not apply to lens disks)[ .09408]
| Image width, TOP :======>  [   1.51]                  [ 2.2921] Image area
| Image width, BOTTOM:====>  [   1.03]     Lens spacing [    N/A]
| Image Height :==========>  [   1.81]
==========================================================================================
```

no.	* HOLE * Locations Dgrs	Radius	X Dim.	Y Dim.	no.	* HOLE * Locations Dgrs	Radius	X Dim.	Y Dim.	no.	* HOLE * Locations Dgrs	Radius	X Dim.	Y Dim.
1	.0	5.75	5.75	0	21	300.0	4.2447	2.1223	-3.676	41	.0	0	0	0
2	15.0	5.6747	5.4814	1.4687	22	315.0	4.1694	2.9482	-2.948	42	.0	0	0	0
3	30.0	5.5995	4.8493	2.7997	23	330.0	4.0941	3.5456	-2.047	43	.0	0	0	0
4	45.0	5.5242	3.9062	3.9062	24	345.0	4.0189	3.8819	-1.040	44	.0	0	0	0
5	60.0	5.4489	2.7245	4.7189	25	.0	0	0	0	45	.0	0	0	0
6	75.0	5.3737	1.3908	5.1906	26	.0	0	0	0	46	.0	0	0	0
7	90.0	5.2984	0	5.2984	27	.0	0	0	0	47	.0	0	0	0
8	105.0	5.2231	-1.352	5.0452	28	.0	0	0	0	48	.0	0	0	0
9	120.0	5.1479	-2.574	4.4582	29	.0	0	0	0	49	.0	0	0	0
10	135.0	5.0726	-3.587	3.5869	30	.0	0	0	0	50	.0	0	0	0
11	150.0	4.9973	-4.328	2.4987	31	.0	0	0	0	51	.0	0	0	0
12	165.0	4.9221	-4.754	1.2739	32	.0	0	0	0	52	.0	0	0	0
13	180.0	4.8468	-4.847	0	33	.0	0	0	0	53	.0	0	0	0
14	195.0	4.7715	-4.609	-1.235	34	.0	0	0	0	54	.0	0	0	0
15	210.0	4.6963	-4.067	-2.348	35	.0	0	0	0	55	.0	0	0	0
16	225.0	4.6210	-3.268	-3.268	36	.0	0	0	0	56	.0	0	0	0
17	240.0	4.5457	-2.273	-3.937	37	.0	0	0	0	57	.0	0	0	0
18	255.0	4.4705	-1.157	-4.318	38	.0	0	0	0	58	.0	0	0	0
19	270.0	4.3952	0	-4.395	39	.0	0	0	0	59	.0	0	0	0
20	285.0	4.3199	1.1181	-4.173	40	.0	0	0	0	60	.0	0	0	0

*NOTE: This program allows for an approximate .25 inch space
from the edge of the disk to the edge of the first hole.
****** Minimum acceptable lens spacing is .03 inches, edge to edge.

THIS DISK IS THE ONE REFERRED TO IN CHAPTER NINE. This chart includes the X, Y coordinates of each hole location, in respect to the center of the disk (X=0, Y=0).


```
*******************************************************************************************||
**** SCANNING DISK DESIGN PROGRAM ****** By Peter Yanczer.    (1/27/86)

== MAKE THE FOLLOWING SELECTIONS & INPUTS.==

[ 16]  Select DISK DIAMETER. (6 thru 36 inches)
[ 48]  Select NUMBER OF HOLES. (16 thru 60)
[  2]  Select LENSES (1), or HOLES (2)
     [    0] Select LENS DIAMETER, in inches.
  [ 1.00] Set ASPECT RATIO, height to width. (.7 to 2.0)
==========================================================================================
| Camera disk hole dia. (Does not apply to lens disks)==[ .02113]
| Receiver disk hole dia. (Does not apply to lens disks)[ .02642]
| Image width, TOP :======>  [   1.01]                  [ .96180] Image area
| Image width, BOTTOM:====>  [    .88]     Lens spacing [    N/A]
| Image Height :==========>  [   1.01]
==========================================================================================
```

no.	* HOLE * Locations Dgrs	Radius	X Dim.	Y Dim.	no.	* HOLE * Locations Dgrs	Radius	X Dim.	Y Dim.	no.	* HOLE * Locations Dgrs	Radius	X Dim.	Y Dim.
