A COMPUTER-CONTROLLED VIDEO SYSTEM FOR

IMAGE ANALYSIS AND PATTERN

RECOGNITION

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 1970

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ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

Since the beginning of the industrial revolution mech-
anical devices of one type or another have continually been
assisting and/or replacing humans in the role of "decision
maker". One area of human decision making which has
yielded to mechanization only very slowly is the identifi-
cation and interpretation of two-dimensional images (1).
A tremendous amount of effort has been expended in several
fields which has brought much nearer the possibility of a
computer being able to "watch" or "look at" a visual dis-
play (2,3).

The application of computers to the problem of the
recognition of two-dimensional patterns draws upon the ef-
forts of researchers in the fields of general pattern rec-
ognition, television and facsimile technology, and modern
digital computer methods (hardware and software).

Zworykin (2) gives a brief history concerning the evo-
lution of the concepts of television and facsimile systems.
It is interesting to note that as early as 1878 it was
realized by the Portuguese physicist de Paiva that a normal
image would be much easier to transmit if a means of
"scanning" were developed, rather than having a parallel

transmission of all the picture element values (4).

It was not until the early 1950's with the development of the stored program computer (in which the machine instructions and data are both inter-mixed in memory) that enough computational versatility was available to allow serious consideration of electronic digital computers as generalized pattern recognition devices (assuming a usable image input format) (5). As Turing's ideas of a stored program computer were implemented, computer languages were developed which permitted a digital computer to perform operations of logic as well as only arithmetic operations (5,6). Wilkes (6) gives a brief history of the history of the development of modern digital computers.

Research directly related to the problem of two-dimensional pattern recognition can be divided into two categories, the techniques which require simultaneous, parallel transmission of the image information and the techniques which employ a time sampling method of image coding into a single data channel. The following two examples are in the category of parallel image element transmission and processing.

One of the first problems of artificial intelligence which was attacked was the problem of optical pattern recognition. The device (the "Perceptron") Rosenblatt (7) constructed was intended to recognize "actual form alone" and not be sensitive to the image location on the retina. The "Perceptron" has retinal points directly coupled to

association cells. Each sensor unit is connected to an "A" unit in either an excitory (+1) or inhibitory (-1) mode. Each "A" unit has a fixed threshold and delivers an output pulse if the algebraic sum of the inputs exceeds a given level. The training of the machine consists of adjusting the weighting factors associated with each "A" unit such that the actual output approaches the desired output. The sum of the weighted outputs of all the "A" units is constrained to be a constant value. The original "Perceptron" model was a computer simulation.

Widrow and Hoff (8) describe a machine, the "Adaline" (adaptive-linear), which was to classify two-dimensional patterns. This system employed n inputs; the weighting factor of each input was adjustable. For a given input pattern the weighting factor of each input was changed in either a positive or negative direction such that the output of the "Adaline" corresponded as closely as possible to the desired output. According to the authors, this process will always converge. The adaption of the machine (adjustment of the n weighting factors) amounts to a search technique of the surface of an n-dimensional paraboloid. The object of this search is the minimization of the mean square error between the summation of the weighted outputs of the system and the desired output. Widrow and Hoff showed that this criterion implies minimization of the average number of neuron errors (after quantization). The experiments with the "Adaline" were conducted with a 3 x 3 field of sensors which were

either excited or not excited. One main difficulty with this machine was its inability to differentiate between patterns which were not linearly separable in the n-dimensional input space.

Hu(9) developed two systems of pattern recognition for two-dimensional planar images based upon the identification of certain properties of the image geometry. He found that by computing the various moments (of which the moments of inertia are a subset) of an image that certain types of patterns could be identified or classified. These moments are invariant for image size and location changes. The techniques could be applied to either parallel or sequential image element availability. The form of the moments is that of integrals over the image of functions which can ultimately be written as functions only of the position coordinates (x,y). For this reason, this method is well suited for implementation in a television type of scanned image device.

Roberts (10) has developed a computer program for the identification of two-dimensional line drawings (given with perspective, such as is found from a photograph) in terms of the original three-dimensional geometric figures and the viewing angle. The main disadvantage of this machine was that the entire image had to be scanned by facsimile gear and the total image information was then stored in a computer core memory. This device would reduce a 4 x 5 inch photograph to a raster array of 256 x 256, with the

intensity of each image element being reduced to eight bits for computer storage. This meant that a 525,000 bit computer memory was required just to store the image; and it still must be considered that this is only approximately one-fourth as many image elements as afforded by a standard, commercial quality television system (10,11).

One of the more difficult problems arising in the area of machine identification of two-dimensional images is the fact that a normal image as might be seen on standard television equipment contains more information than can readily be given to a computer with the techniques presently available (1,3,10). If a technique such as employed by Roberts (10) were employed with a television system in such a way as to rapidly store the image data in a computer memory, there would still be a drawback; in excess of a million bits of computer memory would be required to store the image data.

The aim of the research for this thesis is toward the development of an efficient and effective means by which a standard television system and a modern digital computer can be interfaced. This includes the construction and testing of a system in which a Dage Mobile Camera Control Console (ETS-2B) with two cameras is interfaced with an IBM 1620 computer. Although neither this television gear nor this particular digital computer possesses many attributes now available in newer equipment, the interfacing developed in the course of this research is designed in such a manner as to work without modification on more modern

equipment. For example, the hand-sized Concord MTC-8 solid state television camera could replace the entire Dage console and camera system.

Chapter II contains an over-view of the principles involved in standard television which are pertinent to the design of the computer interfacing equipment. The television gear and the equipment built to convert the available signals into a more usable form will be described in detail in Chapter III. The actual image interrogation equipment which serves as the interface between the video portions of the entire system and the computer portion will be covered in Chapter IV.

The results arising from the application of the system will be covered in Chapters V and VI; Chapter V being devoted to the acquisition of image data and Chapter VI to the application of the image data. Chapter VII gives a summary of the research effort and the resulting conclusions.

CHAPTER II

THE BASIC VIDEO SIGNAL
GENERATION APPARATUS

Of all the techniques which have been developed for
the coding of two dimensional images into electronically
represented information, none has been as widespread or as
versatile as the basic scanning procedure employed in tele-
vision systems (11). Many of the attributes originally re-
quired for standard television systems for use as remote
viewing devices for human use are also desirable attributes
for using television techniques for machine oriented pat-
tern recognition.

The nature of most images is that for any given point
in time, intensity and/or color information exists for each
point of the image area. A moderately complex image geo-
metry may contain in excess of 10^5 bits of luminance infor-
mation alone (11). Considering that the latter may also be
varying in time, it is difficult to conceive of a system
which can economically transfer such intelligence in a par-
allel mode to any device for image reproduction, or image
storage. Therefore, recourse has been made to time-
sampling of small image elements as a practical solution to
the problems of electronic representation of image infor-
mation.

Many sampling schemes have evolved, each serving its own purposes (2). A broad distinction can be made between those sampling schemes which are regularly repeated at prescribed time intervals and those which are random or quasi-random. When the sampling is predictably repetitive, the process is generally known as "scanning". The most familiar example of a scanned display is television. A rectilinear scan such as employed in television systems is comprised of a series of lines in a pattern known as a "raster". "Aspect ratio" refers to the quotient of the width to the height of rectangular displays. Thus, the aspect ratio of a standard television frame is 1.333 (4/3).

The resolution of a television system, or its ability to accurately portray fine structure of an image, is not an isotropic property with respect to the vertical and horizontal image plane coordinates. At best, the maximum number of intensity changes transverse to the scan direction which can be detected is equal to the number of scan lines. The transverse resolution (vertical resolution for standard television) is measured in the number of lines per raster.

The fact is that the image elements are not always aligned such that maximum utilization of the transverse resolution capability is attained. This is illustrated in Figure 1. The upper diagram shows the scanning lines of a transmitter and receiver in synchronism while covering alternate black and white picture elements. The lower diagram shows the same scanning lines, but with the black and

white picture elements positioned such that each line re-
produces the same average luminance with the indicated loss
of detail rendition at the receiver. Under most circum-
stances picture information is not nearly so uniform, and it
contains a fine structure which has a random relationship
to the scanning pattern. The degraded transverse resolution
actually attained in practice is given by

$$R_t = kn_a \qquad\qquad (2\text{-}1)$$

where n_a is the number of active scanning lines and k is
defined as the "Kell factor", which is determined by the
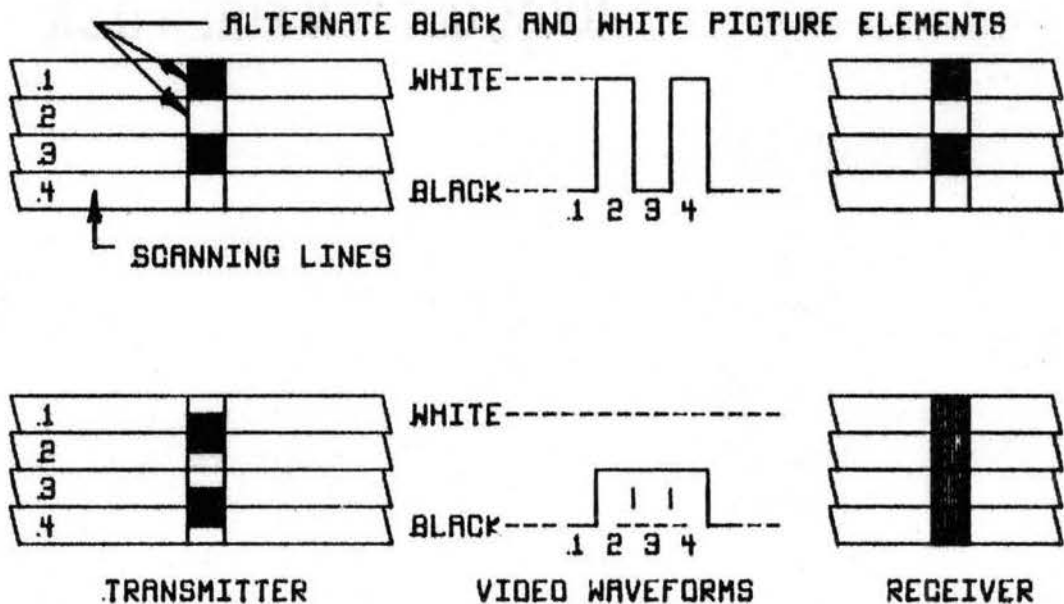
FIGURE 1. TRANSVERSE RESOLUTION DEGRADATION LEADING
TO THE KELL FACTOR

statistical geometry of the image covered by the raster. Experimental observations of television systems have given values for the Kell factor ranging from 0.53 to 0.85. The value k = 0.70 is usually assumed in American broadcast television (11).

Whereas transverse resolution is principally a function of the number of scanning lines employed, longitudinal resolution is a much more complex function of the scanning aperture and available channel bandwidth. In order to maintain optimum usage of the television camera and its associated electronics, an examination of the channel bandwidth versus longitudinal resolution is needed. The relationship of the image resolution and the video bandwidth will be used later in this thesis to establish the switching speed of the required combinational logic in order to maintain the original resolution of the transmitted video signal.

A first order approximation can be made by a single sinusoid for which the positive and negative peaks represent, respectively, a light area and an adjacent dark area. A picture scanned at a rate of N frames per second and containing m alternate black-and-white elements will therefore produce a maximum information, or video frequency, of

$$f_{max} = \frac{mN}{2} \quad . \tag{2-2}$$

If the number of scan lines per raster is n and the longitudinal resolution R_L is taken to be equal to n, then the

maximum total number of elements in the raster is given by

$$m = (\frac{W}{h})\ n^2\ ,$$

(2-3)

where the term $(\frac{W}{h})$ is the aspect ratio of the raster. Equation (2-4) results from substituting equation (2-3) into equation (2-2).

$$f_{max} = (\frac{W}{h})\ n^2\ N\ .$$

(2-4)

By use of the standard data of the American television broadcasting industry, this expression is found to give the result,

$$f_{max} = (\frac{4}{3})\ (525)^2\ (30)$$

$$f_{max} = 11.025\ MHz.$$

(2-5)

Since, in actual practice, the effective transverse resolution is degraded by the Kell factor (see equation (2-1)) the longitudinal resolution is higher than would normally be found. The lower bandwidth requirement when considering the Kell factor affects only the number of elements per scan line, but not the number of scan lines.

$$f_{max} = (\frac{W}{h})\ kn^2\ N$$

(2-6)

$$f_{max} = 7.72 \text{ MHz} \qquad . \qquad (2\text{-}7)$$

A more appropriate method of analysis is to consider the problem of a horizontally scanning aperture which passes a narrow vertical bar (2). If the horizontal transition distance between black and white is to be the same as from center-to-center of adjacent scan lines, then the width of the vertical bar must not be wider than $(\frac{2h}{n})$. In order to determine the channel bandwidth needed to fulfill this requirement it is necessary to make use of a Fourier integral.

In passing over the vertical bar, the scanning beam gives rise to an impulse of very short duration which can be represented as shown in Figure 2. The frequency spectrum of this impulse is given by:

$$F(f) = \frac{2A}{\tau} \int_0^{\tau} \cos(2\pi f t) \cdot dt \qquad (2\text{-}8)$$

which can be evaluated to give

$$F(f) = 2A \frac{\sin(2\pi f \tau)}{2\pi f \tau} \qquad (2\text{-}8a)$$

where 2τ is the duration of the pulse input. Since the frequency spectrum is of the form $\sin(x)/x$, it can be seen that the bandwidth of the input signal is infinite. For

real video systems it isn't possible to attain infinite channel bandwidth.

If it is assumed that a flat frequency response is attainable out to some cut-off frequency f_c, and zero thereafter, it is possible to derive the output attained as a function of the cut-off frequency. The equipment frequency response is illustrated in Figure 2.

If A is the amplitude of the frequency response below f_c, then the integral representing the time-domain output function is

$$P(t) = 2A \int_0^{f_c} \cos(2\pi ft) \cdot df \quad , \qquad (2\text{-}9)$$

which upon integration yields

$$P(t) = \frac{A}{\pi} \frac{\sin(2\pi f_c t)}{t} \quad . \qquad (2\text{-}9a)$$

The shape of this output pulse $P(t)$ is shown in Figure 2. The time between the maximum of the pulse $P(t)$ and its first minimum is determined by setting

$$\frac{dP(t)}{dt} = 0 \quad ,$$

which gives

IMPULSE INPUT

OUTPUT OF CHANNEL

FREQUENCY SPECTRUM
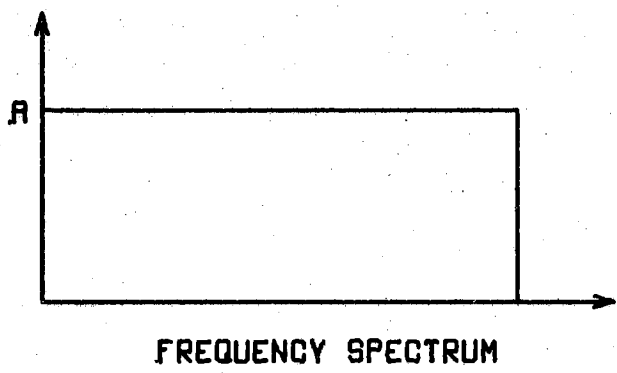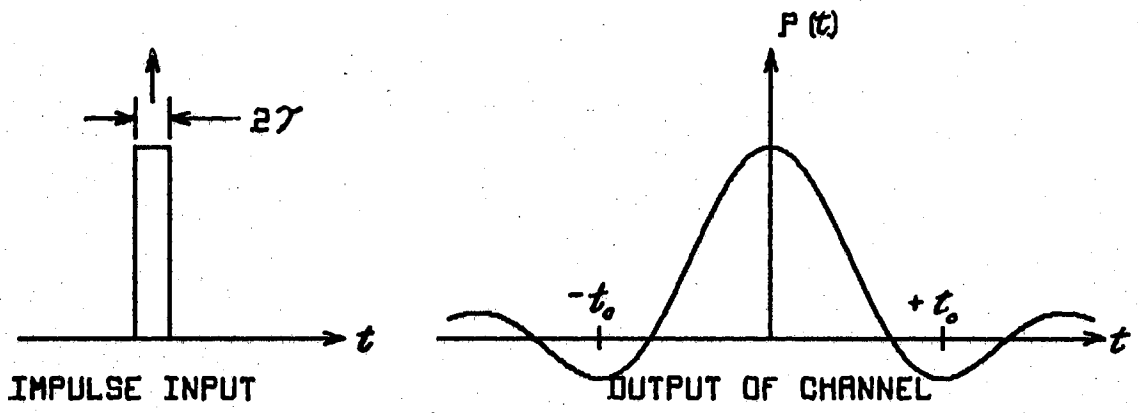
FIGURE 2. SCANNING A NARROW VERTICAL BAR WITH
A SHARP CUTOFF VIDEO CHANNEL

$$2Af_c \frac{\cos(2\pi f_c t)}{t} - \frac{A}{2} \frac{\sin(2\pi f_c t)}{t^2} = 0 \quad . \quad (2\text{-}10)$$

The solution of this equation for the time t_o, which corresponds to the occurrence of the first minimum in $P(t)$, is therefore the transcendental equation,

$$2\pi f_c t_o = \tan(2\pi f_c t_o) \quad ,$$

which gives the desired relationship between the "pulse width" $2t_o$ and the filter cut-off frequency f_c.

$$f_c = \frac{4.4934}{2\pi t_o} \qquad (2\text{-}11)$$

The half width of the reproduced image of the original vertical bar is equal to the product of the velocity of the reproducing spot and the time t_o. Therefore

$$t_o V = \frac{h}{n} \quad ,$$

where h is the height of the raster. Since

$$V = Nnw \quad ,$$

where w is the raster width, it follows that

$$t_o = \frac{h}{wn^2 N}$$

and from this the cutoff frequency of the channel is found
to be

$$f_c = \frac{4.493}{2\pi} \frac{w}{h} n^2 N \quad ,$$

or

$$f_c = 0.715 \left(\frac{w}{h}\right) n^2 N \quad . \tag{2-12}$$

Evaluation of equation (2-12) for the values of w, h, n,
and N employed in obtaining equations (2-5) and (2-7),
gives

$$f_c = 7.88 \text{ MHz.} \tag{2-13}$$

From the results of the two bandwidth derivations,

$$f_c = 7.72 \text{ MHz.}$$

and

$$f_c = 7.88 \text{ MHz.} \quad ,$$

it is a reasonable requirement that the video channel band-
width be 8 MHz. In fact, a flat ($\pm$0.5db) frequency res-
ponse from 30Hz. to 8MHz. is the actual channel width for
much black-and-white broadcast quality television gear.

Therefore, as long as the bandwidth of the entire

video processing system is such that

$$f_c \geq 8MHz. \quad ,$$

then

$$R_t \approx 368 \text{ lines}$$

and

$$R_L \approx 368 \text{ lines}$$

where R_t and R_L are the transverse resolution and longi-
tudinal resolution, respectively. This permits approxi-
mately 1.36×10^5 image elements per raster. If the band-
width is reduced, then

$$R_t \approx 368 \text{ lines} \qquad (2-14)$$

$$R_L \approx \left(\frac{f_c}{8 \times 10^6}\right) 368 \text{ lines} \qquad (2-14a)$$

when

$$f_c \leq 8MHz.$$

The value for n employed in equations (2-7) and (2-13)
was 525, which corresponds to the theoretical number of
horizontal lines per raster. In actuality the number of
active scan lines, n_a, is only 493.5. This reduction of
R_t of 6 percent is due to the video blanking during the
vertical retrace period. The values of f_c which were

derived are correct, even though R_t must employ the number n_a rather than n (see equation (2-1)).

Even though the television hardware and its mode of operation is completely standard (with respect to commercial broadcasting in the United States), a consolidated summary of its operation and functions is needed in order to develop useful interfaces between standard television equipment and a digital computer having analog input-output capability. The remainder of this chapter will be devoted to the raster or scanning format and a description of some of the synchronization techniques employed. This will include a description of the final video signals.

Figure 3 illustrates the path of the scanning beam. Note that the continuous line starts at the upper left-hand corner of the picture and moves in a downward slanting motion to the right. On reaching the right side, the blanking pulse takes effect and the now invisible beam snaps back to the left side of the picture, as indicated by the dotted line. The point at which it reaches the left side of the picture is separated from the starting point of the previous line by a space equal to at least the width of a line. At this point blanking ends and the horizontal synchronization pulse causes a new line to start. This cycle is repeated until the bottom of the picture is reached (12,13).

It can be seen, as shown in Figure 3, that the last line never reaches the right side of the picture but slants

SCANNING LINE, FIRST FIELD
SCANNING LINE, SECOND FIELD
RETRACE LINE
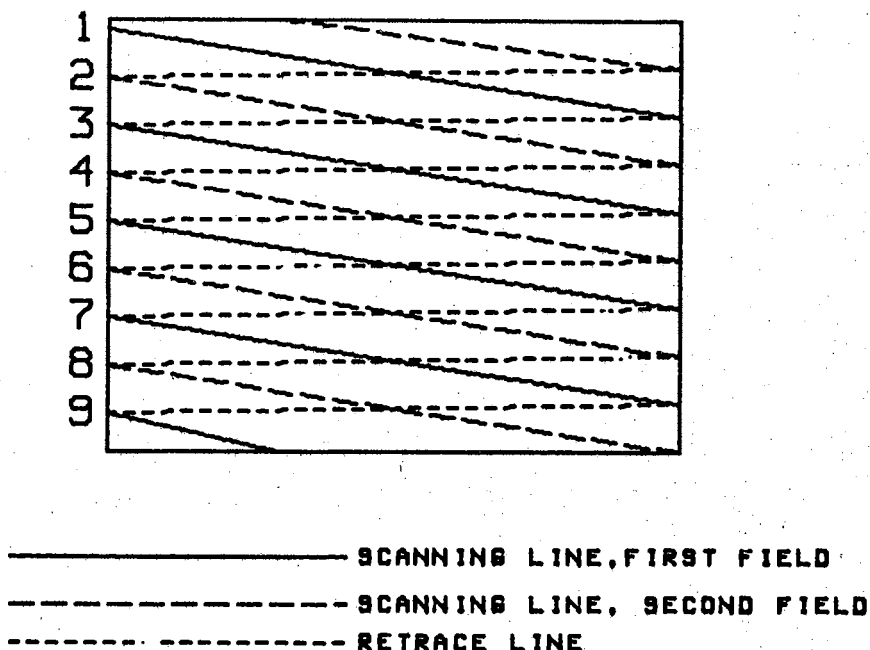
FIGURE 3. SIMPLIFIED PRESENTATION
OF INTERLACED SCANNING

to the bottom of the picture midway between the two sides.
This is the end of the first field. At this point vertical
blanking is applied and the beam zigzags back to the top of
the picture (the horizontal sweep is still operative during
vertical retrace) where, midway between the two sides, the
video blanking terminates and a new scan line begins.