1	.0	7.75	7.75	0	21	150.0	7.3273	-6.346	3.6637	41	300.0	6.9046	3.4523	-5.980
2	7.5	7.7289	7.6627	1.0088	22	157.5	7.3062	-6.750	2.7959	42	307.5	6.8835	4.1904	-5.461
3	15.0	7.7077	7.4451	1.9949	23	165.0	7.2850	-7.037	1.8855	43	315.0	6.8623	4.8524	-4.852
4	22.5	7.6866	7.1015	2.9415	24	172.5	7.2639	-7.202	.94812	44	322.5	6.8412	5.4275	-4.165
5	30.0	7.6655	6.6385	3.8327	25	180.0	7.2428	-7.243	0	45	330.0	6.8201	5.9064	-3.410
6	37.5	7.6443	6.0647	4.6536	26	187.5	7.2216	-7.160	-.9426	46	337.5	6.7989	6.2814	-2.602
7	45.0	7.6232	5.3904	5.3904	27	195.0	7.2005	-6.955	-1.864	47	345.0	6.7778	6.5468	-1.754
8	52.5	7.6021	4.6278	6.0311	28	202.5	7.1794	-6.633	-2.747	48	352.5	6.7567	6.6989	-.8819
9	60.0	7.5809	3.7905	6.5653	29	210.0	7.1582	-6.199	-3.579	49	.0	0	0	0
10	67.5	7.5598	2.893	6.9843	30	217.5	7.1371	-5.662	-4.345	50	.0	0	0	0
11	75.0	7.5387	1.9511	7.2818	31	225.0	7.1160	-5.032	-5.032	51	.0	0	0	0
12	82.5	7.5175	.98123	7.4532	32	232.5	7.0948	-4.319	-5.629	52	.0	0	0	0
13	90.0	7.4964	0	7.4964	33	240.0	7.0737	-3.537	-6.126	53	.0	0	0	0
14	97.5	7.4752	-.9757	7.4113	34	247.5	7.0526	-2.699	-6.516	54	.0	0	0	0
15	105.0	7.4541	-1.929	7.2001	35	255.0	7.0314	-1.820	-6.792	55	.0	0	0	0
16	112.5	7.4330	-2.844	6.8672	36	262.5	7.0103	-.9150	-6.950	56	.0	0	0	0
17	120.0	7.4118	-3.706	6.4188	37	270.0	6.9891	0	-6.989	57	.0	0	0	0
18	127.5	7.3907	-4.499	5.8634	38	277.5	6.9680	.9095	-6.908	58	.0	0	0	0
19	135.0	7.3696	-5.211	5.2111	39	285.0	6.9469	1.7980	-6.710	59	.0	0	0	0
20	142.5	7.3484	-5.830	4.4734	40	292.5	6.9257	2.6504	-6.399	60	.0	0	0	0

*NOTE: This program allows for an approximate .25 inch space
from the edge of the disk to the edge of the first hole.
****** Minimum acceptable lens spacing is .03 inches, edge to edge.

This disk is one of those available from TESLA ELECTRONICS CO.
835 BRICKEN
ST. LOUIS, MO. 63122

```
**** SCANNING DISK DESIGN PROGRAM ****** By Peter Yanczer.
== MAKE THE FOLLOWING SELECTIONS & INPUTS.==
 [ 16]  Select disk diameter (6 thru 36 inches)
 [ 48]  Select number of holes (16 thru 60)
 [  1]  Select Lenses (1), Holes (2)
   SET LENS DIAMETER, in inches:[    .768]
   SET ASPECT RATIO, height to width. (.8 to 2.0):    [      1.2]
==============================================================
| Camera disk hole dia. (not lens disks)      [ .02411]       |
| Receiver disk hole dia. (not lens disks)    [ .03013]       |
| Image width, TOP :       [    .96]     Image[    1.03]Area  |
| Image width, BOTTOM:     [    .81]          [ .04475]       |
| Image Height :           [   1.16]     Minimum lens spacing |
==============================================================
```

no.	* HOLE * Locations Drgs	Radius	no.	* HOLE * Locations Drgs	Radius	no.	* HOLE * Locations Drgs	Radius
1	.0	7.366	21	150.0	6.8839	41	300.0	6.4018
2	7.5	7.3419	22	157.5	6.8598	42	307.5	6.3777
3	15.0	7.3178	23	165.0	6.8357	43	315.0	6.3536
4	22.5	7.2937	24	172.5	6.8116	44	322.5	6.3295
5	30.0	7.2696	25	180.0	6.7875	45	330.0	6.3054
6	37.5	7.2455	26	187.5	6.7634	46	337.5	6.2813
7	45.0	7.2214	27	195.0	6.7393	47	345.0	6.2572
8	52.5	7.1973	28	202.5	6.7152	48	352.5	6.2331
9	60.0	7.1732	29	210.0	6.6911	49	.0	0
10	67.5	7.1491	30	217.5	6.6669	50	.0	0
11	75.0	7.1249	31	225.0	6.6428	51	.0	0
12	82.5	7.1008	32	232.5	6.6187	52	.0	0
13	90.0	7.0767	33	240.0	6.5946	53	.0	0
14	97.5	7.0526	34	247.5	6.5705	54	.0	0
15	105.0	7.0285	35	255.0	6.5464	55	.0	0
16	112.5	7.0044	36	262.5	6.5223	56	.0	0
17	120.0	6.9803	37	270.0	6.4982	57	.0	0
18	127.5	6.9562	38	277.5	6.4741	58	.0	0
19	135.0	6.9321	39	285.0	6.4500	59	.0	0
20	142.5	6.9080	40	292.5	6.4259	60	.0	0

```
==============================================================
*NOTE: This program allows for an approximate .25 inch space
    from the edge of the disk to the edge of the first hole.
****** Minimum lens spacing is .03inches, edge to edge.
```



```
**** SCANNING DISK DESIGN PROGRAM ****** By Peter Yanczer.
== MAKE THE FOLLOWING SELECTIONS & INPUTS.==
 [ 18]  Select disk diameter (6 thru 36 inches)
 [ 48]  Select number of holes (16 thru 60)
 [  1]  Select Lenses (1), Holes (2)
   SET LENS DIAMETER, in inches:[    .768]
   SET ASPECT RATIO, height to width. (.8 to 2.0):    [      1.2]
==============================================================
| Camera disk hole dia. (not lens disks)      [       ]       |
| Receiver disk hole dia. (not lens disks)    [       ]       |
| Image width, TOP :       [   1.10]     Image[    1.33]Area  |
| Image width, BOTTOM:     [    .92]          [ .15509]       |
| Image Height :           [   1.31]     Minimum lens spacing |
==============================================================
```

no.	* HOLE * Locations Drgs	Radius	no.	* HOLE * Locations Drgs	Radius	no.	* HOLE * Locations Drgs	Radius
1	.0	8.366	21	150.0	7.8184	41	300.0	7.2709
2	7.5	8.3386	22	157.5	7.7911	42	307.5	7.2435
3	15.0	8.3112	23	165.0	7.7637	43	315.0	7.2161
4	22.5	8.2839	24	172.5	7.7363	44	322.5	7.1888
5	30.0	8.2565	25	180.0	7.7089	45	330.0	7.1614
6	37.5	8.2291	26	187.5	7.6816	46	337.5	7.1340
7	45.0	8.2017	27	195.0	7.6542	47	345.0	7.1066
8	52.5	8.1744	28	202.5	7.6268	48	352.5	7.0792
9	60.0	8.1470	29	210.0	7.5994	49	.0	0
10	67.5	8.1196	30	217.5	7.5720	50	.0	0
11	75.0	8.0922	31	225.0	7.5447	51	.0	0
12	82.5	8.0648	32	232.5	7.5173	52	.0	0
13	90.0	8.0375	33	240.0	7.4899	53	.0	0
14	97.5	8.0101	34	247.5	7.4625	54	.0	0
15	105.0	7.9827	35	255.0	7.4352	55	.0	0
16	112.5	7.9553	36	262.5	7.4078	56	.0	0
17	120.0	7.9280	37	270.0	7.3804	57	.0	0
18	127.5	7.9006	38	277.5	7.3530	58	.0	0
19	135.0	7.8732	39	285.0	7.3256	59	.0	0
20	142.5	7.8458	40	292.5	7.2983	60	.0	0

```
==============================================================
*NOTE: This program allows for an approximate .25 inch space
    from the edge of the disk to the edge of the first hole.
****** Minimum lens spacing is .03inches, edge to edge.
```

NOTE: THIS IS LENS TYPE DISK

**** SCANNING DISK DESIGN PROGRAM ****** By Peter Yanczer.
== MAKE THE FOLLOWING SELECTIONS & INPUTS.==
[18] Select disk diameter (6 thru 36 inches)
[48] Select number of holes (16 thru 60)
[2] Select Lenses (1), Holes (2)
SET LENS DIAMETER, in inches:[0]
SET ASPECT RATIO, height to width. (.8 to 2.0): [1.2]

Camera disk hole dia. (not lens disks)	[.02863]		
Receiver disk hole dia. (not lens disks)	[.03579]		
Image width, TOP :	[1.15]	Image[1.45]Area	
Image width, BOTTOM:	[.97]		
Image Height :	[1.37]		

* HOLE * no.	Locations Drgs	Radius	* HOLE * no.	Locations Drgs	Radius	* HOLE * no.	Locations Drgs	Radius
1	.0	8.75	21	150.0	8.1773	41	300.0	7.6046
2	7.5	8.7214	22	157.5	8.1487	42	307.5	7.5760
3	15.0	8.6927	23	165.0	8.1200	43	315.0	7.5474
4	22.5	8.6641	24	172.5	8.0914	44	322.5	7.5187
5	30.0	8.6355	25	180.0	8.0628	45	330.0	7.4901
6	37.5	8.6068	26	187.5	8.0341	46	337.5	7.4615
7	45.0	8.5782	27	195.0	8.0055	47	345.0	7.4328
8	52.5	8.5496	28	202.5	7.9769	48	352.5	7.4042
9	60.0	8.5209	29	210.0	7.9482	49	.0	0
10	67.5	8.4923	30	217.5	7.9196	50	.0	0
11	75.0	8.4637	31	225.0	7.8910	51	.0	0
12	82.5	8.4350	32	232.5	7.8623	52	.0	0
13	90.0	8.4064	33	240.0	7.8337	53	.0	0
14	97.5	8.3778	34	247.5	7.8051	54	.0	0
15	105.0	8.3491	35	255.0	7.7764	55	.0	0
16	112.5	8.3205	36	262.5	7.7478	56	.0	0
17	120.0	8.2919	37	270.0	7.7192	57	.0	0
18	127.5	8.2632	38	277.5	7.6905	58	.0	0
19	135.0	8.2346	39	285.0	7.6619	59	.0	0
20	142.5	8.2059	40	292.5	7.6333	60	.0	0

*NOTE: This program allows for an approximate .25 inch space from the edge of the disk to the edge of the first hole.