The scanning procedure just described is a "two-to-one
interlaced" raster. The timing is such that there are 525
lines, 60 fields, and 30 frames; each frame consisting of
one so-called "even" field and one "odd" field. Of the 525
lines per frame only 493.5 of them are active lines, the

remaining lines being scanned during periods for which
video blanking is present.

The fact that standard broadcast television scanning
is of the interlaced type is brought about by the biologi-
cal factors of human viewing of a television image. If a
one field per frame scanning system were employed instead
of two-to-one interlacing one of the following alternatives
would have to be chosen.

1) The use of only 30 fields per second,
   in which case there would be a notice-
   able flicker as the image was scanned
   from top to bottom.

2) The use of 60 frames per second, in
   which case the channel bandwidth of
   the video system would have to be
   doubled in order to maintain the
   same longitudinal image resolution.

3) Use only half as many scan lines per
   frame, in which case there would be a
   50% loss of transverse image resolution.

In other words, interlaced scanning is a means of reducing
the amount of image flicker without increasing the channel
bandwidth of the video equipment.

Even though the concept of image "flicker" is meaning-
less when applied to the problem of image "observation" by
a computer, there are some very useful possible benefits to
such a physical system arising from interlaced scanning.
If the computer is making gross observations (low resolu-
tion) of an image, then the results of observing either the
even or the odd field within a frame would be equivalent.
Since the added resolution to be gained by observing the
image for one entire frame period (1/30 sec.) would be

wasted, the observation period could be halved and thereby doubling the image processing speed. When the added resolution is required by the use of an electronic aperture approximating the limit resolution of the video equipment, the image can be observed for two consecutive fields and thereby receiving the maximum possible image resolution.

The last topic to be considered for the video coding format is the form of the electronic signal which carries the image information. In order to make a transformation of information in the image plane, $f(x,y)$, into a function of time, $h(t)$, which can be transformed again into a reasonable approximation of the original function $f(x,y)$, some additional functions of time are required.

$$f(x,y) \longrightarrow h(t)$$

$$h(t) \longrightarrow f(x,y)$$

For some given time t_o it is necessary that there be a unique value (x_o, y_o) for which

$$t = t_o \implies (x,y) = (x_o, y_o)$$

The vertical and horizontal sweep functions $V(t)$ and $H(t)$ perform this task. Therefore

$$f\left[H(t), V(t)\right] \longrightarrow h(t)$$

and

$$h(t) \longrightarrow f\left[H(t), V(t)\right] \qquad .$$

Let $M(t)$ be the intensity received by the scanning aperture, then with the three functions $M(t)$, $V(t)$, and $H(t)$ the image description, $f(x,y)$ can be transmitted and reconstructed by the following relation:

$$f\left[H(t), V(t)\right] = M(t) \qquad\qquad (2\text{-}15)$$

Equation (2-15) does not yield all of the possible values of (x,y) as attainable at any one given time, but rather gives each possible value a "time slot" within the frame period.

Some television systems function by actually transmitting the three functions $V(t)$, $H(t)$, and $M(t)$. A more efficient means of transmission is employed by standard television practices. Since $V(t)$ and $H(t)$ are periodic in time, and are of a known form, they can be generated at the receiver if synchronization pulses for the two sweep generators are available. The "sync" pulses are superimposed on the image illumination function $M(t)$ and equalizing pulses are added so that the average value of the entire time function is such that the correct "black level" or total brightness of the reproduced image is maintained through the A.C. Coupling of data transmission. This composite

video function is illustrated in Figures 4 and 5.

The blanking pulses are also a part of the video modulation inasmuch as they are required to maintain $M(t) = 0$ for those times during which retrace is occurring. The amplitude of the blanking pulse is adjusted so that the average value of the entire signal is such that its voltage level corresponds to the "black level" of the image. The blanking pulse is considered as part of the video modulation signal, whereas the vertical and horizontal sync signals are not.

Further specific details of the electronic hardware used to generate the above described signals are presented in the next chapter.
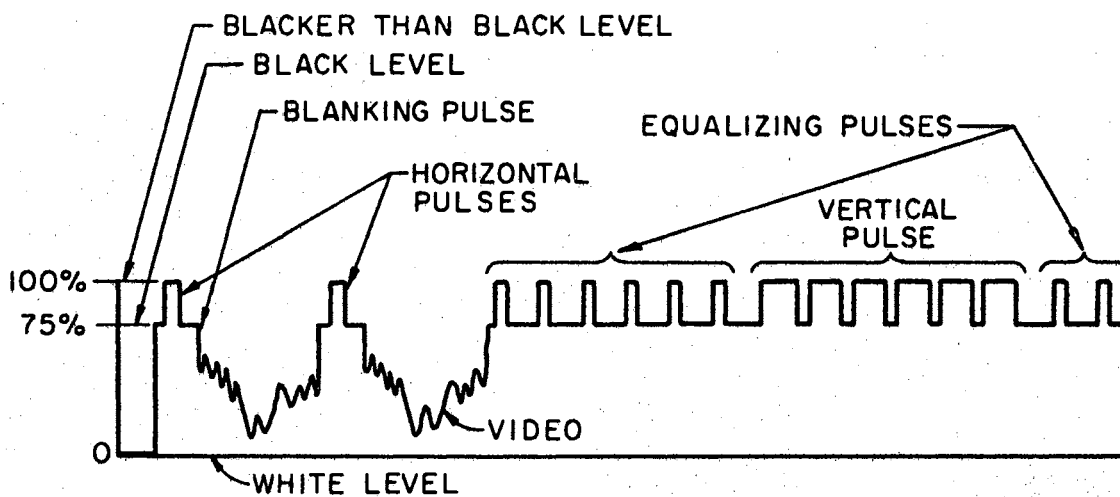
Figure 4. Simplified Waveform for a Television Signal
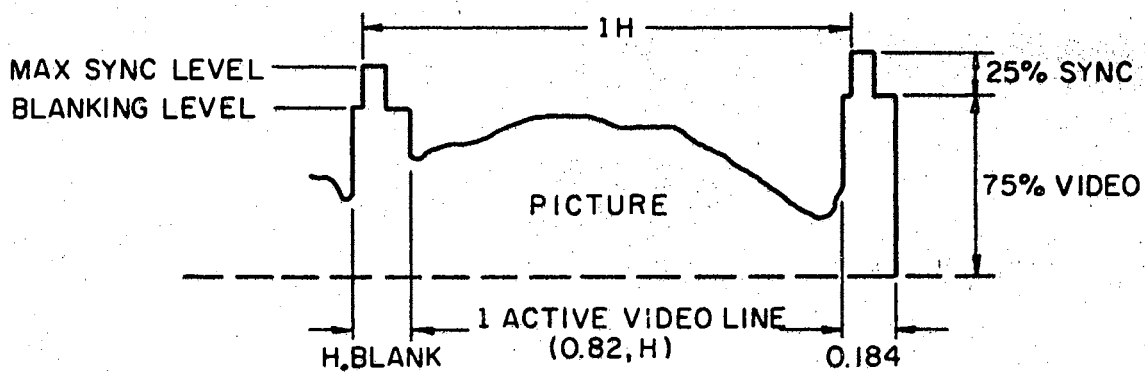
Figure 5. One Line (1 H) of Composite Television Signal

CHAPTER III

THE EXPERIMENTAL TELEVISION APPARATUS

The actual television gear used in this investigation was commercial, broadcast equipment which operates within the Federal Communications Commission regulations for television. The actual television equipment consisted of two portions, the commercial portion and a "video signal consolidator". This composite unit was used as the source of the video signals used in the research reported here.

The Commercial Television Equipment

The Dage (a division of TRW, Inc.) Mobile Camera Control Console ETS-2B formed the nucleus of the television system. Table I shows a list of the separate electronic units which were employed in this console. Although these components are considered as integral parts of the Mobile Camera Control Console, various modes of operation are available to the user by simple cable changes. For this reason the versatility of the television equipment was ideal for application in pattern recognition.

Table II shows a list of the equipment which was separately chosen for operation in this system. The equipment listed in Table I and Table II is described in great detail

in the handbooks supplied by the manufacturer (12-17).

TABLE I

BASIC TELEVISION EQUIPMENT

Equipment Description	Dage Model Number
Console Housing and Cables	200001-01
Camera Control Panel	202531-03
Camera Connector Panel	261105-01
Video Processing Assembly	
Filament and Bias Supply	202530-01
Pulse Amplifier	202401-01
Processing Amplifiers	202284-02
Switcher-Fader Panel and Amplifiers	200862-01
Regulated D.C. Power Supply	200862-01

TABLE II

AUXILIARY TELEVISION EQUIPMENT

Equipment Description	Dage Model Number
Two Cameras and Electronic Viewfinders	320BF
Two Camera Cables	861780
One Synchronizing Generator	410-D
One Line Video Monitor	602-C
Two Camera Video Monitors	602-C
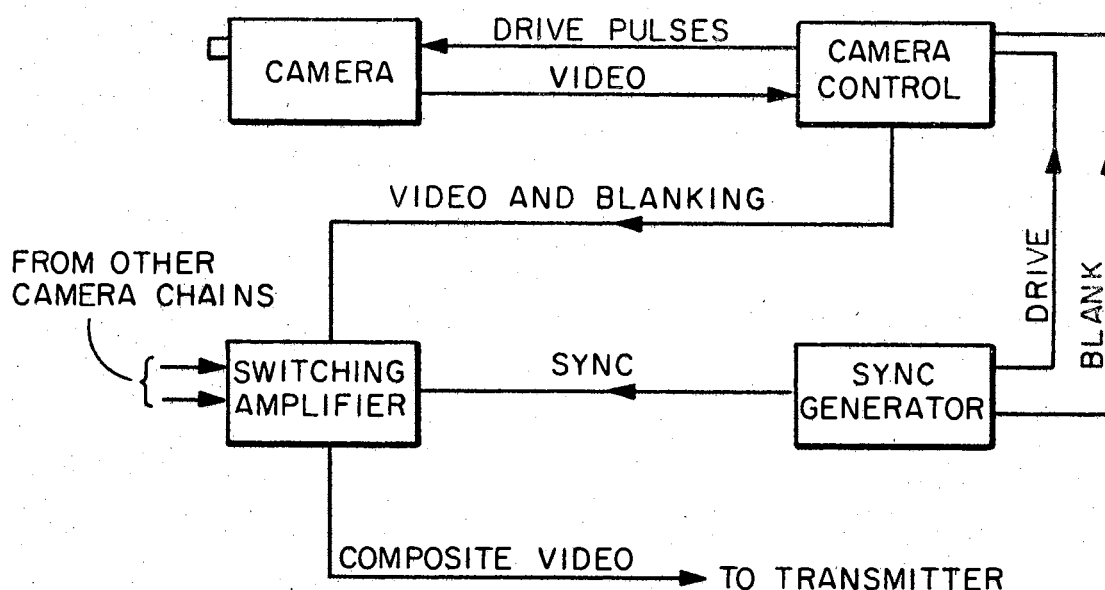
Figure 6. TV Camera Chain Block Diagram

The basic block diagram of a single camera chain is illustrated in Figure 6. The system used for this research employed two cameras and was cabled in such a manner that the video plus blanking signals were available simultaneously for both cameras. The switching amplifier worked in conjunction with a fader control such that if V_{z1} and V_{z2} were, respectively, the composite video signals for camera 1 and camera 2, then

$$V_z = AV_{z1} + (1-A) V_{z2} \quad .$$

V_z is the composite video signal leaving the switching amplifier and "A" is variable from zero to one.

Figure 7 illustrates the cabling procedure for operating the ETS-2B in its normal mode. The second video terminal of each of the three monitors can be used as a video output. The output from the line monitor is the same composite signal as found at the console video output (VID of Camera Control Panel).

The available video outputs are from 75 Ω sources and the video output (black negative) is 1.4 volts peak-to-peak. The frequency response is from 30Hz to 8MHz, ±1db. Table III is of the various pulses found within the system. The horizontal drive pulses, vertical drive pulses, blanking pulses, and synchronization pulses are all directly available from the "sync" generator either as positive pulses or negative pulses. The pulse amplitudes from the sync generator are from 3 to 6 volts, either positive or negative.

Although the Video Signal Consolidator (described in the next section of this chapter) employs the vertical and horizontal drive pulses, it can function equally well by using the vertical and horizontal blanking pulses. The significant point of this fact is that the drive pulses are not available in the composite video signal which originates from standard television broadcasts, whereas the blanking pulses are included in this signal. The reason that the vertical and horizontal drive pulses were chosen for this effort is that for a television system whose only purpose is to be employed as a computer input device there would be no reason to even generate a composite video
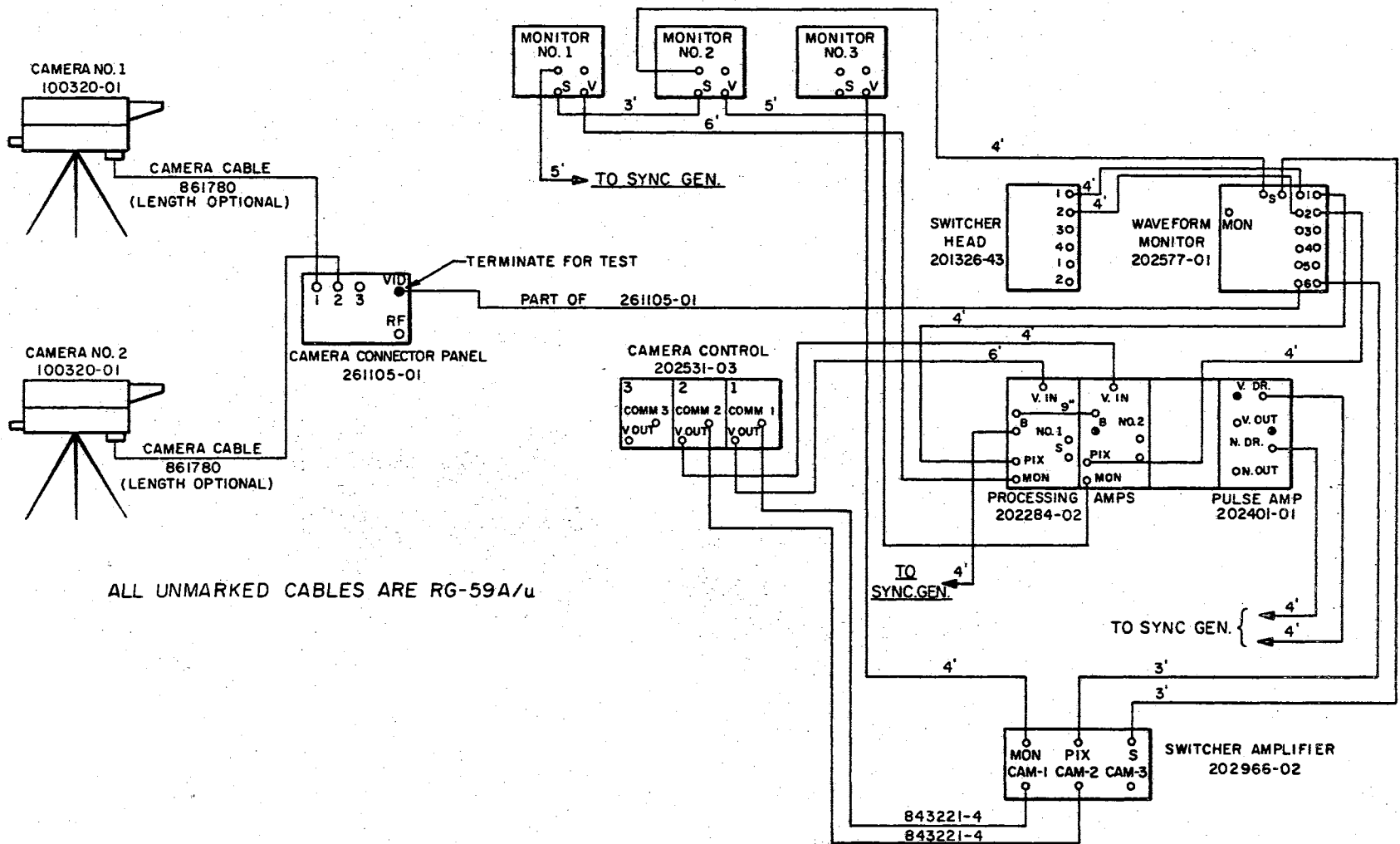
Figure 7. Cabling Diagram For The ETS-2B Video Console

signal; the normal "sync" pulses would need never be gener-
ated. Figure 8 illustrates the relationship between a hor-
izontal drive pulse and a horizontal blanking pulse.

TABLE III

FUNDAMENTAL TV PULSES (MONOCHROME)

PULSE IDENTITY	PULSE RATE (Freq. in pps)	DURATION IN MICROSECONDS			REPETITION RATE (CPS)
		MIN.	NOMINAL	MAX.	
H. SYNC	15,750	4.48	5.08	5.68	15,750
H. BLANKING	15,750	10.5	11	11.43	15,750
EQUALIZING	31,500	2.2	2.5	2.8	60
V. SYNC	31,500	26.9	27.5	28.1	60
V. SERRATION	31,500	3.85	4.45	5.05	60
V. BLANKING	60	833.4	1000	1333.3	60
H. DRIVING	15,750	5.25	7.6	11.43	15,750
V. DRIVING	60	416.5	575	1333.3	60

The Video Signal Consolidator

In order to apply any significance to the video modu-
lation signal, V_z, it is necessary to be able to associate
a given image location with each point along the video
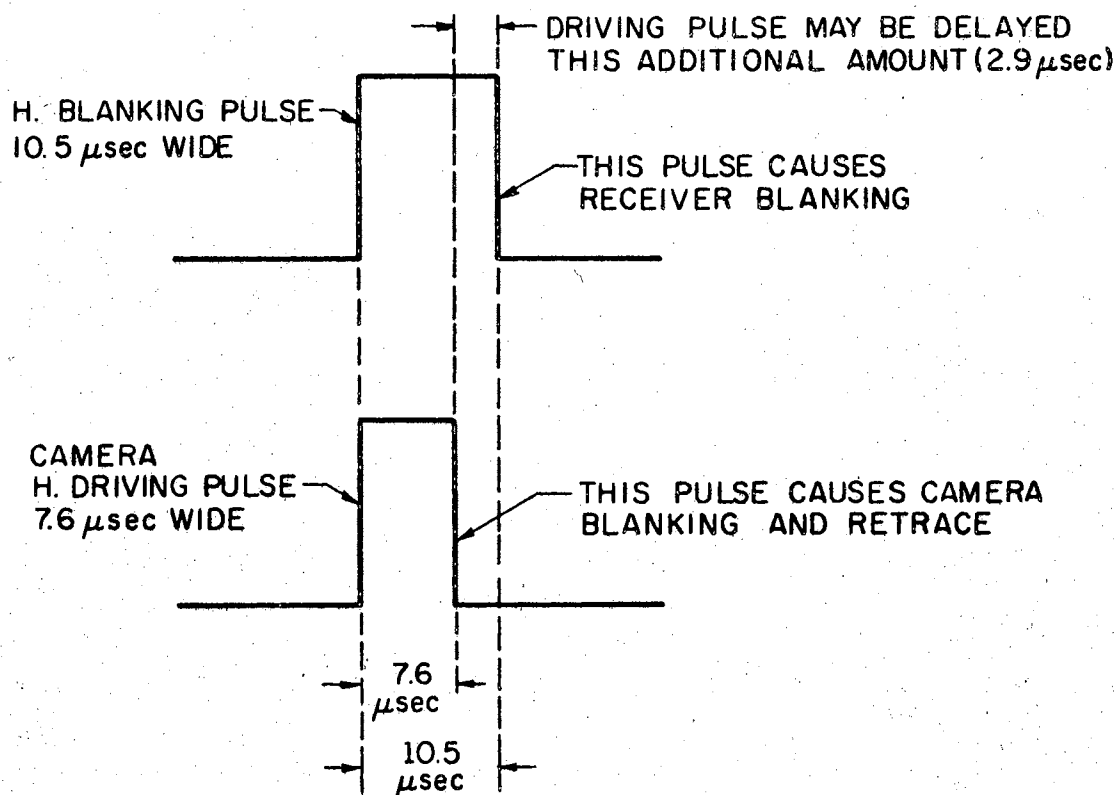
Figure 8. Horizontal Blanking Pulse Relationships

video signal (plotted as a function of time). In order to accomplish this requirement two sweep voltages were generated, V_x and V_y, which are the Cartesian coordinates of the scanning aperture (electron beam) within the image area. A signal conditioning and consolidating device, identified here as a Video Signal Consolidator, was constructed so that all the relevant signals were available from one location and of the proper form.

The video signals available as outputs from the Video Signal Consolidator are listed below.

1. The vertical sweep voltage
2. The horizontal sweep voltage
3. Video Modulation plus Blanking
    a. Normal Polarity for Camera 1
    b. Inverted Polarity for Camera 1
    c. Normal Polarity for Camera 2
    d. Inverted Polarity for Camera 2
4. Horizontal Drive Pulses
5. Vertical Drive Pulses
6. Power Supply
    a. Regulated +15 volts
    b. Regulated -15 volts
7. Signal and Power Common Terminals

Figure 9 illustrates the panel layout for the video signal consolidator. Figure 10 is the block diagram of the unit, and Figures 11 through 13 are details of the various component blocks.

The video modulation signals are 1.4 volts peak-to-peak with a 75 Ω output impedance, equipped with BNC connector outputs. The video amplifiers have at least a 30 MHz bandwidth (response is down 1 decibel at 30 MHz).

The horizontal and vertical drive pulse jacks have a 75 Ω output impedance. The horizontal drive pulses are 6 microseconds wide and 3.5 volts in amplitude (positive pulses). The vertical drive pulses are 600 microseconds wide and are 5 volts in amplitude. The pulse repetition rates are 15,750 per second and 60 per second, respectively.

The outputs of the Vertical Sawtooth Generator and the Horizontal Sawtooth Generator have an output impedance less than 10KΩ. Both signals range from -10 volts to +10 volts and are D.C. coupled. The center of the image area is denoted by $V_x = 0$ and $V_y = 0$, the upper edge of the image corresponds to $V_y = -10$ volts, and the lower edge to
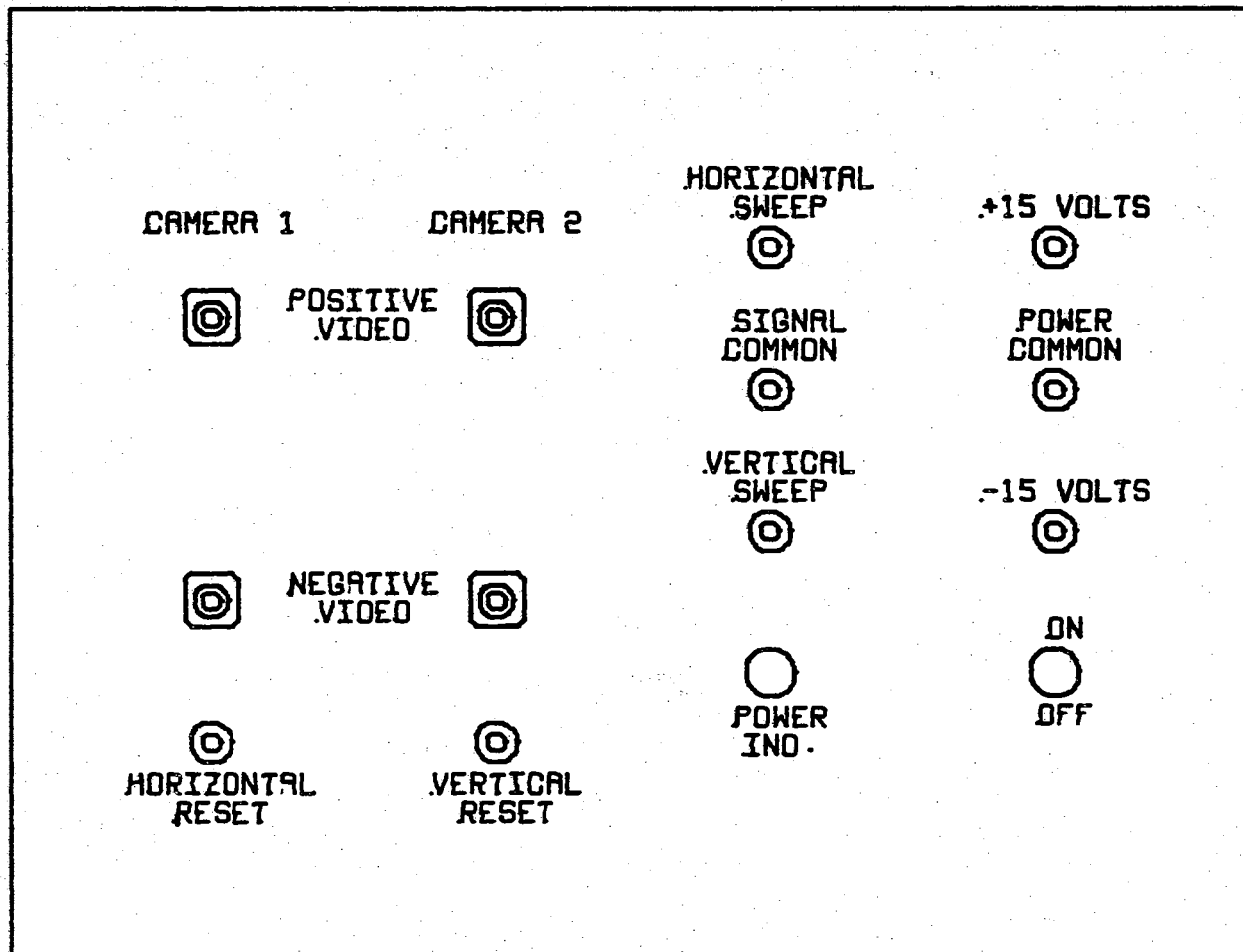
FIGURE 9. CONTROL PANEL OF THE VIDEO SIGNAL CONSOLIDATOR

INPUTS

VIDEO, CAMERA 2

VERT. DRIVE

VERTICAL
SAWTOOTH
GENERATOR

HORIZONTAL
SAWTOOTH
GENERATOR

HORIZ. DRIVE

VIDEO, CAMERA 1

OUTPUTS

VIDEO
AMPLIFIER

-VIDEO, CAMERA 2

+VIDEO, CAMERA 2

VERTICAL SWEEP

VERTICAL DRIVE

HORIZONTAL DRIVE

HORIZONTAL SWEEP

VIDEO
AMPLIFIER

-VIDEO, CAMERA 1

+VIDEO, CAMERA 1
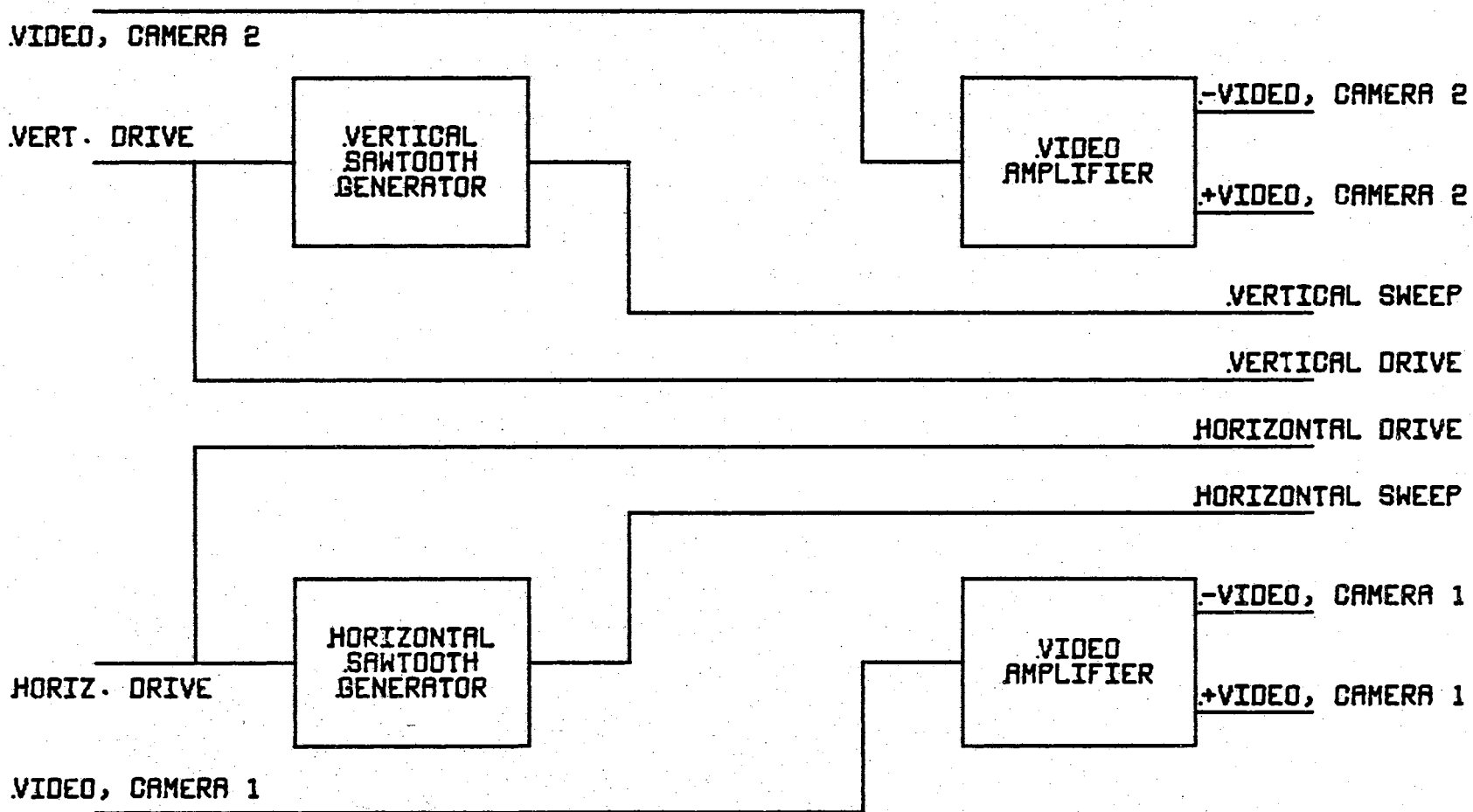
FIGURE 10.   BLOCK DIAGRAM OF THE VIDEO SIGNAL CONSOLIDATOR

34
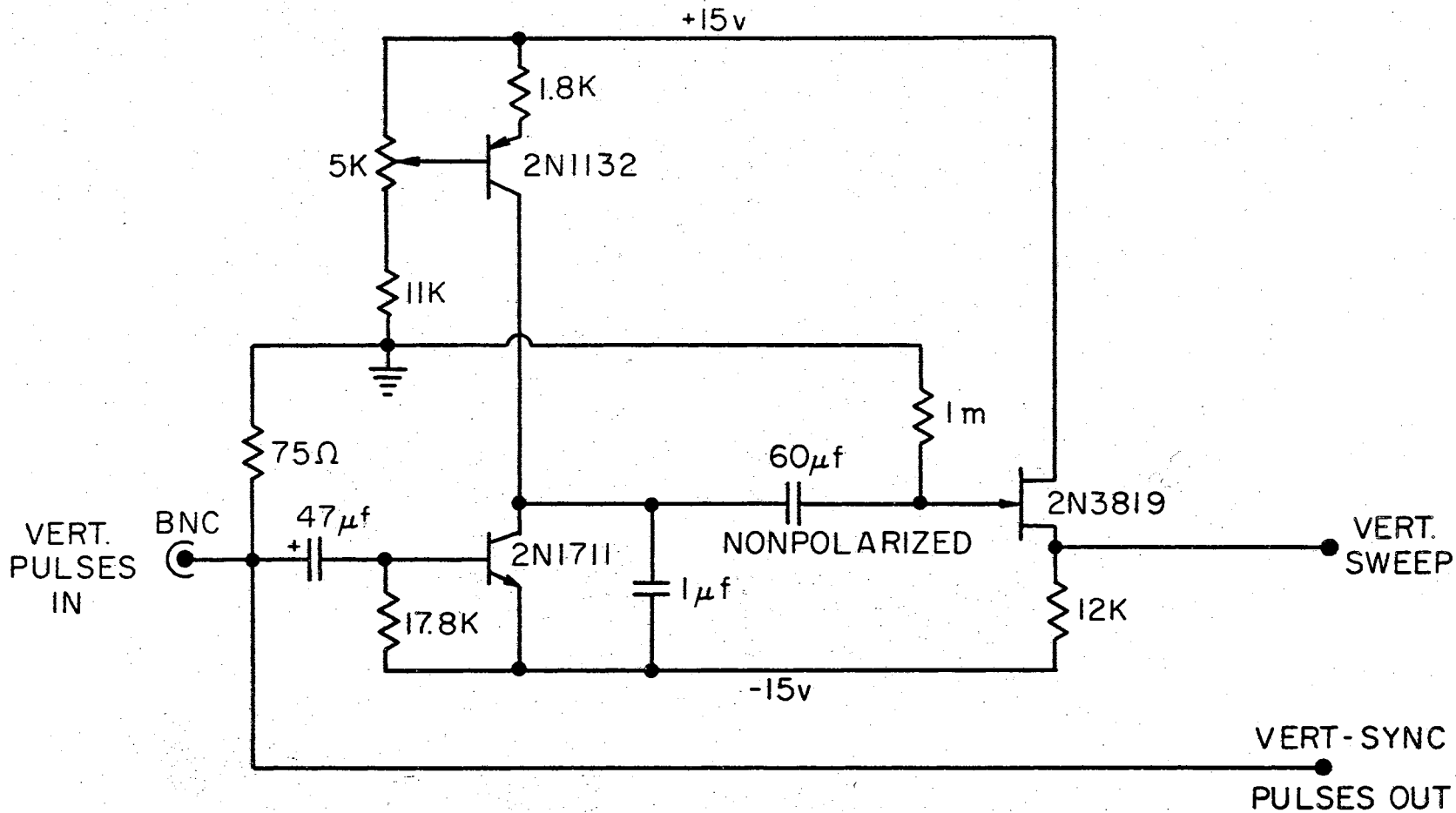
Figure 11. Vertical Sweep Generator

35
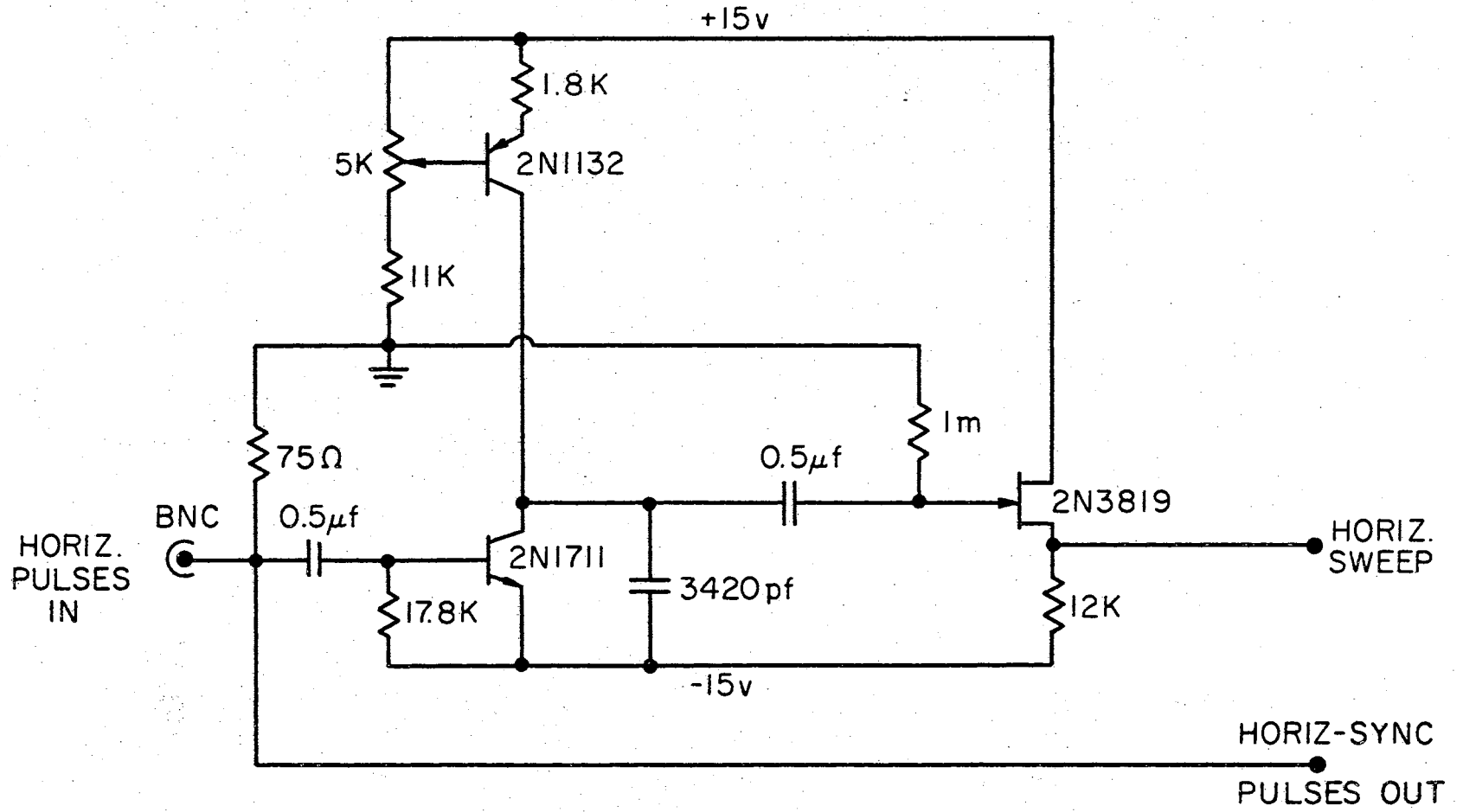
Figure 12.   Horizontal Sweep Generator

36
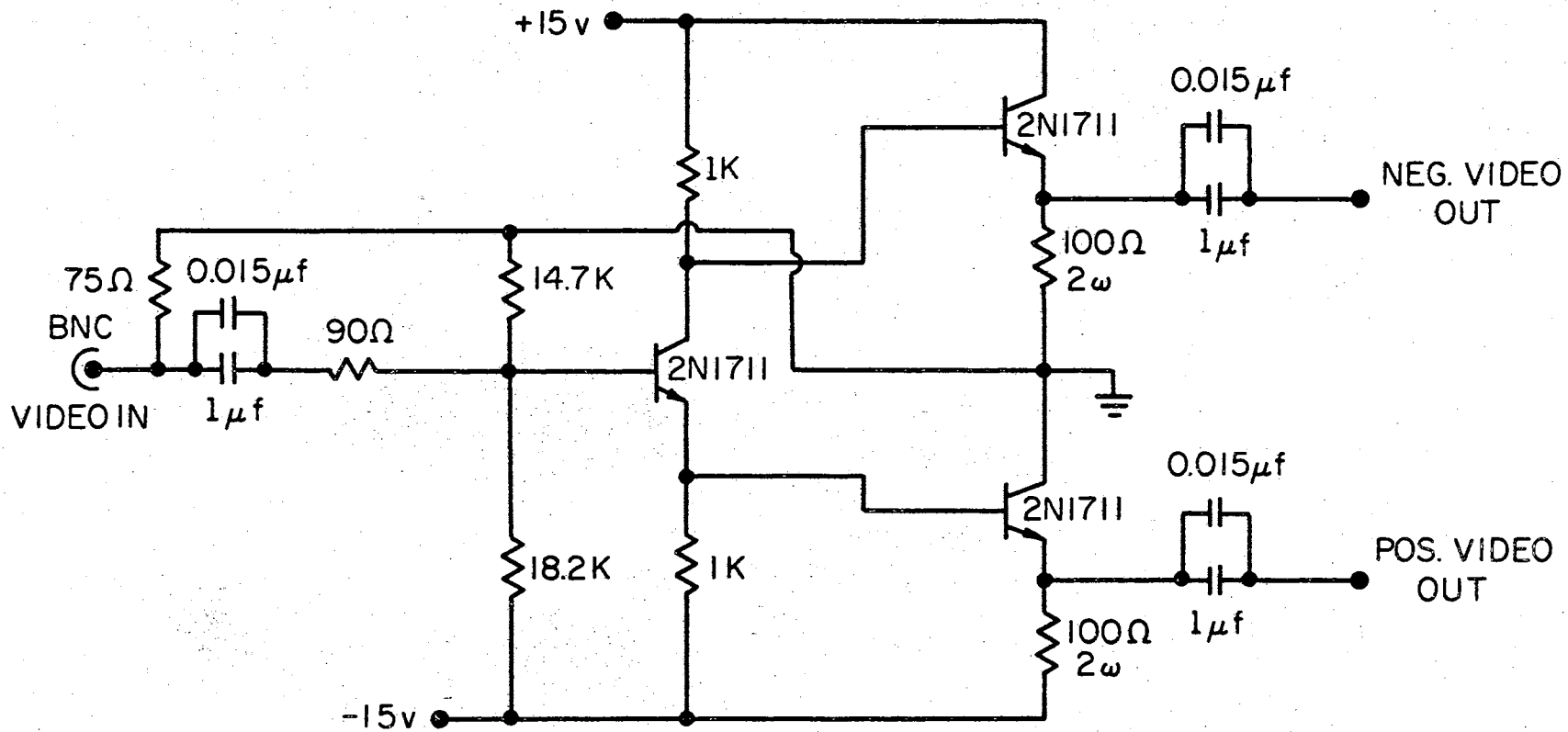
Figure 13. Video Amplifier

$V_y = +10$ volts. The left edge and right edge correspond to $V_x = -10$ volts and $V_x = +10$ volts, respectively. The wave-forms of these signals are shown in Figure 14.