****** Minimum lens spacing is .03inches, edge to edge.

**** SCANNING DISK DESIGN PROGRAM ****** By Peter Yanczer.
== MAKE THE FOLLOWING SELECTIONS & INPUTS.==
[18] Select disk diameter (6 thru 36 inches)
[60] Select number of holes (16 thru 60)
[2] Select Lenses (1), Holes (2)
SET LENS DIAMETER, in inches:[0]
SET ASPECT RATIO, height to width. (.8 to 2.0): [1.2]

Camera disk hole dia. (not lens disks)	[.01833]		
Receiver disk hole dia. (not lens disks)	[.02291]		
Image width, TOP :	[.92]	Image[.94]Area	
Image width, BOTTOM:	[.80]		
Image Height :	[1.10]		

* HOLE * no.	Locations Drgs	Radius	* HOLE * no.	Locations Drgs	Radius	* HOLE * no.	Locations Drgs	Radius
1	.0	8.75	21	120.0	8.3835	41	240.0	8.0170
2	6.0	8.7317	22	126.0	8.3652	42	246.0	7.9986
3	12.0	8.7133	23	132.0	8.3468	43	252.0	7.9803
4	18.0	8.6950	24	138.0	8.3285	44	258.0	7.9620
5	24.0	8.6767	25	144.0	8.3102	45	264.0	7.9437
6	30.0	8.6584	26	150.0	8.2919	46	270.0	7.9253
7	36.0	8.6400	27	156.0	8.2735	47	276.0	7.9070
8	42.0	8.6217	28	162.0	8.2552	48	282.0	7.8887
9	48.0	8.6034	29	168.0	8.2369	49	288.0	7.8704
10	54.0	8.5851	30	174.0	8.2185	50	294.0	7.8520
11	60.0	8.5667	31	180.0	8.2002	51	300.0	7.8337
12	66.0	8.5484	32	186.0	8.1819	52	306.0	7.8154
13	72.0	8.5301	33	192.0	8.1636	53	312.0	7.7971
14	78.0	8.5118	34	198.0	8.1452	54	318.0	7.7787
15	84.0	8.4934	35	204.0	8.1269	55	324.0	7.7604
16	90.0	8.4751	36	210.0	8.1086	56	330.0	7.7421
17	96.0	8.4568	37	216.0	8.0903	57	336.0	7.7237
18	102.0	8.4385	38	222.0	8.0719	58	342.0	7.7054
19	108.0	8.4201	39	228.0	8.0536	59	348.0	7.6871
20	114.0	8.4018	40	234.0	8.0353	60	354.0	7.6688

*NOTE: This program allows for an approximate .25 inch space from the edge of the disk to the edge of the first hole.
****** Minimum lens spacing is .03inches, edge to edge.