The regulated D.C. power supply not only powers the devices integral to the Video Signal Consolidator, but also has +15 and -15 volt outlets for auxiliary equipment. For loads drawing less than 150 mA. the D.C. output resistance is 1.7Ω. The power supply is normally expected to carry an additional 300 mA., at most. Regulation can be maintained for a 1 ampere output without damaging the supply if an increased power input voltage is employed (rather than 117 V.A.C.).
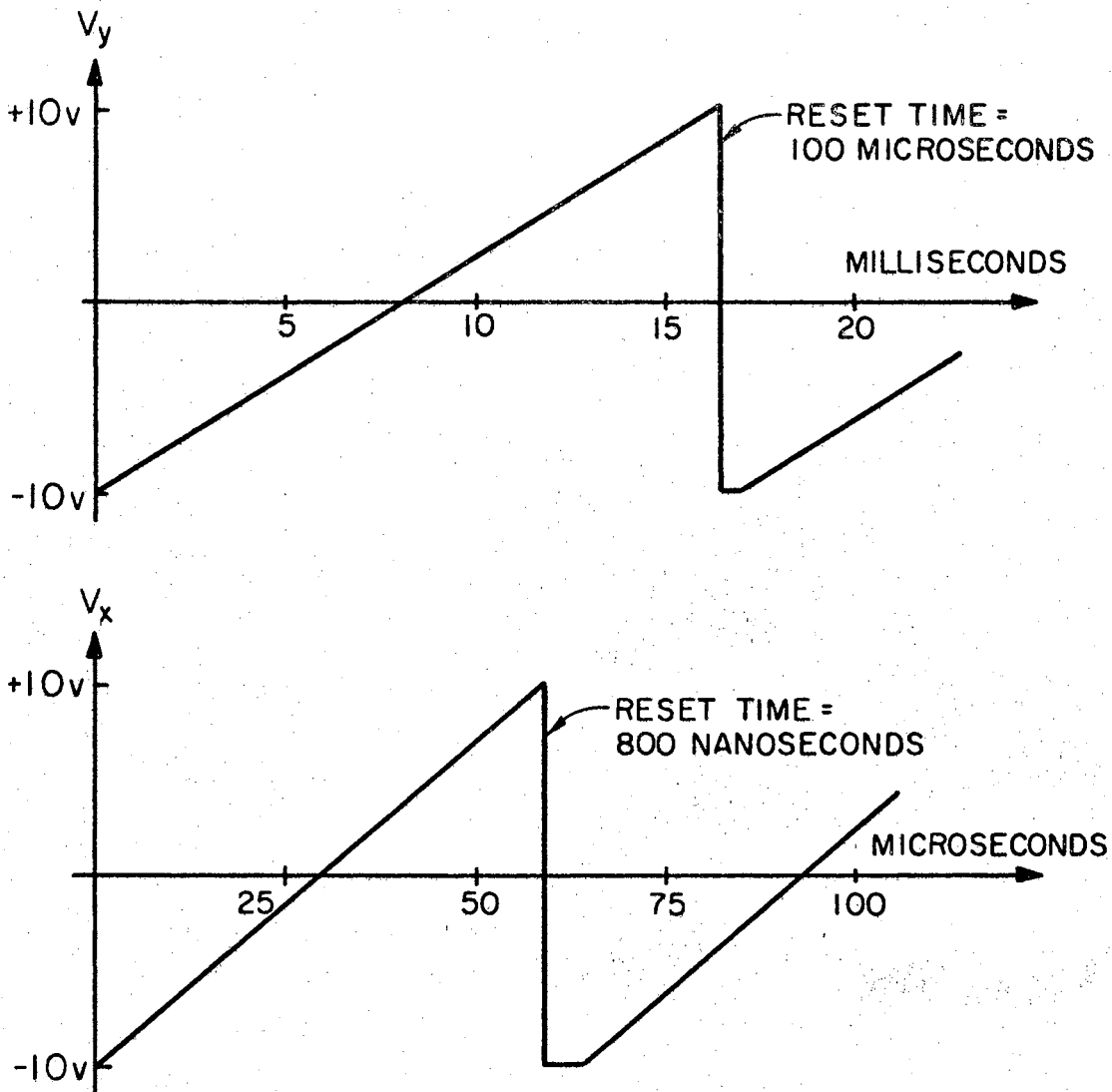
Figure 14. Waveforms of V_x and V_y

CHAPTER IV

THE IMAGE INTERROGATION EQUIPMENT

The equipment which accepts the television signals from the video signal consolidator (described in Chapter 3) and performs a pre-processing function for the digital computer is the "image interrogator". The image interrogator is controlled by the digital computer and is able to present various attributes of the image under observation to the computer in a usable format. An important characteristic of this type of video image pre-processing is that the portion of the image under observation and, to some extent, its method of observation is always under the direct control of the computer. In this way the computer can make its own "decisions" as to the form of image pre-processing which would be appropriate for any given image.

Figure 15 illustrates the manner in which the complete image analyzing system was connected. Since the information transmission is bilateral between the image interrogator and the digital computer, the system as a whole can be considered as a "hybrid computer" (a computer in which both analog and digital computation and/or logical decisions are made). Five separately addressable channels are employed for the digital-to-analog conversions, and

INPUT TELEVISION
SIGNALS

VIDEO SIGNAL
CONSOLIDATOR

IMAGE INTERROGATOR

D/A
CONVERTER

A/D
CONVERTER

DIGITAL COMPUTER
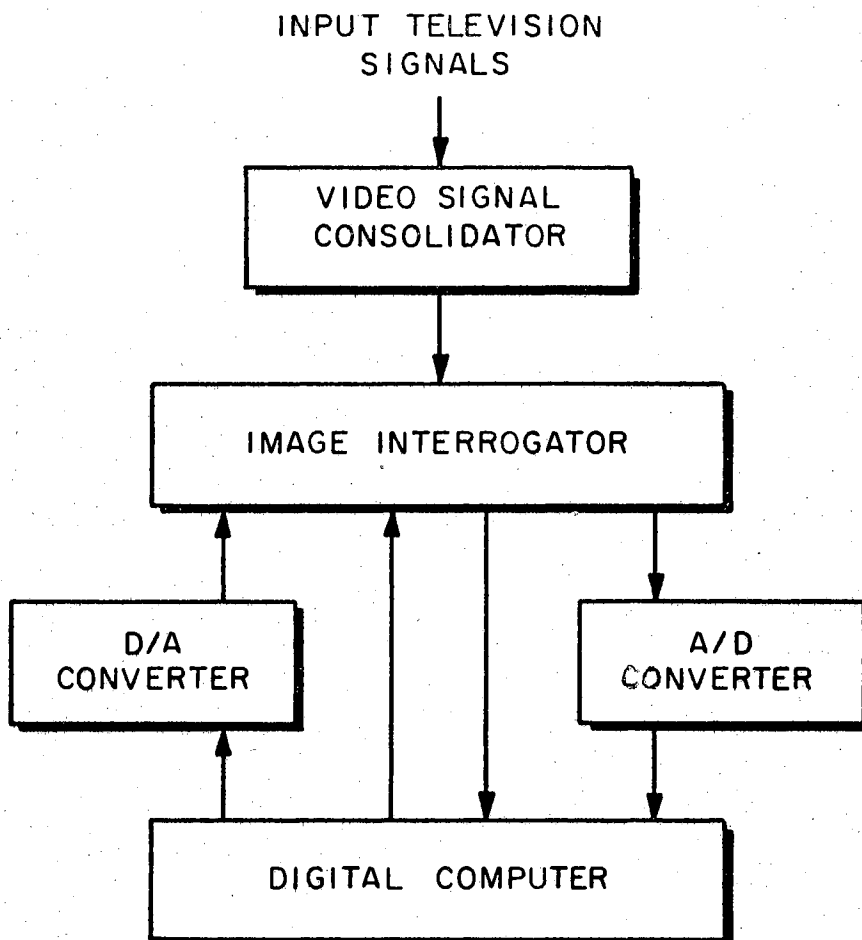
Figure 15.   Block Diagram of the Complete
Image Analyzing System

three analog-to-digital channels are employed.   The oper-

ation of the Digital-to-Analog and Analog-to-Digital con-

verters and their interfacing to the IBM 1620 is covered in

Appendix A.   The use of the control lines out of the com-

puter and its sense lines are also discussed in Appendix A.

The image interrogator can be thought of as a "gated video integrator" in which the video control gate corresponds to a "window" or electronic aperture on the image plane. This window is controllable from either a second television image or directly from the computer. When controlled by the computer, the position, size, and shape (always rectangular) is variable. The name image interrogator arose from the fact that any portion of the image plane can be electronically interrogated to determine the percentage of the area of the specified window which contains image intensity information in excess of some adjustable threshold level.

Figure 16 is a block diagram of the image interrogator. The block labeled "integrator control circuitry" is almose entirely a digital system which produces the necessary timing relationships between the digital computer and the in-coming television signals (V_x, V_y, and V_z).

The input labeled "$\overline{W}$" is in actuality four different inputs which control the location and dimensions of the gating window. These inputs are identified in Table IV. When the horizontal and vertical scan voltages (V_x and V_y) indicate that the scanning aperture is within the window defined by $\overline{W}$, then a gating signal (G) is sent to the Integrator Control Circuitry.

When the computer begins an interrogation of a given window area of the image, the first thing that is done is for the computer to set the voltages W_1, W_2, W_3, and W_4.
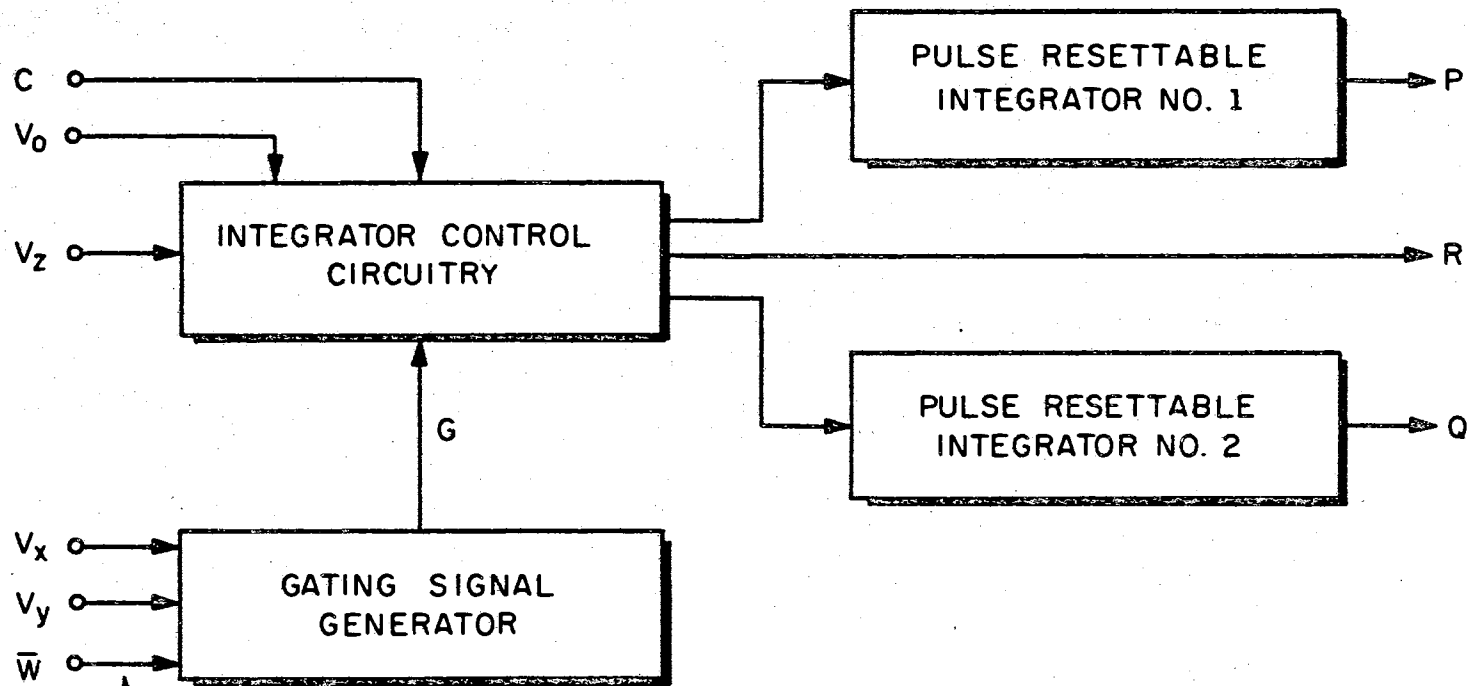
Figure 16. Block Diagram of the Image Interrogator

The next thing is for the computer to deliver a reset pulse
to the input "C" of the integrator control circuitry (via
D/A Channel 5). This pulse should be between 1 microsecond
and 100 microseconds in duration with a pulse height of 5
volts. The voltage at "R" immediately goes to zero (or
remains at zero volts). The digital computer will be able
to "test" the output at R until it rises to approximately
4 volts. This will indicate that the outputs at "P" and
"Q" are available for sampling. The voltage P is propor-
tional to the area of the window and Q is proportional to
the image area within the window of greater intensity than
that which was chosen as the threshold level. For small
window sizes where the accuracy of the window dimensions is
questionable, the voltage P is available as a reference.
The input V_D is the vertical drive (or vertical reset)
pulses from the Video Signal Consolidator.

TABLE IV

WINDOW DIMENSIONING INPUTS

Input	D/A Channel	Window Edge	Voltage Limits
W_1	1	Left	-99.9v. to W_2
W_2	2	Right	W_1 to +99.9v.
W_3	3	Top	-99.9v. to W_4
W_4	4	Bottom	W_3 to +99.9v.

The integrator control circuitry logic diagram is
shown in Figure 17. The memory elements of this digital
system is composed of three master-slave type J-K flip-
flops (Texas Instruments SN7473N) and one R-S type flip-
flop constructed from the NAND gates (as shown). The alpha-
betic designations A through E refer to the individual
integrated circuits shown in Figure 24, and the input and
output numbers refer to the pin numbers of the integrated
circuits. Figures 20, 21, and 22 are detailed schematics
of Figure 17.

A toggle switch is available for two modes of opera-
tion; in the unoperated position the video signal will be
"observed" for an entire raster (dual frame operation)
whereas if the switch is in the operated position, then
only a single field (or one-half raster) will be "observed".
Figures 18 and 19 show the timing diagrams for the inte-
grator control circuitry in both of these modes of oper-
ation. The pulse shown as "C" is the interrogation command
from the computer, and C' is the corresponding 10 micro-
second clear pulse for the flip-flops.

Figure 23 shows the locations of all the input/output
terminals for the video threshold detector, integrator
control circuitry, and the pulse resettable integrators,
which are all mounted on a single 5 inch by 17 inch circuit
board. Figure 24 illustrates the component locations on
the same board.

The video threshold detector is a double unit. Either
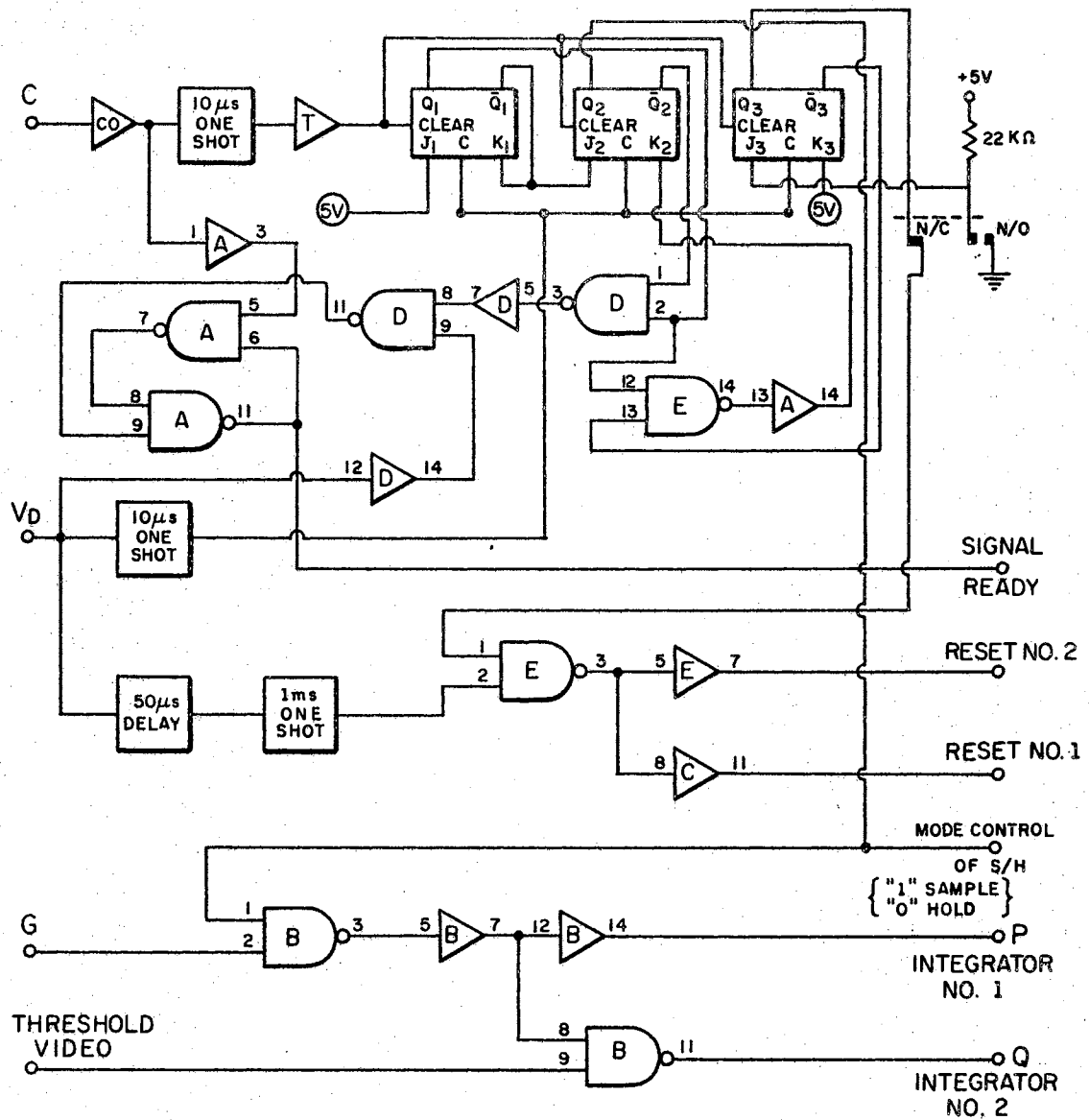
SWITCH POSITIONS:

UNOPERATED ⟹ DUAL FIELD SCANNING
OPERATED ⟹ SINGLE FIELD SCANNING

Figure 17. Integrator Control Circuitry
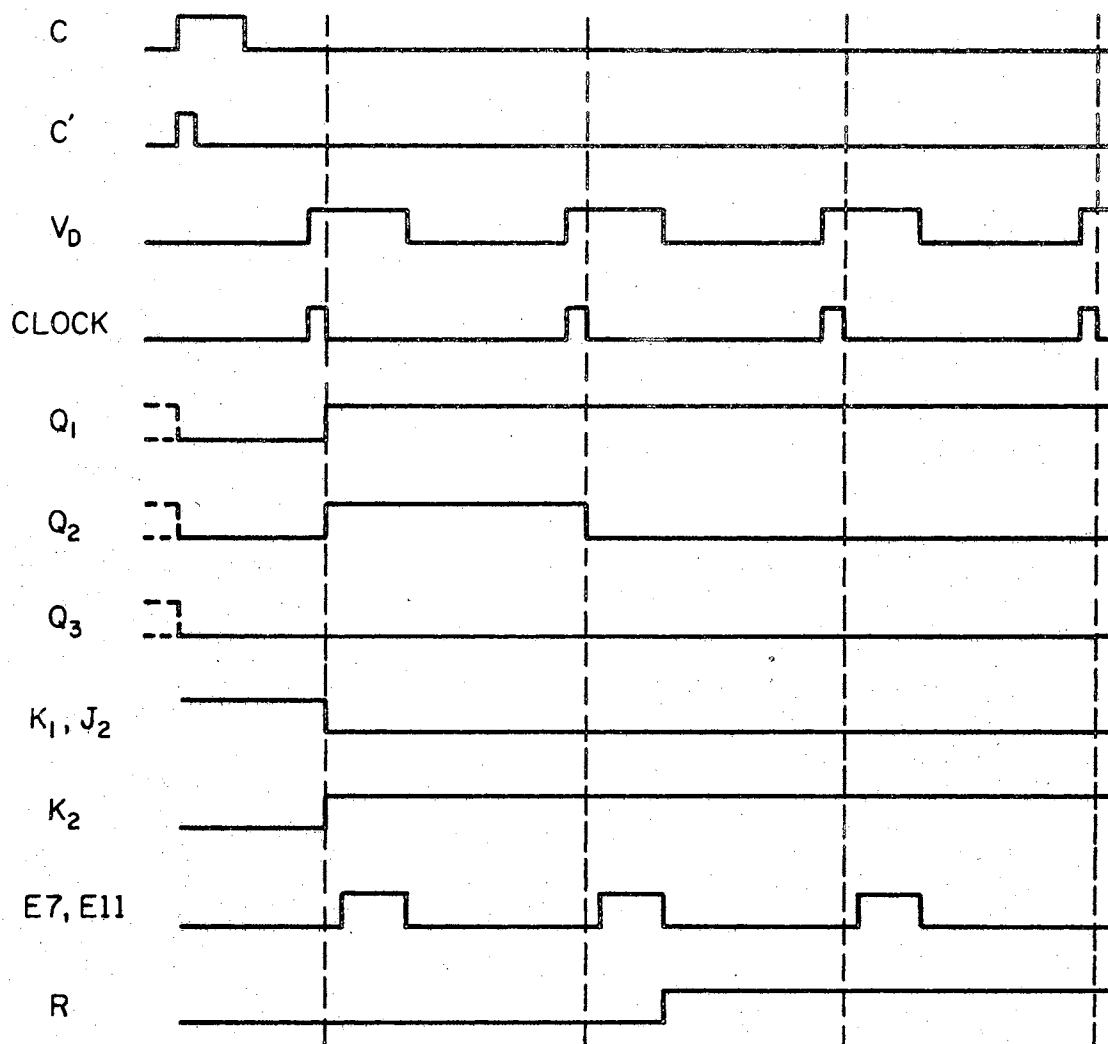
1. POSITIVE LOGIC CONVENTION