**** SCANNING DISK DESIGN PROGRAM ****** By Peter Yanczer.

== MAKE THE FOLLOWING SELECTIONS & INPUTS.==

[20] Select disk diameter (6 thru 36 inches)
[60] Select number of holes (16 thru 60)
[1] Select Lenses (1), Holes (2)
SET LENS DIAMETER, in inches:[.768]
SET ASPECT RATIO, height to width. (.8 to 2.0): [1.2]

Camera disk hole dia. (not lens disks)	[.01962]		
Receiver disk hole dia. (not lens disks)	[.02452]		
Image width, TOP :	[.98]	Image[1.08]Area	
Image width, BOTTOM:	[.86]	[.08955]	
Image Height :	[1.18]	Minimum lens spacing	

* HOLE * no.	Locations Drgs	Radius	* HOLE * no.	Locations Drgs	Radius	* HOLE * no.	Locations Drgs	Radius
1	.0	9.366	21	120.0	8.9737	41	240.0	8.5814
2	6.0	9.3464	22	126.0	8.9541	42	246.0	8.5617
3	12.0	9.3268	23	132.0	8.9344	43	252.0	8.5421
4	18.0	9.3072	24	138.0	8.9148	44	258.0	8.5225
5	24.0	9.2875	25	144.0	8.8952	45	264.0	8.5029
6	30.0	9.2679	26	150.0	8.8756	46	270.0	8.4833
7	36.0	9.2483	27	156.0	8.8560	47	276.0	8.4637
8	42.0	9.2287	28	162.0	8.8364	48	282.0	8.4440
9	48.0	9.2091	29	168.0	8.8167	49	288.0	8.4244
10	54.0	9.1895	30	174.0	8.7971	50	294.0	8.4048
11	60.0	9.1698	31	180.0	8.7775	51	300.0	8.3852
12	66.0	9.1502	32	186.0	8.7579	52	306.0	8.3656
13	72.0	9.1306	33	192.0	8.7383	53	312.0	8.3460
14	78.0	9.1110	34	198.0	8.7187	54	318.0	8.3263
15	84.0	9.0914	35	204.0	8.6991	55	324.0	8.3067
16	90.0	9.0718	36	210.0	8.6794	56	330.0	8.2871
17	96.0	9.0521	37	216.0	8.6598	57	336.0	8.2675
18	102.0	9.0325	38	222.0	8.6402	58	342.0	8.2479
19	108.0	9.0129	39	228.0	8.6206	59	348.0	8.2283
20	114.0	8.9933	40	234.0	8.6010	60	354.0	8.2086

*NOTE: This program allows for an approximate .25 inch space from the edge of the disk to the edge of the first hole.
****** Minimum lens spacing is .03inches, edge to edge.

**** 3 SECTOR SCANNING DISK DESIGN PROGRAM **** PETER YANCZER

== MAKE THE FOLLOWING SELECTIONS & INPUTS.==

[9] Select DISK DIAMETER...(6 thru 36 inches)
[45] Select NUMBER OF HOLES...(16 thru 60)
[1] Select LENSES (1) or HOLES (2)
[.343] Select LENS DIAMETER in inches.
[1.2] Set ASPECT RATIO, height to width, (.8 to 2.0)

Camera disk hole dia.(Does not apply to lens disks)==	[.01519]		
Receiver disk hole dia.(Does not apply to lens disks)	[.01898]		
Image width, TOP :[.57]	[.35655] Image AREA		
Image width, BOT: [.47]	[.13105] Lens SPACING		
Image HEIGHT : [.68]			

* HOLE * no.	Locations Dgrs	Radius	(SECTOR 1) X Dim.	Y Dim.	* HOLE * no.	Locations Dgrs	Radius	(SECTOR 2) X Dim.	Y Dim.	* HOLE * no.	Locations Dgrs	Radius	(SECTOR 3) X Dim.	Y Dim.
1	.0	4.0785	4.0785	0	16	120.0	4.0633	-2.032	3.5189	31	240.0	4.0481	-2.024	-3.506
2	8.0	4.0329	3.9937	.56127	17	128.0	4.0178	-2.474	3.1660	32	248.0	4.0026	-1.499	-3.711
3	16.0	3.9874	3.8329	1.0991	18	136.0	3.9722	-2.857	2.7593	33	256.0	3.9570	-.9573	-3.839
4	24.0	3.9418	3.6010	1.6033	19	144.0	3.9266	-3.177	2.3080	34	264.0	3.9115	-.4089	-3.890
5	32.0	3.8963	3.3042	2.0647	20	152.0	3.8811	-3.427	1.8221	35	272.0	3.8659	.13491	-3.864
6	40.0	3.8507	2.9498	2.4752	21	160.0	3.8355	-3.604	1.3118	36	280.0	3.8203	.66339	-3.762
7	48.0	3.8052	2.5461	2.8278	22	168.0	3.7900	-3.707	.78797	37	288.0	3.7748	1.1665	-3.590
8	56.0	3.7596	2.1023	3.1168	23	176.0	3.7444	-3.735	.26119	38	296.0	3.7292	1.6348	-3.352
9	64.0	3.7140	1.6281	3.3382	24	184.0	3.6989	-3.690	-.2580	39	304.0	3.6837	2.0599	-3.054
10	72.0	3.6685	1.1336	3.4889	25	192.0	3.6533	-3.573	-.7596	40	312.0	3.6381	2.4344	-2.704
11	80.0	3.6229	.62911	3.5679	26	200.0	3.6077	-3.390	-1.234	41	320.0	3.5926	2.7521	-2.309
12	88.0	3.5774	.12484	3.5752	27	208.0	3.5622	-3.145	-1.672	42	328.0	3.5470	3.0080	-1.880
13	96.0	3.5318	-.3692	3.5125	28	216.0	3.5166	-2.845	-2.067	43	336.0	3.5014	3.1987	-1.424
14	104.0	3.4863	-.8434	3.3827	29	224.0	3.4711	-2.497	-2.411	44	344.0	3.4559	3.322	-.9526
15	112.0	3.4407	-1.289	3.1902	30	232.0	3.4255	-2.109	-2.699	45	352.0	3.4103	3.3771	-.4746
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

*NOTE: This program allows for an approximate .25 inch space from the edge of the disk to the edge of the first hole.