2. SWITCH IN OPERATED POSITION

$\Rightarrow J_1 = "1"$

$J_3 = "0"$

$K_3 = "1"$

3. TIME RELATIONSHIPS NOT DRAWN TO SCALE.

Figure 18.   Timing Sequence for Single Field Scanning
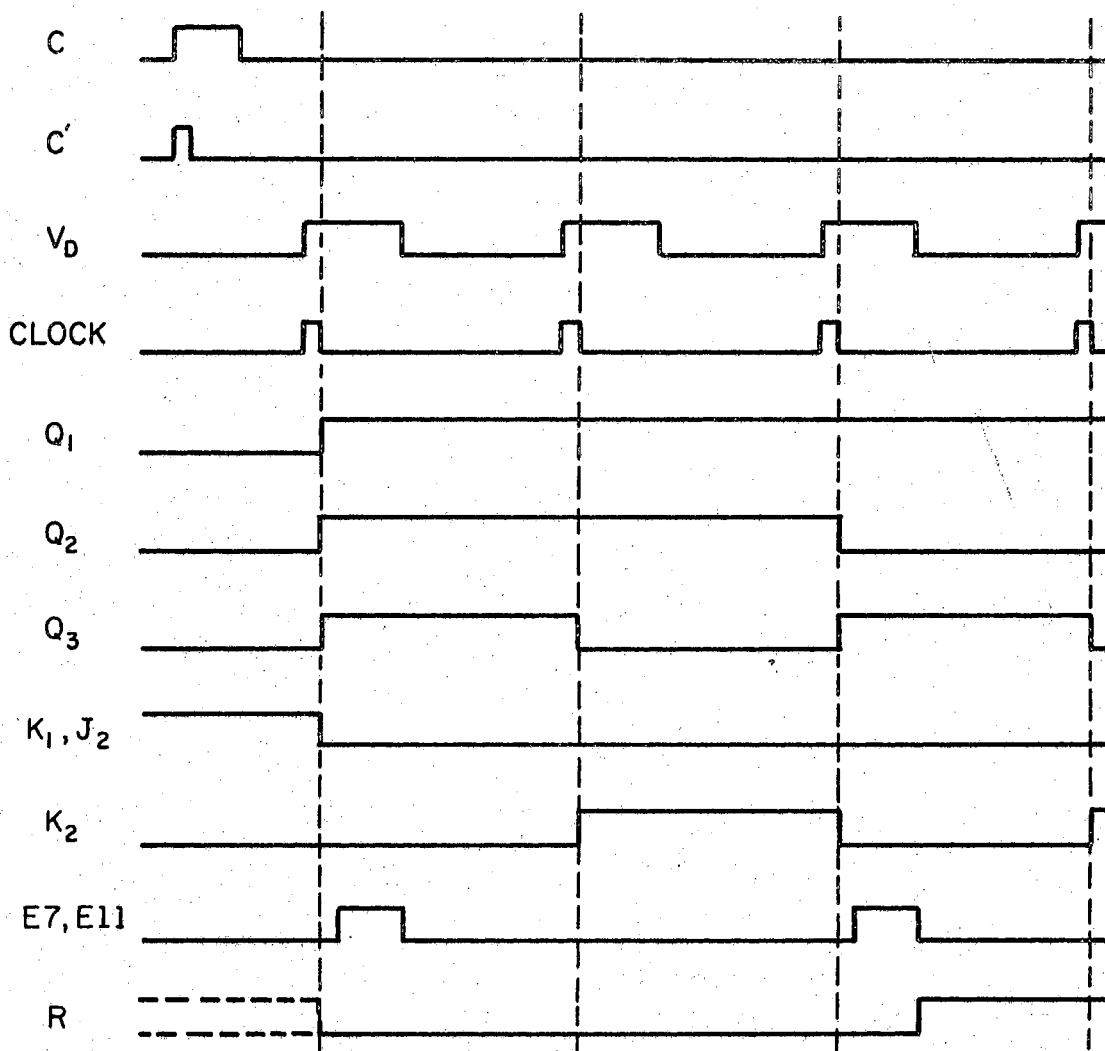
1. POSITIVE LOGIC CONVENTION

2. SWITCH IN UNOPERATED POSITION

$\Rightarrow J_1 = "1"$

$J_3 = "1"$

$K_3 = "1"$

3. TIME RELATIONSHIPS NOT DRAWN TO SCALE.

Figure 19. Timing Sequence for Dual Field Scanning
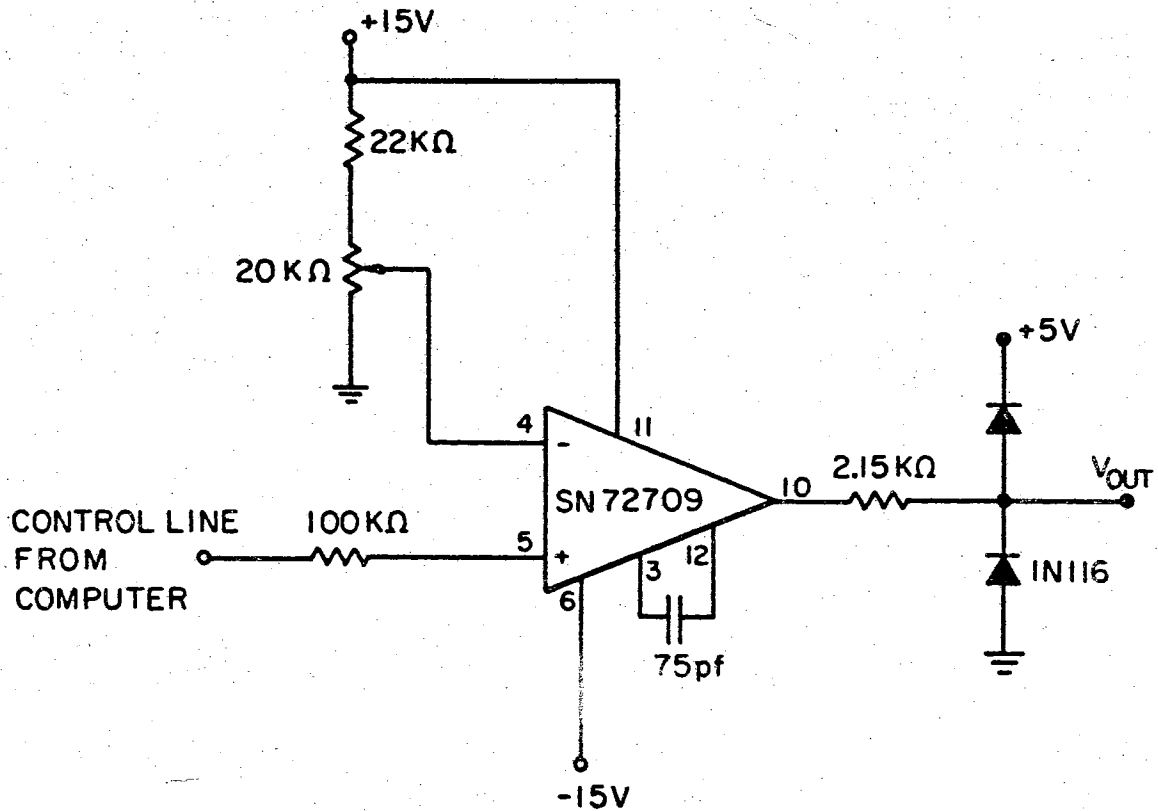
Figure 20.   Control Line Comparator
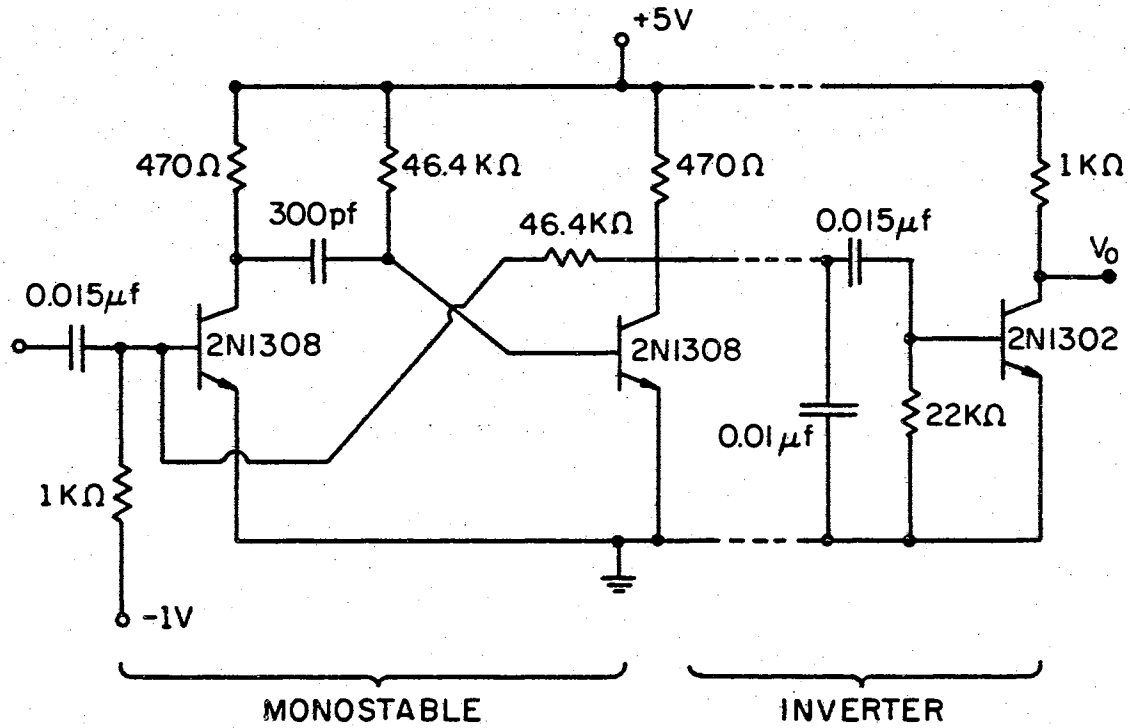
Figure 21.   Schematic of a 10 microsecond Monostable with Inverter
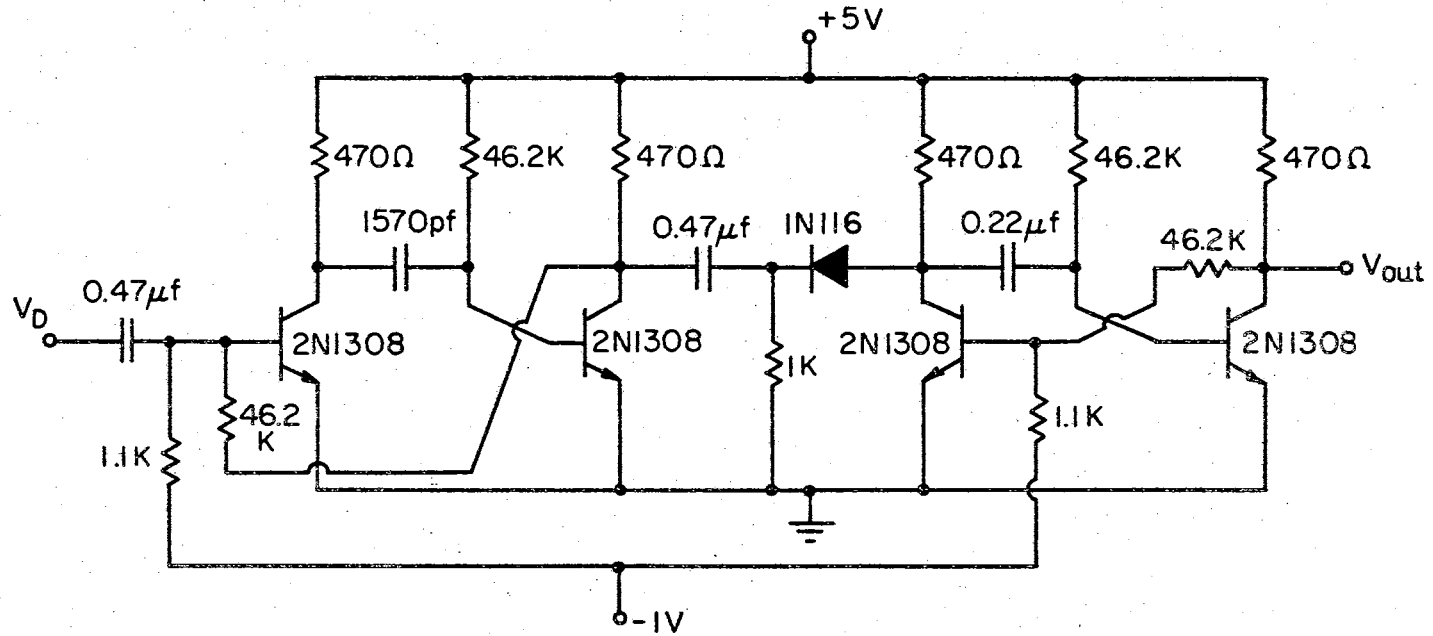
Figure 22.   Schematic of delayed Pulse Generator
              (50 microsecond delay, 1 millisecond pulse)

1. V_a Video Input #1

2. V_b Video Threshold #1

3. V_c Video Input #2

4. V_d Video Threshold #2

5. C (Control Line Comparator)

6. +15 V.

7. GND

8. -15 V.

9. V_D (Vertical Drive)

10. +5 V.

11. GND
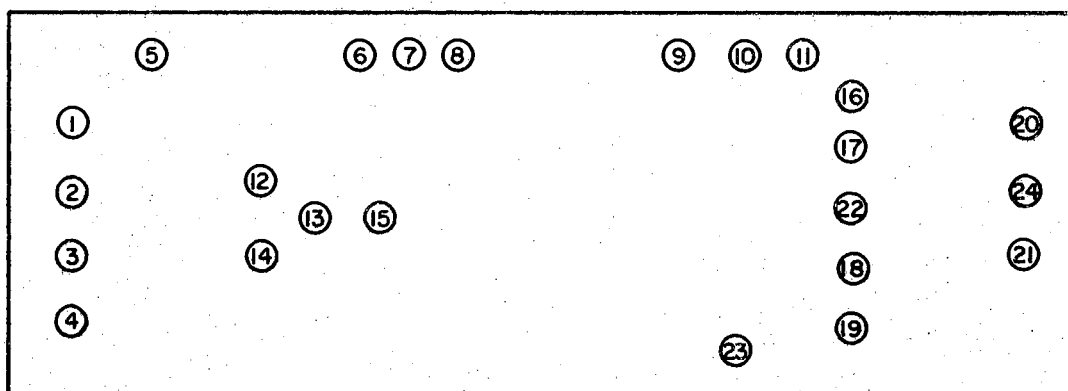
12. Output #1 or Strobe for Output #2

13. Output of (#1) and (#2)

14. Output #2 or Strobe for Output #1

15. Video Input to Logic

16. Reset #1

17. Integrator #1

18. Reset #2

19. Integrator #2

20. Sampled Output #1

21. Sampled Output #2

22. Mode Control of Sample and Hold Units

23. Gate Input

24. Ready Line Output

Figure 23. Plug Layout for the Integrator Control
Circuitry and Integrators
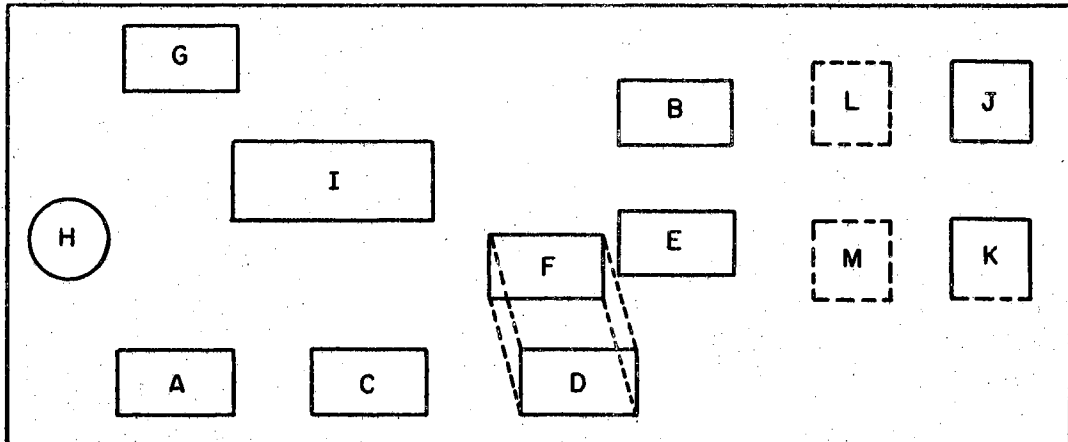
A. Quad 2 Input NAND Gates Westinghouse 6G222K

B. Quad 2 Input NAND Gates Westinghouse 6G222K

C. Dual J-K Flip-Flop (Q_3) TI SN7473N

D. Quad 2 Input NAND Gates Westinghouse 6G222K

E. Quad 2 Input NAND Gates Westinghouse 6G222K

F. Dual J-K Flip-Flop (Q_1 and Q_2) TI SN7473N

G. Differential Comparator (Op-Amp) TI SN72709N

H. Dual Differential Comparator MC 1711 CG

I. Various Monostable Multivibrators

J. Sample and Hold #1 Burr Brown 4034/25

K. Sample and Hold #2 Burr Brown 4034/25

L. Integrator #1

M. Integrator #2

Figure 24. Component Layout for the Integrator Control
Circuitry and Integrators

unit can be operated independently by taking the output from the strobe inputs. The total output is present only when both units yield outputs individually (for positive logic). The normal mode of operation (Figure 23) is for the video signal to be placed into plugs #1 and #3, with the video threshold voltage into plugs #2 and #4. Then plugs #13 and #15 are connected together. The video threshold detector is shown in Figure 25.

The two pulse resettable integrators are identical, and are shown in Figure 26. The Burr-Brown Sample/Hold Unit #4034/25 is used simply to store the values of P and Q until the computer is ready to accept these values.

The Gating Signal Generator block shown in Figure 16 is shown in greater detail in Figure 27. Figure 28 shows the details of the differential comparators used and Figure 29 shows the circuit-board plug locations (which refer to the numbers shown in Figure 27).

Figure 30 is a photograph of the television camera when in operation. Both the test image itself and its facsimile in the camera monitor are shown. The remainder of the Dage television gear is shown in Figure 31. The vertical electronics rack on the left side of the photograph in Figure 31 houses the D/A and A/D interfacing equipment for the IBM 1620 computer. Sitting on the top of the television control console, and to the left of the two television monitors, is the Video Signal Consolidator. The image interrogator circuitry is shown sitting on the shelf
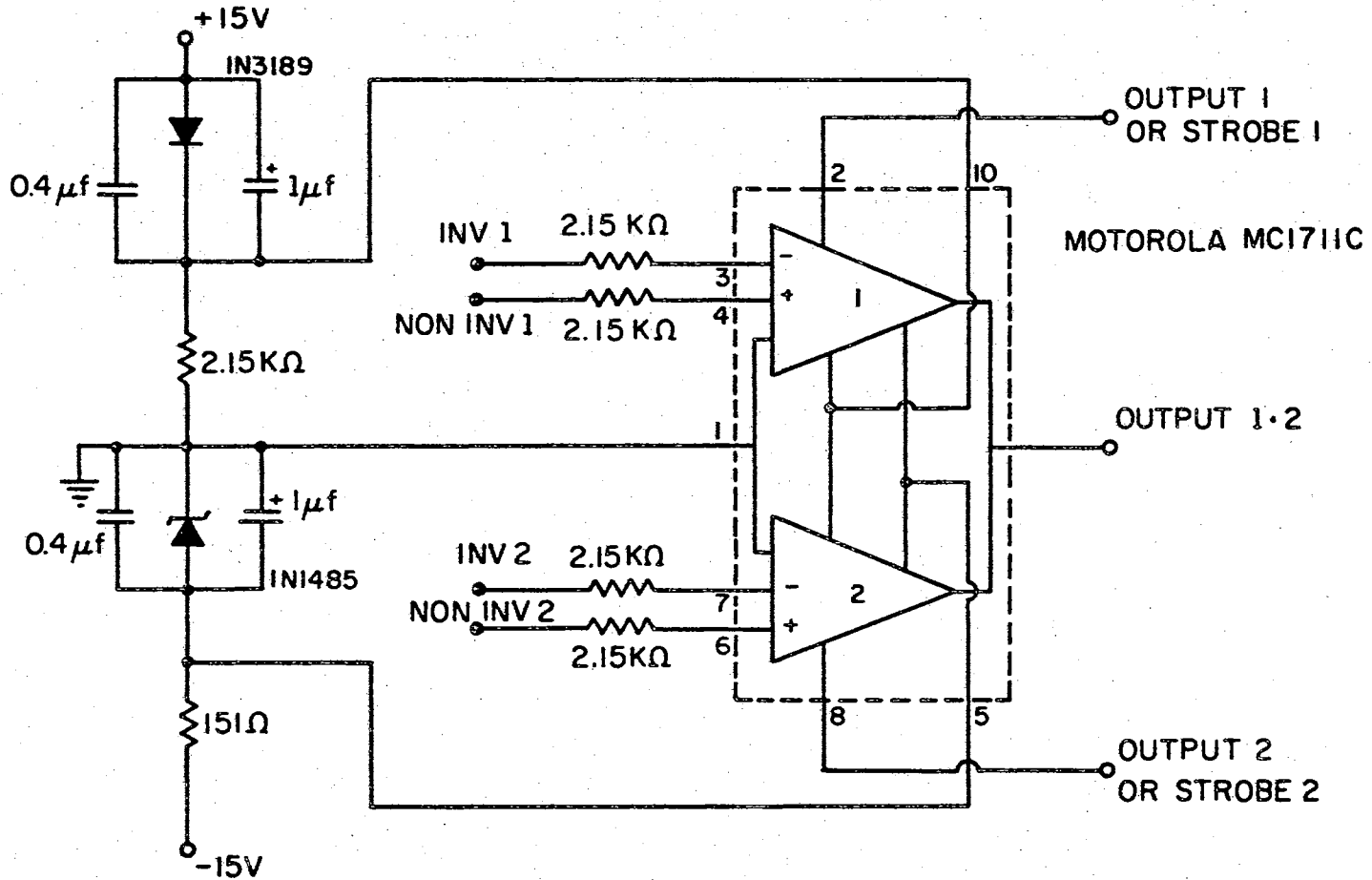
Figure 25. The Dual Differential Comparator
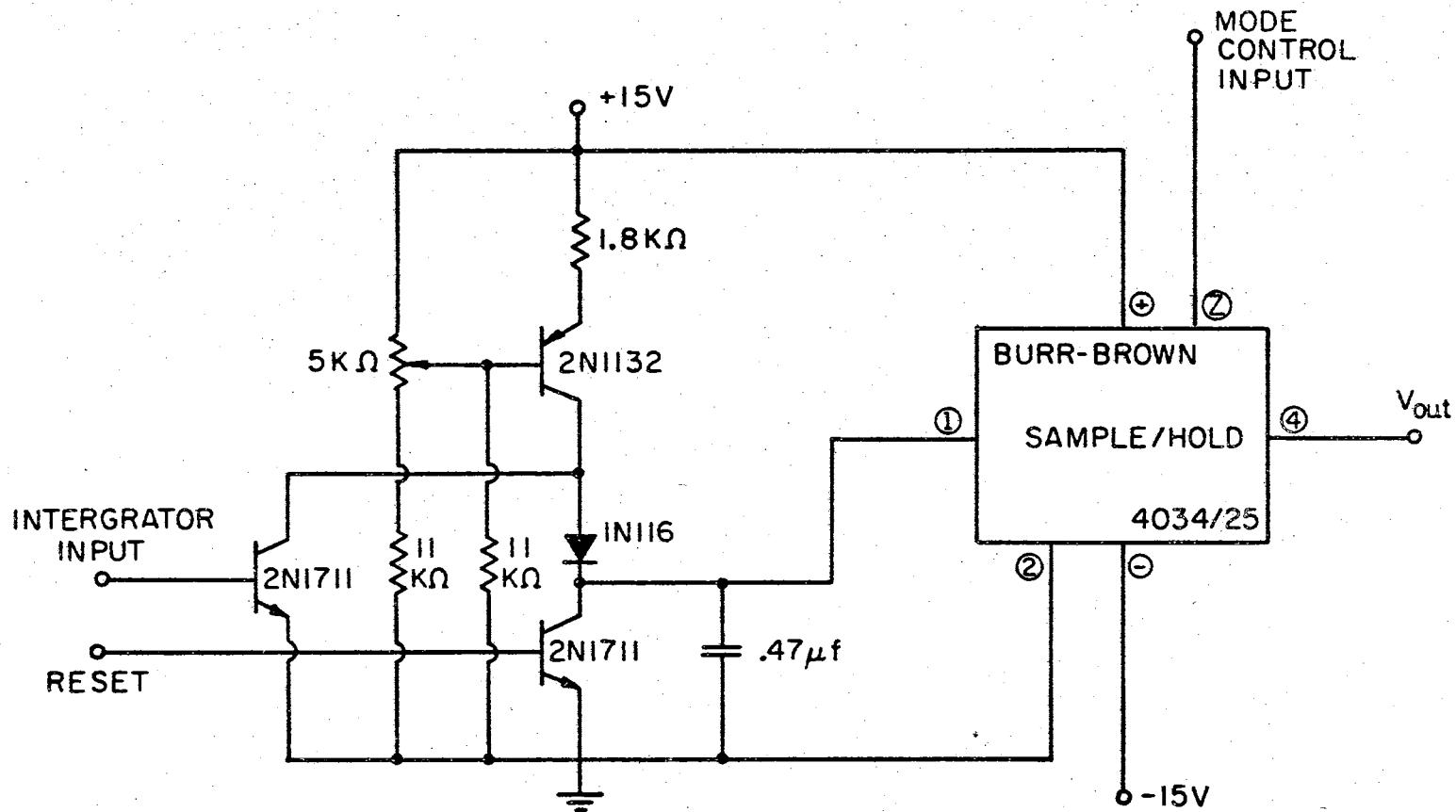
Figure 26. Pulse Resettable Integrator