*NOTE: Minimum lens spacing is .03 inches, edge to edge.

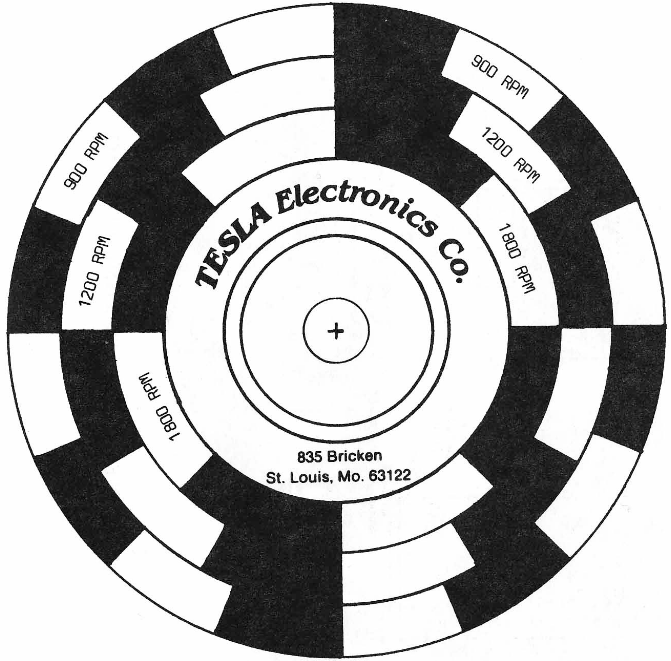
NOTE: THIS IS A 3 SECTOR LENS DISK.

APERTURE SCANNING DISK DESIGN TABLE

DISK DIA	OUTER HOLE RADIUS	--60 HOLES --(6 dgrs)-- IMAGE HEIGHT	IMAGE WIDTH (TOP)	HOLE DIA & SPACING	--48 HOLES --(7.5 dgrs)-- IMAGE HEIGHT	IMAGE WIDTH (TOP)	HOLE DIA & SPACING	--24 HOLES --(15 dgrs)-- IMAGE HEIGHT	IMAGE WIDTH (TOP)	HOLE DIA & SPACING
8	3.75	.47	.39	.0079	.59	.49	.0123	1.18	.98	.0491
9	4.25	.53	.45	.0089	.67	.56	.0139	1.34	1.11	.0556
10	4.75	.60	.50	.0099	.75	.62	.0155	1.49	1.24	.0622
12	5.75	.72	.60	.0120	.90	.75	.0188	1.81	1.51	.0753
14	6.75	.85	.71	.0141	1.06	.88	.0221	2.12	1.77	.0884
16	7.75	.97	.81	.0162	1.22	1.01	.0254	2.43	2.03	.1014
18	8.75	1.10	.92	.0183	1.37	1.15	.0286	2.75	2.29	.1145
20	9.75	1.23	1.02	.0204	1.53	1.28	.0319	3.06	2.55	.1276
22	10.75	1.35	1.13	.0225	1.69	1.41	.0352	3.38	2.81	.1407
24	11.75	1.48	1.23	.0246	1.85	1.54	.0385	3.69	3.08	.1538

Notes:
*Image height is an arbitrary value. In this chart it is 120% of the image width at the top.
*Hole sizes given are for camera disks. Increase hole (not spacing) size by 25% for receiver disks.
*The outermost hole is located .250 inches from the edge of the disk.