C - DIFFERENTIAL COMPARATOR

I - LOGIC INVERTER

N - NAND GATES
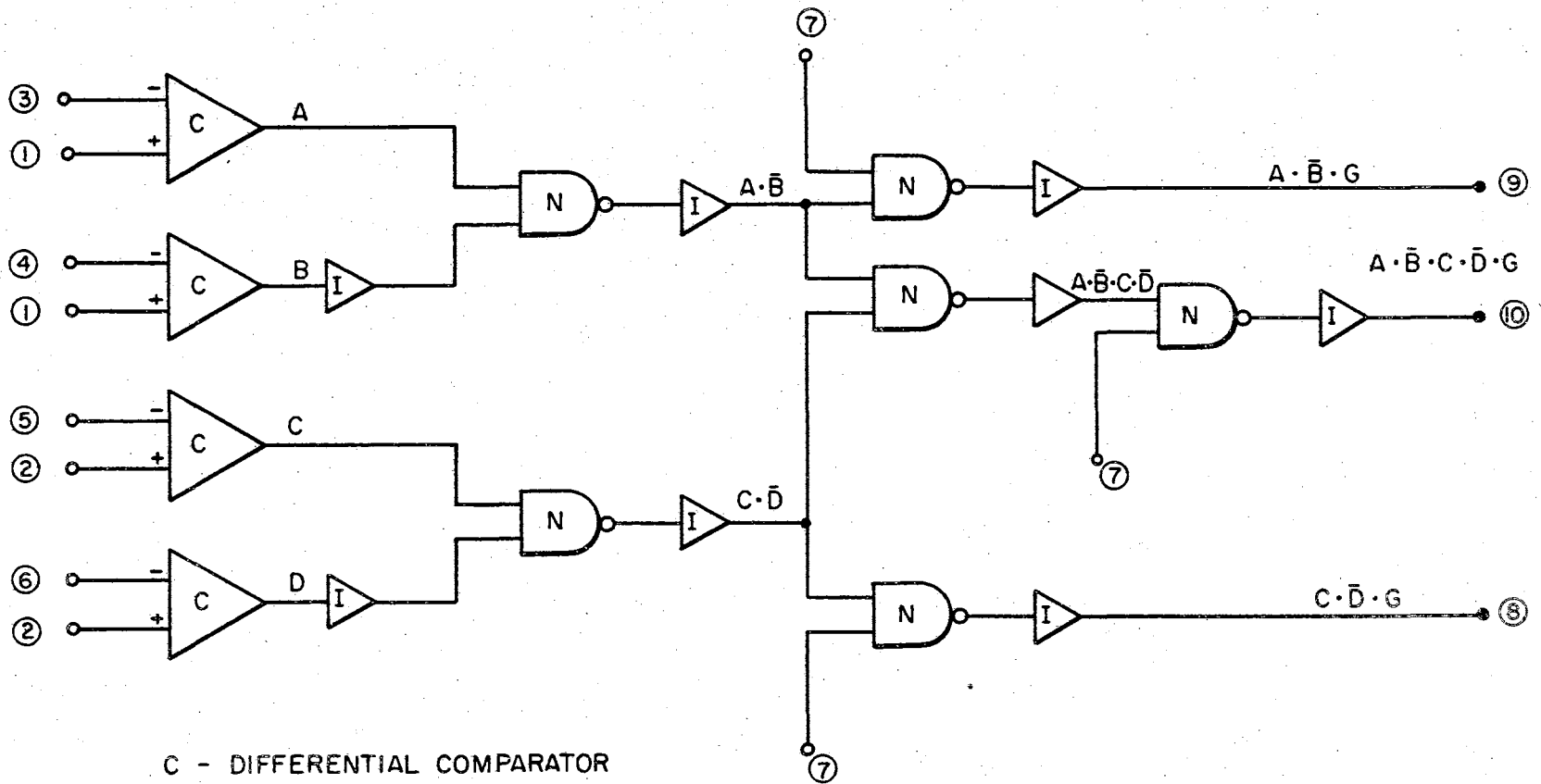
Figure 27. Gating Signal Generator
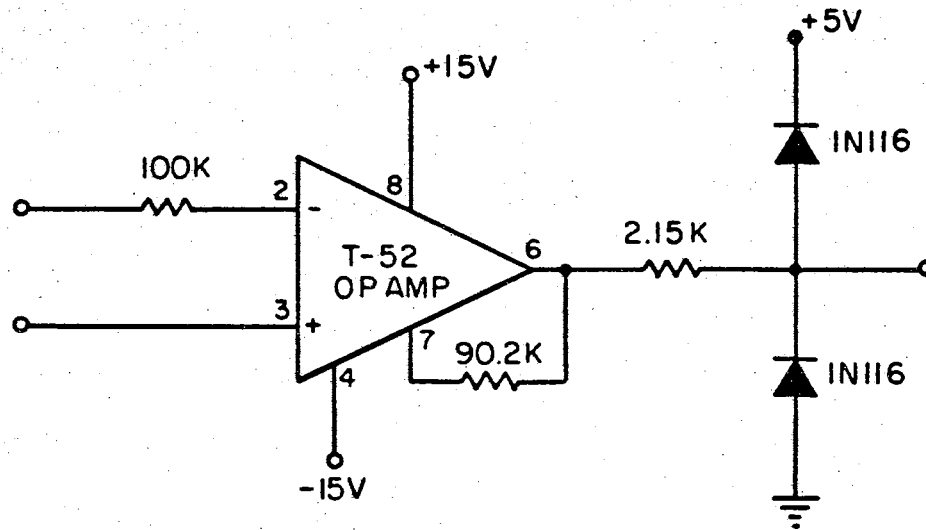
Figure 28. Comparator
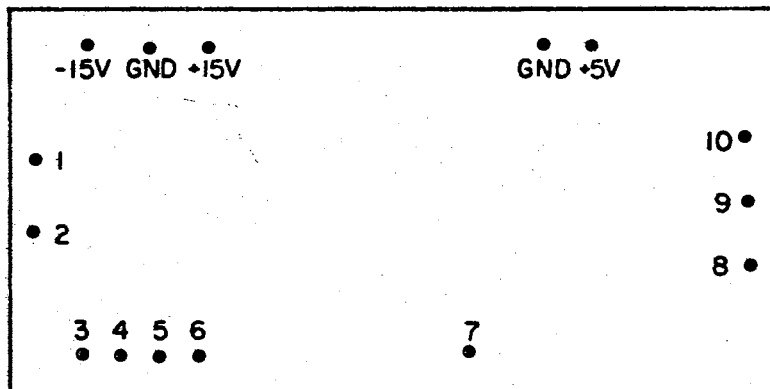
PIN IDENTIFICATION

1. V_x 7. V_z

2. V_y

3. V_3 ⎫ HORIZ. GATES
4. V_4 ⎭ $V_3 > V_4$

5. V_5 ⎫ VERT. GATES
6. V_6 ⎭ $V_5 > V_6$

8. ⎫
9. ⎬ GATED VIDEO OUTPUT
10. ⎭

Figure 29. Pin Locations for the Voltage Controllable Video Gating System
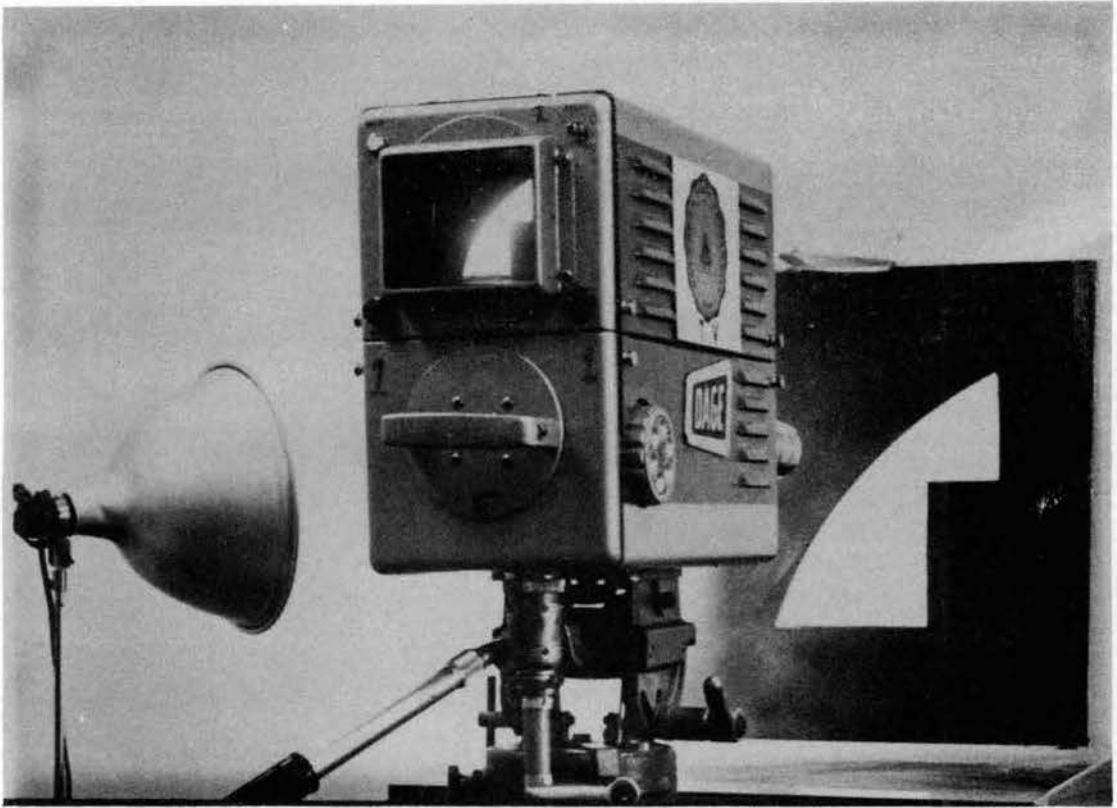
Figure 30. Television Camera and Test Image

of the control console.

The video information is transmitted from the equip-
ment shown in Figure 31 to the IBM 1620 digital computer.
This computer and its associated magnetic disc unit and
card reader/card punch unit are shown in Figure 32.

Figure 33 is a photograph of the image interrogator
and television control console. The equipment layout is
the same as described for Figure 31. A reproduction of the
test image is shown on the television monitors. The wave-
form shown on the oscilloscope screen is for one vertical
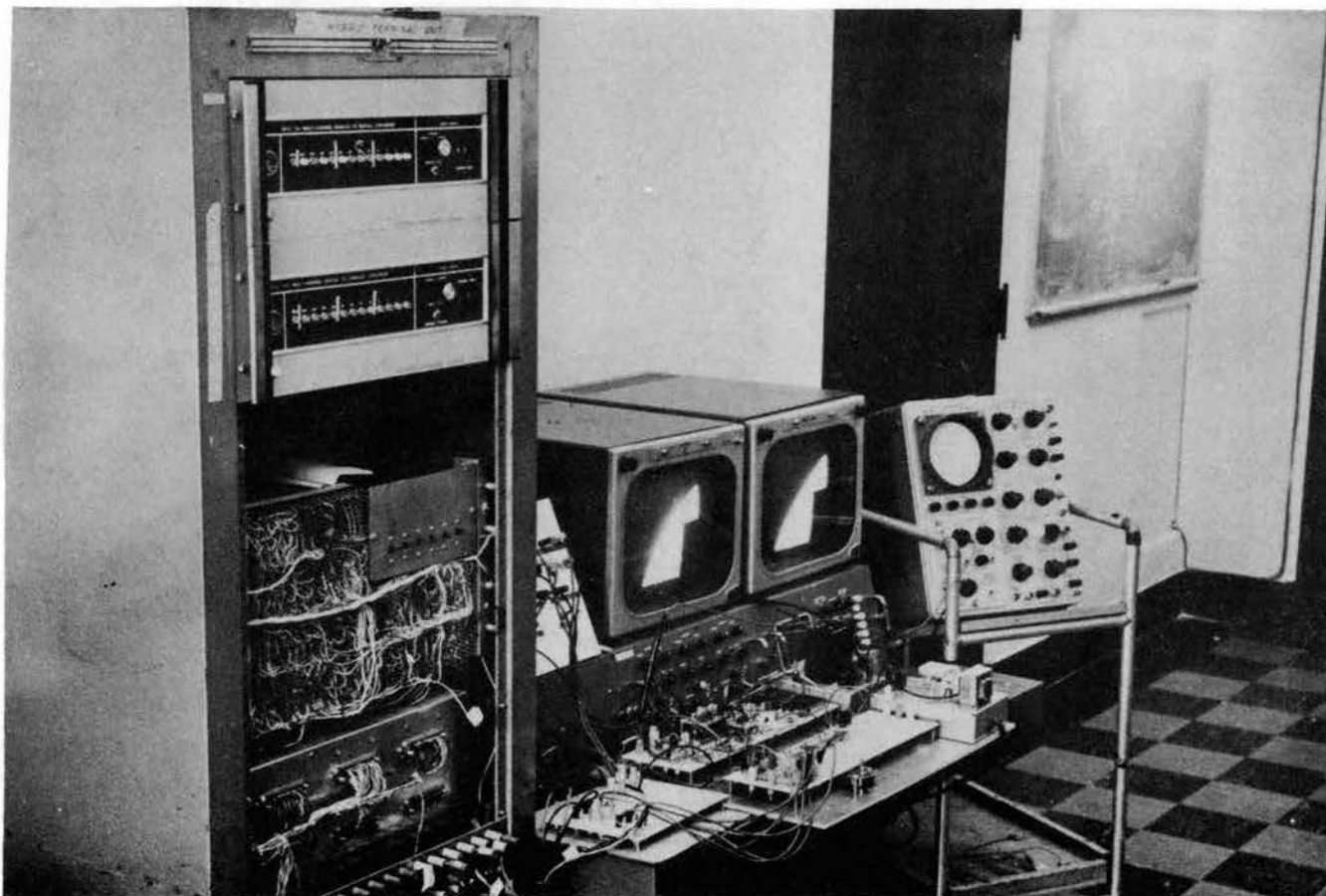
Figure 31.   The Television Control Console
and Computer Interfacing
Equipment

Figure 32.   The IBM 1620 Computer and its
Peripheral Equipment
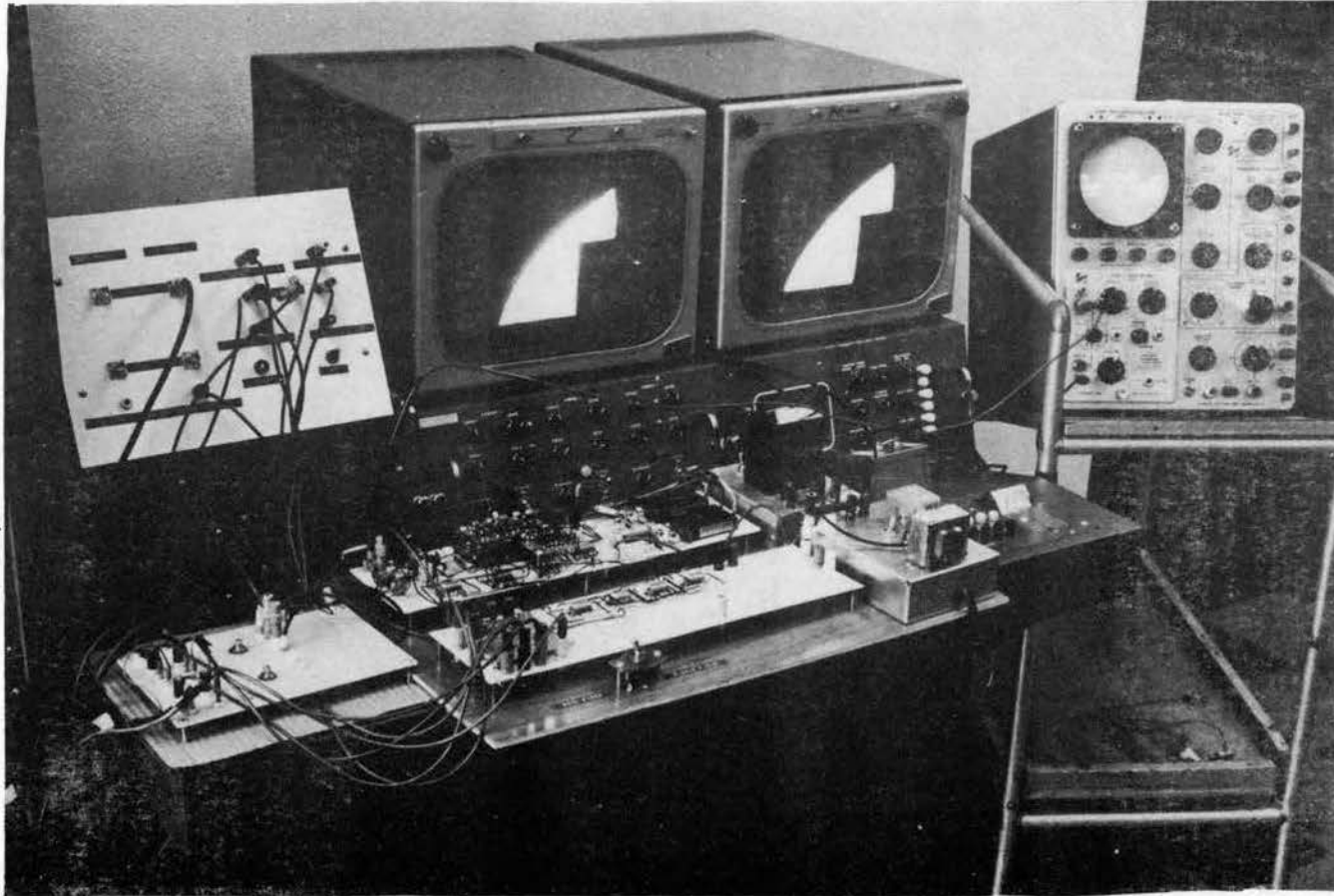
Figure 33. The Television Control Console
and the Image Interrogator

sweep period and shows the video waveform corresponding to test image shown in the monitors and Figure 30.