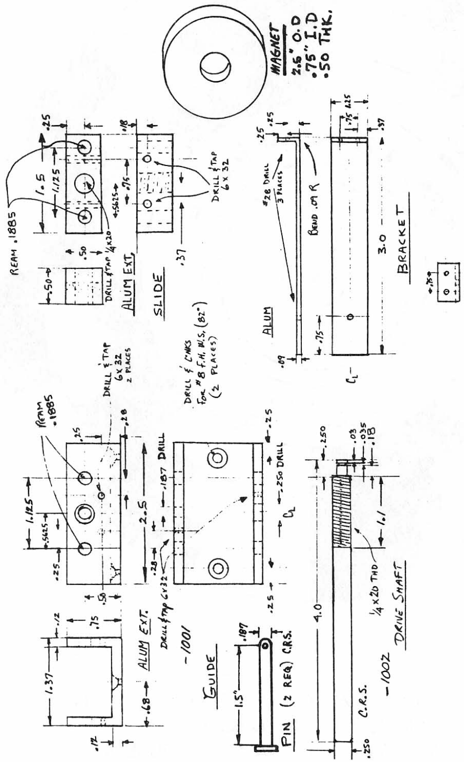
APPENDIX C



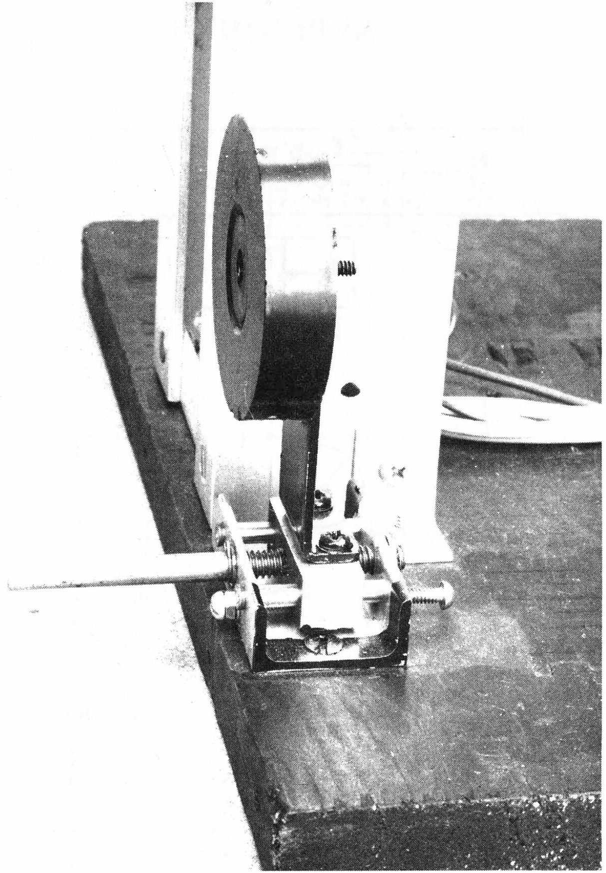
STROBETACH MOTOR SPEED INDICATOR

MOUNT THIS INDICATOR ON YOUR TELEVISION DISK AND CHECK YOUR MOTOR RPM. CONNECT A 115 VOLT NEON LAMP TO 60Hz, TO VIEW THE STROBETACH.

APPENDIX D

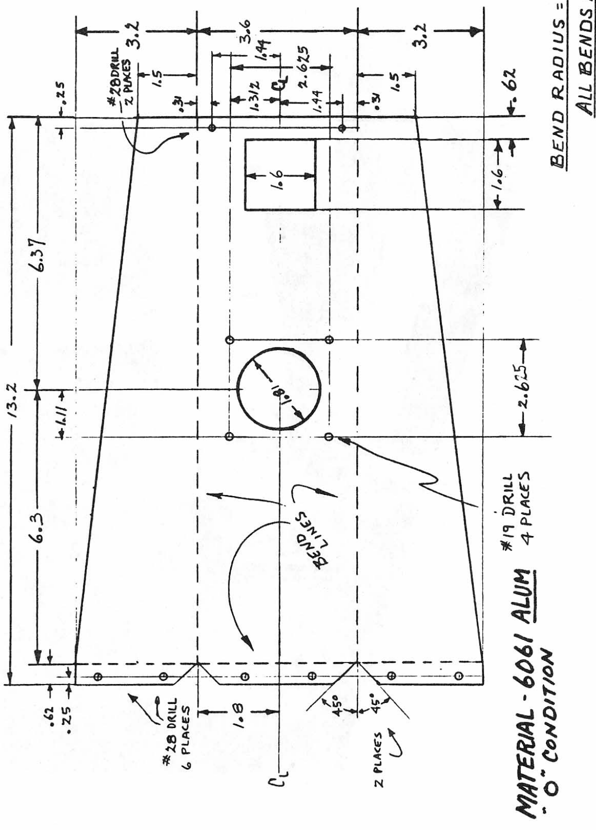


ADJUSTABLE MAGNETIC SCANNING DISK BRAKE

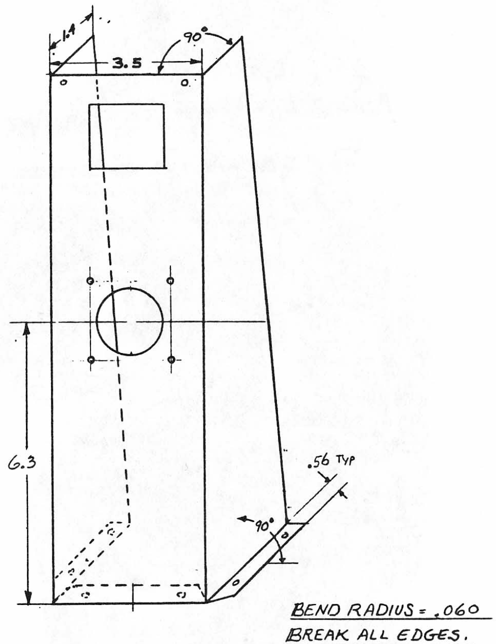


ADJUSTABLE MAGNETIC SCANNING DISK BRAKE

APPENDIX E

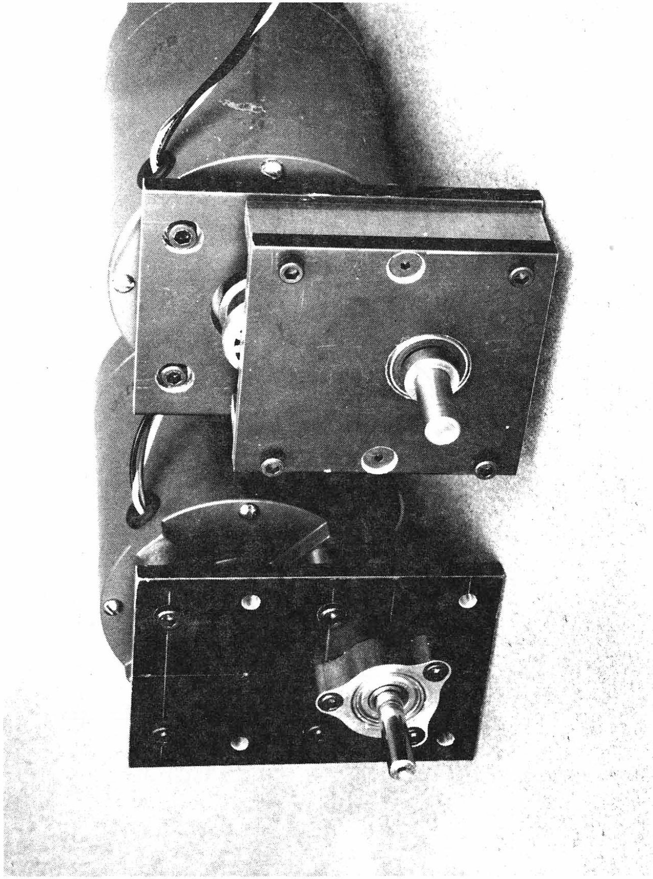