A more detailed view of the image interrogator is shown in Figure 34. The lower circuit assembly is the gating signal generator (Figures 27 and 29) and the upper circuit board contains the integrator control circuitry, pulse resettable integrators, and the sample-and-hold units (Figures 17, 23, and 24). The power supply shown in the upper left corner is the source of ±15 volts needed by the linear circuitry. The +5 volt power supply in the lower left corner is for the digital circuitry.
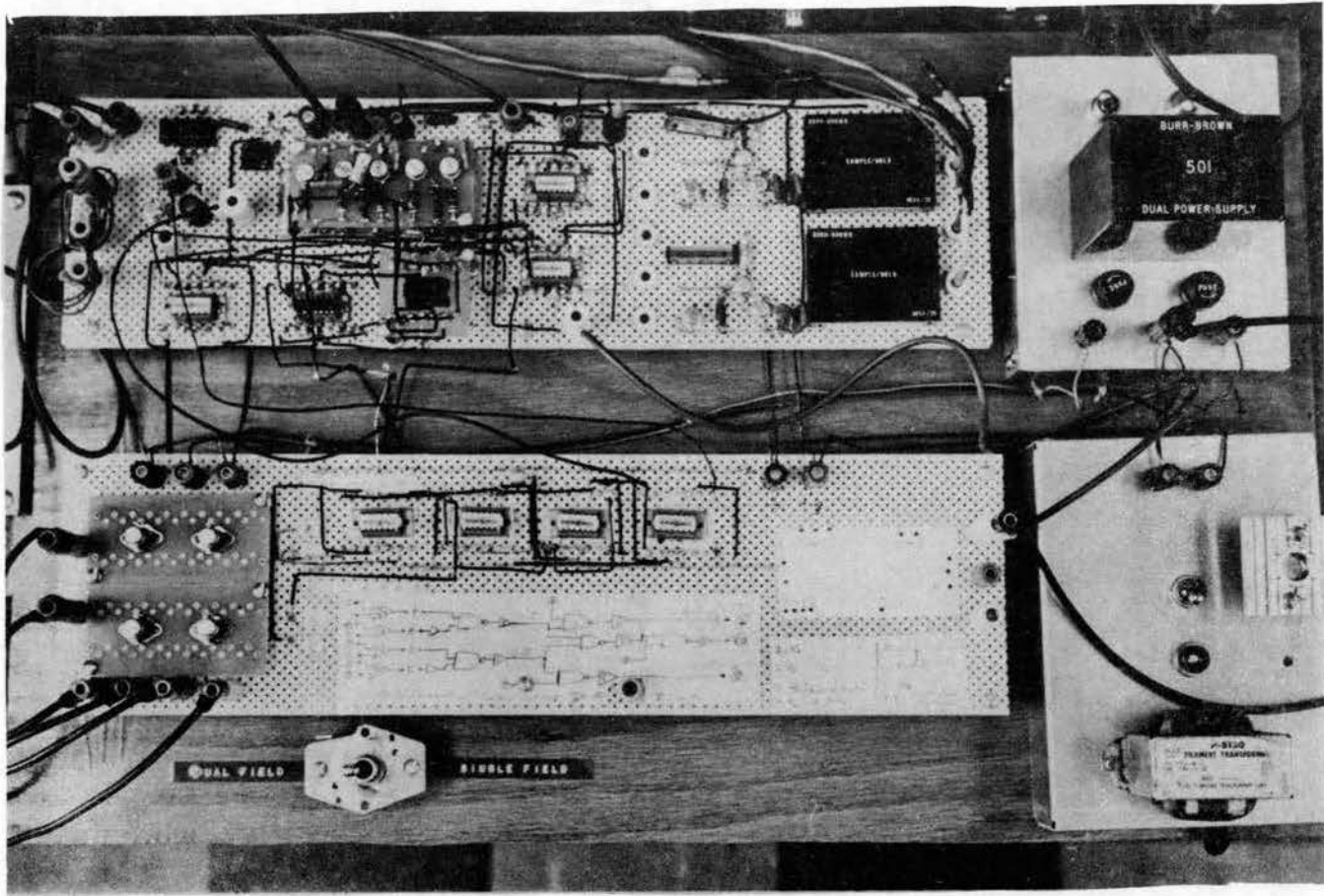
Figure 34.　The Image Interrogator and
Power Supplies

CHAPTER V

UTILIZATION OF TELEVISION SIGNALS AS A
COMPUTER INPUT

The physical equipment described in Chapter IV does
not make any distinctions between different applications of
a video input to the digital computer. The real differen-
tiation of equipment application is based upon the soft-
ware of the digital computer. There is, though, a certain
set of basic software capabilities which need to be avail-
able in order to "read" in the information content of the
video image. This chapter describes the programs and sub-
routines which were developed in order to control the op-
tical interrogator and convert the image data into a
usable (to the computer) format. In order to test the cap-
abilities of the equipment, the stored image data was used
to generate a two level (black or white) reproduction of
the test image. Several examples will be given.

The main programs were written in Fortran II-D. All
of the subroutines were written in an assembly language, in
this case, SPS II-D (A Symbolic Programming System). There
are two distinct advantages to the use of SPS subroutines,
the first being that the core (computer memory) require-
ments are much less than would be necessary for the compar-
able Fortran subroutine. The second advantage of the SPS

66

subroutines is that if great care is taken, then the speed
of execution is minimal. It was the need of fast operation
that made it mandatory to use the SPS subroutines "PULSE5"
and "WINDOW", even though the same operations could have
been accomplished with the normally available subroutine
"PUTDAI(n,I)" (see Appendix A).

The SPS subroutine, PULSE5, is shown in Table V. When
a Fortran statement

<p align="center">CALL PULSE5</p>

is encountered, a 5 volt pulse of approximately 100 micro-
seconds duration is given through D/A channel number five.
The machine commands which set the output to five volts and
then back to zero volts occur in consecutive machine
instructions, which means that this is the shortest dura-
tion pulse attainable with this hardware.

In order to establish the dimensions of the scanning
aperture, or window, the following Fortran Statements are
required.

```
CALL PUTDAI(1,IL)
CALL PUTDAI(2,IR)
CALL PUTDAI(3,IT)
CALL PUTDAI(4,IB)
```

The variables IL, IR, IT, and IB determine, respectively,
the left, right, top, and bottom edges of the aperture
window. Unfortunately, the execution time for the above
series of statements is sufficiently long that the edges
of the window try to "drift away" (decaying of the voltage
of the output sample-and-hold amplifiers).

TABLE V

SPS SUBROUTINE "PULSE5"

```
‡‡JOB

‡‡SPSX

* LIST TYPEWRITER
* NAME PULSE5
* ASSEMBLE RELOCATABLE
* STORE RELOADABLE
*   ID NUMBER 0266

      S       DS    0,*+101                 00100 00000
              DC    6,987898,5-S            00095 00006 987898
              DAC   6,PULSE5,7-S            00093 00012
              DVLC  22-S,5,LAST,2,08,2,04,5,PULSE5-6,5,0,30,0
                 00078 00049 000740804000000000000000000000000000000000000000000000
              DSC   17,0,0                  00000 00017 00000000000000000
              DORG  S-100                   00000
              DC    5,000                   00004 00005 00000
   PULSE5 AM       PULSE5-1,1    ,10        00006 11 00005 00001
              WN    FIVE,5000,,,            00018 38 00070 05000
              WN     ZERO,5000,,,,          00030 38 00066 05000
              BI     *+12,00700             00042 46 00054 00700
              B      PULSE5-1,,6            00054 49 00005 00000
   ZERO    DSC   4,-00@                     00066 00004 000‡
   FIVE    DSC   4,N00@                     00070 00004 500‡
   LAST    DC    1,@                        00074 00001 ‡
              DEND                          00000

END OF ASSEMBLY.
00076 CORE POSITIONS REQUIRED PLUS RELOCATION INCREMENT
00016 STATEMENTS PROCESSED


DK LOADED PULSE5 0266 107397003599990000‡
EXECUTION
```

A single SPS subroutine was written to perform the operations done by the previously given four Fortran statements. In order to speed the execution of the subroutine the argurment, (IL, IR, IT, IB), is not transmitted to the subroutine, but rather is stored in COMMON. The following statement is required

COMMON IDUM,IB,IT,IR,IL   .

Therefore, the only statement needed to establish the scanning aperture is

CALL WINDOW   .

A listing of the subroutine WINDOW is given in Table VI.

The SPS subroutine PEEK reads the values at the sample and hold units through A/D channels 2 and 3 and performs a significance test to see whether to call the test area black or white. The first time the subroutine is called in a program, it "asks" for the significance value. This value will be between zero and one and is the fractional portion of the window area that must be white in order for the area to be "labeled" as white. If sense switch 1 is off, then a black area will be denoted by a "1" and a white area by a "0". If sense switch 1 is turned on, the "1" will denote a white area and a "0" a black area. The output of the subroutine PEEK is found in the core locations corresponding sixth integer in COMMON, for example, IC if

COMMON IDUM,IB,IT,IR,IL,IC

TABLE VI

SPS SUBROUTINE "WINDOW"

```
‡‡SPS

* LIST TYPEWRITER
* NAME WINDOW
* ASSEMBLE RELOCATABLE
* STORE RELOADABLE
* ID NUMBER 0260


        S       DS      0,*+101                  00100 00000
                DC      6,987898,5-S             00095 00006 987898
                DAC     6,WINDOW,7-S             00093 00012
                DVLC    22-S,5,LAST,2,08,2,04,5,WINDOW-6,5,0,30,0
                    00078 00049 00174080400000000000000000000000000000000000000000000
                DSC     17,0,0                   00000 00017 00000000000000000
                DORG    S-100                    00000
                DC      5,0                      00004 00005 00000
        WINDOW  AM      WINDOW-1,1               00006 11 00005 00001
                TDM     19996,0                  00018 15 19996 00000
                DC      1,@,*                    00029 00001 ‡
                TR      BUFF,19981               00030 31 00157 19981
                SF      BUFF                     00042 32 00157 00000
                SF      BUFF+4                   00054 32 00161 00000
                SF      BUFF+8                   00066 32 00165 00000
                SF      BUFF+12                  00078 32 00169 00000
                WN      BUFF,1000                00090 38 00157 01000
                WN      BUFF+4,2000              00102 38 00161 02000
                WN      BUFF+8,3000              00114 38 00165 03000
                WN      BUFF+12,4000             00126 38 00169 04000
                BI      *+12,700                 00138 46 00150 00700
                B7      WINDOW-1,,6              00150 49 00005 00000
        BUFF    DSC     16,0                     00157 00016 0000000000000000
                DC      1,@                      00173 00001 ‡
        LAST    DC      1,@                      00174 00001 ‡
                DEND                             00000

END OF ASSEMBLY.
00176 CORE POSITIONS REQUIRED PLUS RELOCATION INCREMENT
00025 STATEMENTS PROCESSED


DK LOADED WINDOW 0260 10897400459999900000‡
```

is the COMMON statement of the main program. A listing of
this subroutine is given in Table VII.

The image data is "packed" by the main program so that
a 60 x 60 grid array is stored in a 15 x 60 integer array.
In order to use this output, the SPS subroutine UNPACK is
employed. It converts fifteen integer numbers into the
appropriate sixty integers. Therefore,

$$ABCD, \ EFGH, \ IJKL, \ . \ . \ .$$

Would become

$$D,C,B,A,H,G,F,E,L,K,J,I, \ . \ . \ . \ \ \ .$$

Table VIII is a listing of the subroutine UNPACK.

The actual testing of the complete system was perform-
ed with the program shown in Table IX. This program scans
the television image with a non-overlapping series of
"windows". The data is given by a punched deck which re-
produces the output of each of the 3600 image elements (in
a 60 x 60 array). In place of the "1" or "0" that the sub-
routine UNPACK initially obtains, the computer operator has
the option of any alphanumeric character instead of a "1"
and a blank instead of a "0". This is determined just
prior to each scanning of a test image.

The total time needed to scan an image in the dual
frame mode is twelve minutes and forty seconds and the
total computer run time including punching the output deck
is fourteen minutes and ten seconds. By operating in the

TABLE VII

SPS SUBROUTINE "PEEK"

---

‡‡SPS

* LIST TYPEWRITER
* ASSEMBLE RELOCATABLE
* STORE RELOADABLE
* NAME PEEK
* ID NUMBER 0261

```
         S      DS      *+101                   00100 00000
                DC      6,987898,5-S            00095 00006 987898
                DAC     6,PEEK  ,7-S            00093 00012
                DVLC    22-S,5,LAST,2,08,2,04,5,PEEK-6,5,0,30,0
                    00078 00049 00386080400000000000000000000000000000000000000
                DSC     17,0,0                  00000 00017 00000000000000000
                DORG    S-100                   00000
                DS      5                       00004 00005
         PEEK   AM      PEEK-1,1                00006 11 00005 00001
                RN      P-2,02000               00018 36 00372 02000
                RN      Q-2,03000               00030 36 00376 03000
                LD      00096,Q                 00042 28 00096 00378
                D       00094,P                 00054 29 00094 00374
                SF      00094                   00066 32 00094 00000
                CM      19979,5,8               00078 14 19979 00005
                BNP     GOGO                    00090 47 00174 01100
                RCTY                            00102 34 00000 00102
                WATY    ESLP                    00114 39 00315 00100
                RNTY    10                      00126 36 00380 00100
                SF      10                      00138 32 00380 00000
                TF      A+11,10+2               00150 26 00197 00382
                TF      SEVEN+11,10+2           00162 26 00261 00382
         GOGO   BNC1    SEVEN                   00174 47 00250 00100
         A      CM      00096,500,9             00186 14 00096 00500
                BNN     TWELVE                  00198 46 00230 01300
                TFM     19979,0,8               00210 16 19979 00000
                B7      EIGHT                   00222 49 00306 00000
         TWELVE TFM     19979,1,8               00230 16 19979 00001
                B7      EIGHT                   00242 49 00306 00000
         SEVEN  CM      00096,500,9             00250 14 00096 00500
                BNN     SIX                     00262 46 00294 01300
                TFM     19979,1,8               00274 16 19979 00001
                B7      EIGHT                   00286 49 00306 00000
         SIX    TFM     19979,0,8               00294 16 19979 00000
         EIGHT  B7      PEEK-1,,6               00306 49 00005 00000
         ESLP   DAC     29,ENTER SIGNIFICANCE LEVEL = .@    00315 00058
         P      DS      3                       00374 00003
                DS      1                       00375 00001
         Q      DS      3                       00378 00003
                DS      1                       00379 00001
         10     DSS     6                       00380 00006
         LAST   DC      1,@                     00386 00001 ‡
                DEND                            00000
```

END OF ASSEMBLY.
00388 CORE POSITIONS REQUIRED PLUS RELOCATION INCREMENT
00042 STATEMENTS PROCESSED

DK LOADED PEEK   0261 109588007599990000‡

TABLE VIII

SPS SUBROUTINE "UNPACK"

---

‡‡SPS

```
* LIST TYPEWRITER
* ASSEMBLE RELOCATABLE
* STORE RELOADABLE
* NAME UNPACK
* ID NUMBER 0262


      S       DS      ,*+101              00100 00000
              DC      6,987898,5-S        00095 00006 987898
              DAC     6,UNPACK,7-S        00093 00012
              DVLC    22-S,5,LAST,2,08,2,04,5,UNPACK-6,5,0,30,0
                00078 00049 0015008040000000000000000000000000000000000000000000
              DSC     17,0,0              00000 00017 00000000000000000
              DORG    S-100               00000
              DS      5                   00004 00005
      UNPACK  AM      UNPACK-1,1          00006 11 00005 00001
              TF      BUFF,IC             00018 26 00148 19979
              CF      BUFF-3              00030 33 00145 00000
              TFM     IT,0,8              00042 16 19995 00000
              TFM     IB,0,8              00054 16 19991 00000
              TFM     IL,0,8              00066 16 19987 00000
              TFM     IR,0,8              00078 16 19983 00000
              TD      IT,BUFF             00090 25 19995 00148
              TD      IB,BUFF-1           00102 25 19991 00147
              TD      IL,BUFF-2           00114 25 19987 00146
              TD      IR,BUFF-3           00126 25 19983 00145
              B7      UNPACK-1,,6         00138 49 00005 00000
      BUFF    DS      4                   00148 00004
      IT      DS      ,19995              19995 00000
      IB      DS      ,19991              19991 00000
      IL      DS      ,19987              19987 00000
      IR      DS      ,19983              19983 00000
      IC      DS      ,19979              19979 00000
              DC      1,@                 00149 00001 ‡
      LAST    DC      1,@                 00150 00001 ‡
              DEND                        00000

END OF ASSEMBLY.
00152 CORE POSITIONS REQUIRED PLUS RELOCATION INCREMENT
00028 STATEMENTS PROCESSED


DK LOADED UNPACK 0262 1091960049999900000‡
```

TABLE IX

FORTRAN PROGRAM IMAGE SCAN CONTROL

```
‡‡JOB

‡‡FORX

C     THIS PROGRAM CONTROLS THE OPTICAL INTERROGATOR AND
C     AND THEREBY SCANS THE IMAGE, GIVING AN OUTPUT GRID
C     OF THE SIZE 60X60.
      DIMENSION  IQ(15,60),LINE(60)
      COMMON IDUM,IB,IT,IR,IL,IC
    9 PAUSE
      PRINT 44
   44 FORMAT(26HENTER DISPLAY CHAR. (A1)
      ACCEPT    45,IALFA
   45 FORMAT(A1)
      IC=999
      DO 8 J=1,53
      IL=999-30*J
      IR=999-30*(J-1)
      DO 8 L =1,15
      DO 8 I=1,4
      IT=30*(4*(L-1)+I-1) -801
      IB=30*(4*(L-1)+I) -801
      CALL WINDOW
      CALL WINDOW
      CALL PULSE5
      CALL WINDOW
    1 CALL GETADF(4,R)
      CALL WINDOW
      IF(R-50.0) 1,1,2
    2 CALL PEEK
      IF(I-1)     50,50,51
   50 IQ(L,J)=IC
      GO TO 8
   51 IF(I-2)     52,52,53
   52 IQ(L,J)=IQ(L,J)+10*IC
      GO TO 8
   53 IF(I-3)     54,54,55
   54 IQ(L,J)=IQ(L,J)+100*IC
      GO TO 8
   55 IQ(L,J)=IQ(L,J)+1000*IC
    8 CONTINUE
      DO 20 J=1,53
      DO 30 L=1,15
      IC=IQ(L,J)
      K=4*(L-1)
      CALL UNPACK
      LINE(K+1)    =IB*IALFA
      LINE(K+2)=IT*IALFA
      LINE(K+3)=IR*IALFA
   30 LINE(K+4)=IL*IALFA
      PUNCH  35,(LINE(II),II=1,60)
   35 FORMAT(60A1)
   20 CONTINUE
      PUNCH 91
   91 FORMAT(1H //////)
      GO TO 9
      END

06536 CORES USED
19975 NEXT COMMON
END OF COMPILATION
EXECUTION
```

single frame scanning mode there is a time reduction of seventy seconds.

As an example of the types of signal processing that can be performed on the resultant output data, a program for reducing the random noise (errors) in the output data was written. The program inspects each image element location in the 60 x 60 array and tests each adjacent (left, right, above, and below) image element. If an image element location contains a character, but all the adjacent locations are empty, then the lone image character will be suppressed. If, on the other hand, a blank element is found which has image characters in all of its adjacent locations, then the blank element is given an image character. A listing of this program is found in Table X.

Figure 35 shows one of the test images which was employed. The raw data output obtained is shown in Figure 36. After the raw data was processed by the noise reduction program, the new data showed an improvement as can be seen by comparing Figures 36 and 37.

A pattern containing only two levels of intensity is relatively easy to handle. In fact, this type of problem can be handled with very little thought as to what intensity level the video threshold detector should be set. By observing the video waveform on an oscilloscope the voltage levels corresponding to the two intensity levels is obvious.

A much more difficult problem is encountered when there is a continuous grading in intensity levels. Either

TABLE X

FORTRAN PROGRAM FOR NOISE SUPPRESSION

```
‡‡JOB

‡‡FORX

C     THIS PROGRAM IS TO PROCESS DATA CONSISTING OF ALPHANUMERIC
C     CHARACTERS IN A 60X60 GRID FORMING A 2-D PATTERN, TENDING
C     TO SUPPRESS RANDOM NOISE IN THE DATA
      DIMENSION    LLINE(60),LINE(60),NLINE(60)
   60 PAUSE
      READ 1, LLINE
      READ 1,  LINE
      READ 1, NLINE
    1 FORMAT(60A1)
      IF(LLINE(2))    2,3,2
    3 IF(LINE(1))    2,4,2
    4 LLINE(1)=0
    2 IF(LLINE(59))    50,51,50
   51 IF(LINE(60))    50,52,50
   52 LLINE(60)=0
   50 DO 6    I=2,59
      IF(LLINE(I-1))    6,5,6
    5 IF(LLINE(I+1))    6,7,6
    7 IF(LINE(I))    6,8,6
    8 LLINE(I)=0
    6 CONTINUE
    9 PUNCH 1,  LLINE
      DO 27    I=2,59
      IF(LLINE(1))    13,14,13
   14 IF(NLINE(1))    13,15,13
   15 IF(LINE(2))    13,16,13
   16 LINE(1)=0
   13 DO 18    J=2,59
      IF(LLINE(J))    40,41,40
   40 IF(NLINE(J))    42,41,42
   42 IF(LINE(J-1))    43,41,43
   43 IF(LINE(J+1))    44,41,44
   44 LINE(J)=LLINE(J)
   41 CONTINUE
```

TABLE X (Continued)

```
      IF(LINE(J-1))     18,17,18
17 IF(LINE(J+1))     18,19,18
19 IF(LLINE(J))     18,20,18
20 IF(NLINE(J))     18,21,18
21 LINE(J)=0
18 CONTINUE
      IF(LINE(59))     22,23,22
23 IF(LLINE(60))     22,24,22
24 IF(NLINE(60))     22,25,22
25 LINE(60)=0
22 PUNCH 1,     LINE
      DO 26     K=1,60
      LLINE(K)=LINE(K)
26 LINE(K)= NLINE(K)
      IF(I-59)     28,27,28
28 READ 1,   NLINE
27 CONTINUE
      IF(LLINE(1))     29,30,29
30 IF(LINE(2))     29,31,29
31 LINE(1)=0
29 IF(LINE(59))     32,33,32
33 IF(LLINE(60))     32,34,32
34 LINE(60)=0
32 PUNCH 1, LINE
      GO TO 60
      END

03912 CORES USED
T9999 NEXT COMMON
END OF COMPILATION
EXECUTION
```
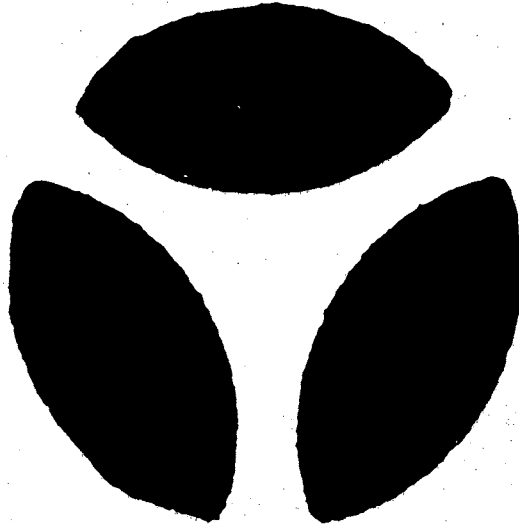
Figure 35.   A Two Intensity Level Test Image

multiple scans with different threshold levels for each
scan is required, or a compromise in image data acquisi-
tion.