SHEET METAL STRUCTURE, SUITABLE FOR 12 INCH DISK SYSTEMS.

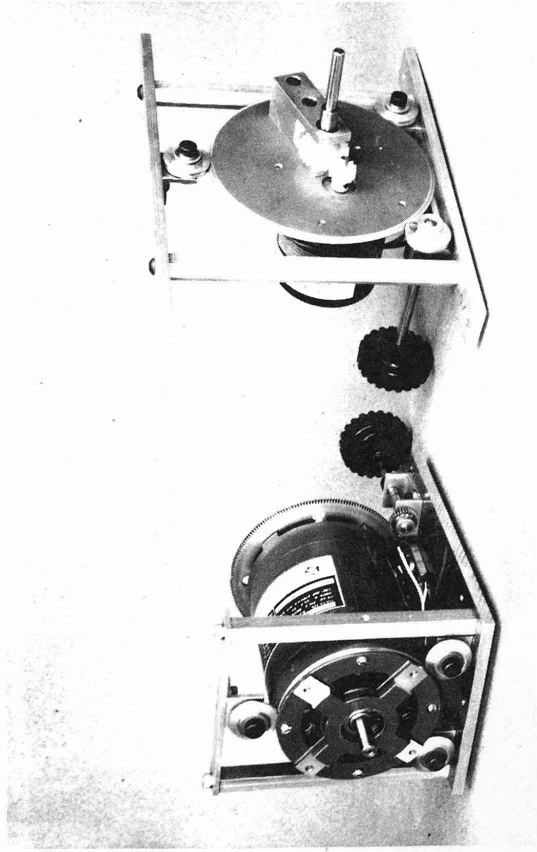


SHEET METAL STRUCTURE, SUITABLE FOR 12 INCH DISK SYSTEMS.

APPENDIX F



2:1 BALL BEARING SPEED REDUCERS USING .2 INCH PITCH, TIMING BELTS



(LEFT) 900 RPM DIRECT DRIVE MOTOR. THE HOUSING IS ROTATED TO PROVIDE A FRAMING ADJUSTMENT. (RIGHT) 2:1 GEAR AND MOTOR ASSEMBLY MOUNTED ON ROLLERS. THE ENTIRE CIRCULAR ASSEMBLY IS ROTATED TO PROVIDE THE FRAMING ADJUSTMENT.