Figures 38, 39, 40, 41, and 42 are indicative of the
results when a single threshold level is chosen for each
test image.   The test photographs show a variety of back-
ground lighting conditions and facial contrast areas.   It
is informative to note that in spite of the drastic infor-
mation content reduction, that the main characteristics of
the faces (for identification purposes) were still evident.

After observing the results obtained with various
parameter settings it was found that the "significance

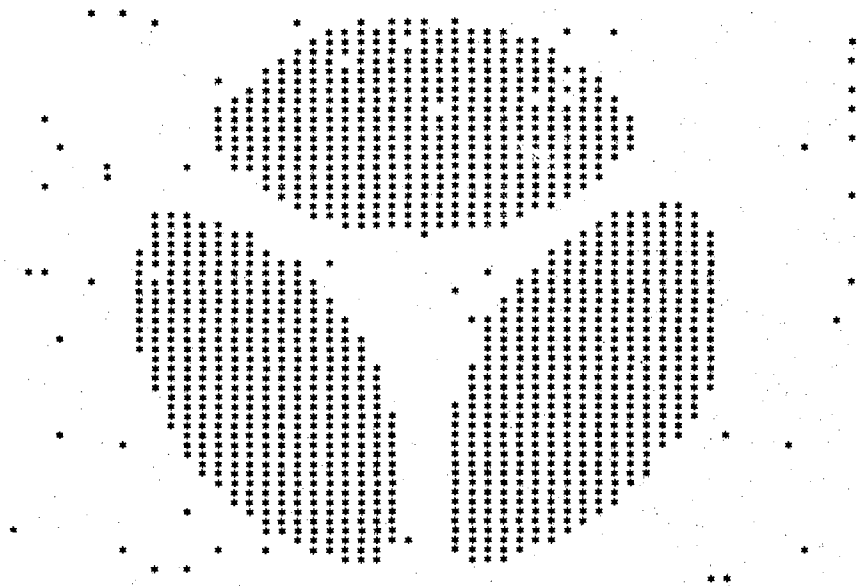Figure 36.   The Quantized Facsimile of the Test Image
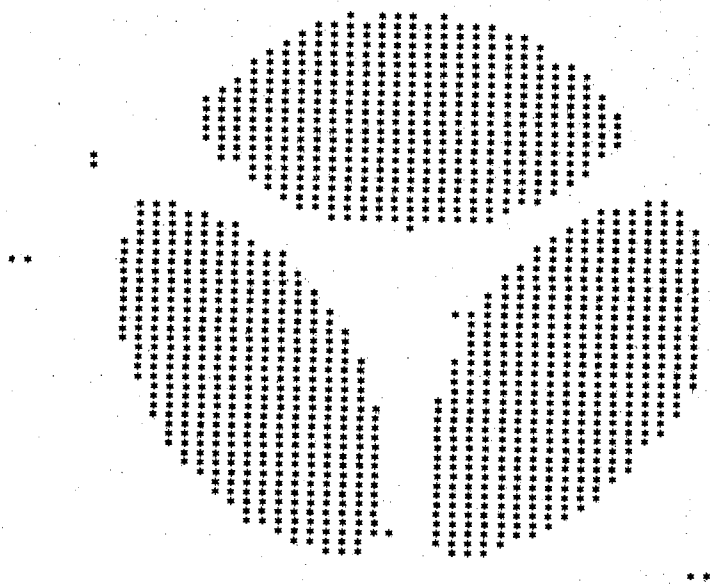
Figure 37.   The Quantized Facsimile of the Test Image
              after Noise Suppression

Original Image   Quantized Image   Filtered Image

Figure 38.   Successive Conversions of Test Photograph (VWB)

Original Image   Quantized Image   Filtered Image

Figure 39.   Successive Conversions of Test Photograph (WLH)

Original Image   Quantized Image   Filtered Image

Figure 40. Successive Conversions of Test Photograph (RBK)
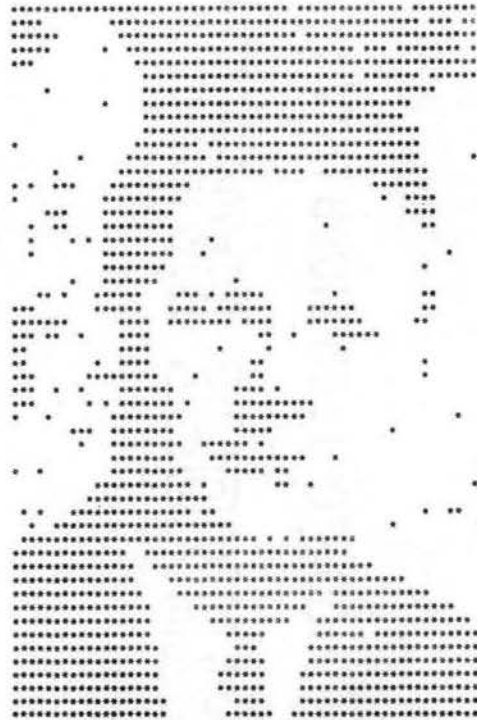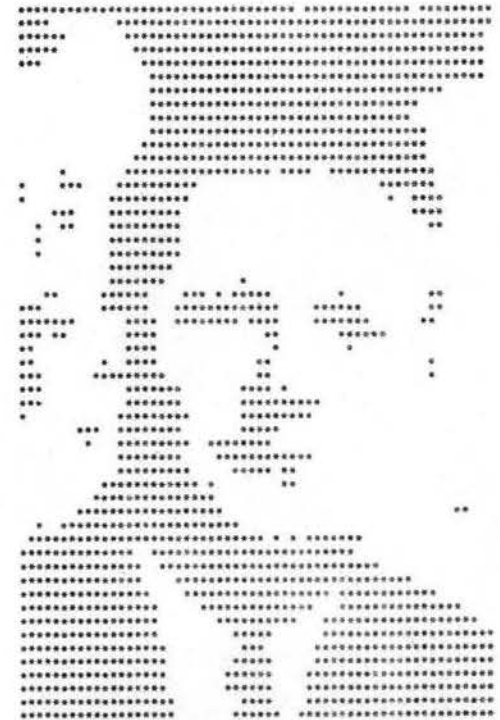
Original Image   Quantized Image   Filtered Image

Figure 41. Successive Conversions of Test Photograph (MRL)
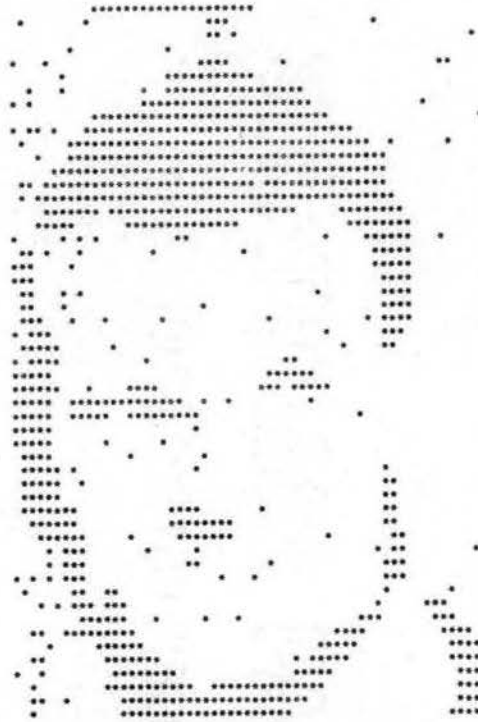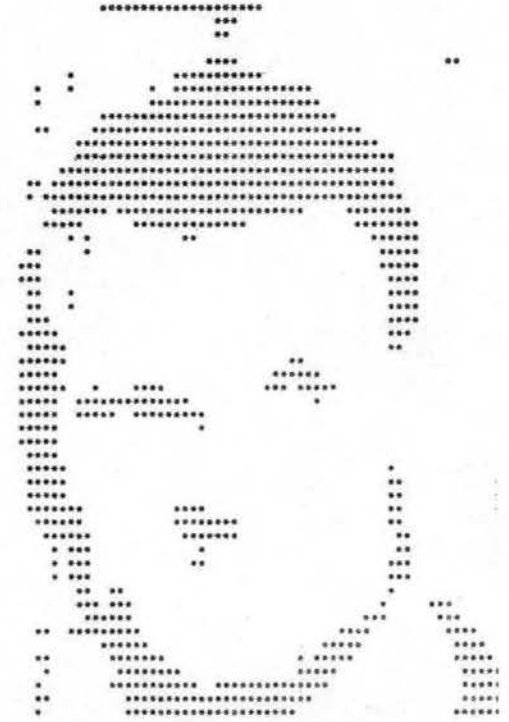
Original Image   Quantized Image   Filtered Image

Figure 42. Successive Conversions of Test Photograph (DEM)

level" (defined previously in the description of the sub-routine PEEK) for best results was always between 0.500 and 0.625 and usually between 0.550 and 0.600. There was little difference in results when the significance level varied between 0.500 and 0.600. Therefore it was concluded that the "significance level" adjustment need not be adjusted or changed for all normally illuminated and contrasting images.

CHAPTER VI

THE USE OF A TELEVISION INPUT AS AN ANALYTICAL TOOL

There are many problems for which the solution is de-
rivable from the geometric properties of a two dimensional
pattern. An example of this type of problem is the deter-
mination of the location of the centroid (commonly called
the "center of gravity"), the moments of inertia, and the
product of inertia of the cross section of a structural
member. In order to indicate the usefulness of having a
television input into a computer for this type of problem,
the following example is given.

The test cross section shown in Figure 43 is a silhou-
ette of a piece of aluminum plate (it could just as well
have been the plate itself). The pattern was first scanned
and noise processed by the techniques and computer programs
described in Chapter V. The resultant output is shown in
Figure 44 with the centroid location indicated. This out-
put data (in punched card form) was used as input data for
the program listed in Table X. This program computed
various attributes of the given geometric pattern, as shown
by the computer print-out given in Table XI.

The types of problems solvable by a digital computer
with an optical input capability might not be any different
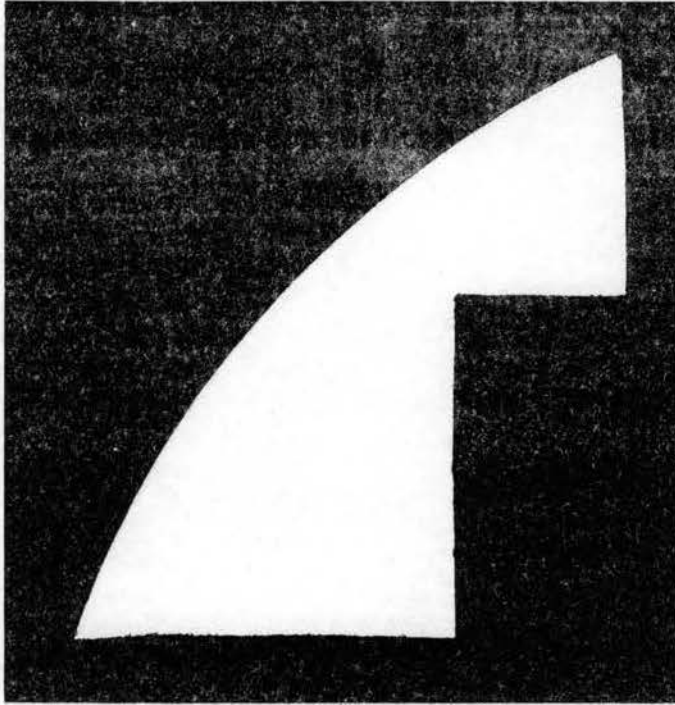
Figure 43. Silhouette of an Aluminum Plate
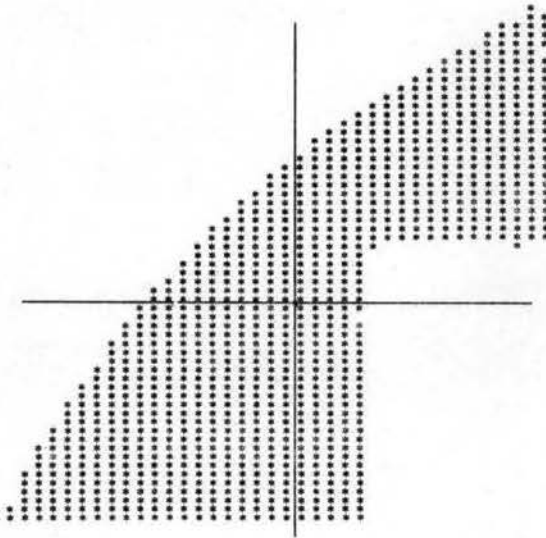
Figure 44. Computer Output with Centroid Location
of the Aluminum Plate

TABLE XI

A FORTRAN PROGRAM FOR IMAGE ANALYSIS

```
‡‡JOB

‡‡FORX

C       THIS PROGRAM COMPUTES VARIOUS ATTRIBUTES OF 2-D PATTERNS
C       WHICH ARE PRESENTED IN A 60X60 GRID FORMAT.
        DIMENSION    LINE(60)
      9 PAUSE
     14 FORMAT(23H                        IX=,F11.8)
     15 FORMAT(23H                        IY=,F11.8)
     16 FORMAT(24H                        IXY=,F10.8)
     44 FORMAT(24H                        IXC=,F11.8)
     45 FORMAT(24H                        IYC=,F11.8)
     46 FORMAT(25H                        IXYC=,F10.8)
        X5=0.0
        X6=0.0
        X7=0.0
        X8=0.0
        X9=0.0
        X10=0.0
        DO 20     I=1,60
        XI=61-I
        XI = .013333 * XI
        READ 1, LINE
      1 FORMAT(60A1)
        X1=0.0
        X2=0.0
        X3=0.0
        X4=0.0
        DO 11 J=1,60
        XJ=61-J
        XJ = .01 * XJ
        IF(LINE(J))        10,11,10
     10 X1=X1+1.0
        X2=X2+XJ
        X3=X3+XJ*XJ
        X4=X4+XI*XJ
     11 CONTINUE
        X5=X5+XI*X1
        X6=X6+X1
        X7=X7+X2
        X8=X8+X3
        X9=X9+X1*X1*X1
     20 X10=X10+X4
        XC=X5/X6
        YC=X7/X6
        XA=X6/3600.
        X8 = X8 * .00013333
        X9 = X9 * .00013333
        X10 = X10 * .00013333
        TYPE 2
```

TABLE XI (Continued)

```
   2 FORMAT(38H    FOR A COORDINATE SYSTEM OF THE FORM///)
     DO 6     I=1,3
   6 TYPE 3
     DO 7     I=1,8
   7 TYPE 4
     TYPE 5
   3 FORMAT(19H                    X)
   4 FORMAT(19H            ********X)
   5 FORMAT(19H         YYYYYYYYYYYYØ)
     TYPE 47
  47 FORMAT(1H //)
     TYPE 40
  40 FORMAT(22HWITH THE SCALE FACTORS /)
     TYPE 41
  41 FORMAT(24HX=AXIS....  Ø.Ø1333/DIV.)
     TYPE 42
  42 FORMAT(21HY-AXIS....  Ø.Ø1/DIV.//)
     CALL RETYPE
     TYPE 8
   8 FORMAT(34HWITH RESPECT TO THE INDICATED AXES/)
     TYPE 21,    XC,YC
  21 FORMAT(42HLOCATION OF CENTER OF GRAVITY IS (X,Y) = (  F7.5, 1H,,
    1F7.5, 1H))

     TYPE 12,XA
  12 FORMAT(25HTHE FRACTIONAL AREA IS    ,F7.4,4H    .)
     CALL RETYPE
     TYPE 13
  13 FORMAT(26HTHE MOMENTS OF INERTIA ARE)
     TYPE 14,  X8
     TYPE 15,   X9
     TYPE 16,    X1Ø
     CALL RETYPE
     X8=X8 -YC*YC*Ø.48*XA
     X9=X9 - XC*XC*Ø.48*XA
     X1Ø = X1Ø - XC * YC * .48 * XA
     TYPE 51
  51 FORMAT(1H /////)
     TYPE 52
  52 FORMAT(52HWITH RESPECT TO NEW AXIS (PARALLEL) THROUGH THE C.G./)
     TYPE 13
     TYPE 44, X8
     TYPE 45, X9
     TYPE 46, X1Ø
     GO TO 9
     END


Ø4496 CORES USED
19999 NEXT COMMON
END OF COMPILATION
EXECUTION
```

TABLE XII

SAMPLE COMPUTER OUTPUT FOR THE ALUMINUM PLATE

FOR A COORDINATE SYSTEM OF THE FORM

```
                   X
                   X
                   X
          ********X
          ********X
          ********X
          ********X
          ********X
          ********X
          ********X
          ********X
       YYYYYYYYYYYØ
```

WITH THE SCALE FACTORS

X-AXIS.... 0.01333/DIV.
Y-AXIS.... 0.01/DIV.

WITH RESPECT TO THE INDICATED AXES

LOCATION OF CENTER OF GRAVITY IS (X,Y) = (.51911, .25104)
THE FRACTIONAL AREA IS   .2758   .
THE MOMENTS OF INERTIA ARE
                 IX= .01158153
                 IY= .03767736
                 IXY= .01918815

WITH RESPECT TO NEW AXIS (PARALLEL) THROUGH THE C.G.

THE MOMENTS OF INERTIA ARE
                 IXC= .00323705
                 IYC= .00199828
                 IXYC= .00193349

than for a normal computer, but certainly, the ease and rap-
idity of entering many types of input data to a computer
would be enhanced by the availability of a system such as
the one demonstrated here. For this type of application a
video input terminal would be employed as a means of using
a digital computer more effectively as an analytical tool.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary

This study has been conducted towards the goal of
attaining an effective and efficient means of data input to
a computer from an optical or two dimensional image source.
This thesis research effort included the following items.

1. The literature was searched for previous
   efforts in the fields of pattern recognition
   algorithms and television systems. The
   results were presented in Chapter I.

2. The Dage television gear was obtained and
   thoroughly renovated and calibrated to the
   specifications of the F.C.C.

3. The Video Signal Consolidator was designed and
   constructed to make available the video and
   sweep signals (V_x, V_y, and V_z).

4. The image interrogator was designed and
   constructed for the bilateral information
   handling ability needed with the IBM 1620
   computer. This hybrid circuitry utilized both
   integrated circuits and discrete components.

5. The entire system was interfaced with the IBM
   1620, and the necessary software was generated
   for image scanning, data collection, and data
   storage and output. A program for suppressing
   random noise (allowing better agreement be-
   tween the input and output images) was devel-
   oped.

6. Experiments were conducted on transferring the
   photographic images of five different human
   faces through the complete system, and the

results were presented.

7. The equipment was used in conjunction with a
computer program which was written to deter-
mine certain features of geometric patterns;
such as the location of the centroid, the de-
termination of the fractional area of the
image within the image plane, and the moments
of inertia of the test image.

Conclusions

On the basis of the studies reported it appears that
the following conclusions are justifiable.

1. The accuracy and speed capabilities of the
discreet and integrated circuit components now
available as mass produced items are suf-
ficient to implement direct control by a dig-
ital computer of the information retrieval
from a television system.

2. It was determined experimentally that the
information content (bits required for
storage) could be reduced by applying the
interrogating window technique without des-
troying many of the essential features of the
pattern.

3. The computer controlled video system reported
here appears to be applicable to a wide range
of image analysis and pattern recognition
problems.

4. Highly individualistic facial features, as re-
corded by a television camera, are still iden-
tifiable after rather drastic thresholding and
bandwidth reduction operations were applied.

5. Further refinements in the electronics and
packaging techniques could, based on the
developments reported here, produce a compact
and easily operated video input terminal for a
digital computer.

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       Indiana: TRW, Inc. (Dage Division), 1959.

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       Model 520-A, Manual No. IM-520-A. Michigan City,
       Indiana: TRW, Inc. (Dage Division), 1962.

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APPENDIX A

USE OF ANALOG INTERFACING TO THE IBM 1620 COMPUTER

The IBM 1620 digital computer in the Engineering Com-
puter Laboratory, Oklahoma State University, is equipped
with auxilliary apparatus which gives it an analog input/
output capability. Table XIII is a reproduction of the
handout furnished by Professor Paul McCollum of the Depart-
ment of Electrical Engineering to his "Hybrid Computations"
Class (ELEN 6213). This computer interfacing equipment was
originally designed and built to allow the digital computer
to control the operation of an analog computer. For the
research reported here the digital computer, working
through this interface, was able to control the image inter-
rogator quite effectively.

TABLE XIII

REPRODUCTION OF THE COMPUTER INTERFACING HANDOUT

Oklahoma State University

Engineering Computing Laboratory

The Hybrid Facility on the IBM 1620 Digital Computer
(Preliminary)

The hybrid I/O terminal on the IBM 1620 digital computer provides the means for the 1620 to communicate with an outside, analog system. The salient features are:

      a. Nine analog signal channels into the 1620 via an analog-to-digital (A/D) converter. Each channel program addressable.

      b. Five output analog signal channels from the 1620 to an external system via a digital-to-analog (D/A) converter. Each channel program addressable.

      c. Three control lines from the 1620 to the external system.

      d. Two sense lines from the external system into the 1620.

Figure 1 shows a diagrammatic picture of these features. The details of operation and programming of the various features will be described following. Appropriate subroutines have been added to the Fortran system in order that the hybrid features can be called upon by Fortran programming. The use of Fortran slows down the maximum possible speed of the system; so, if more speed is necessary, then machine language or SPS programming will have to be used.
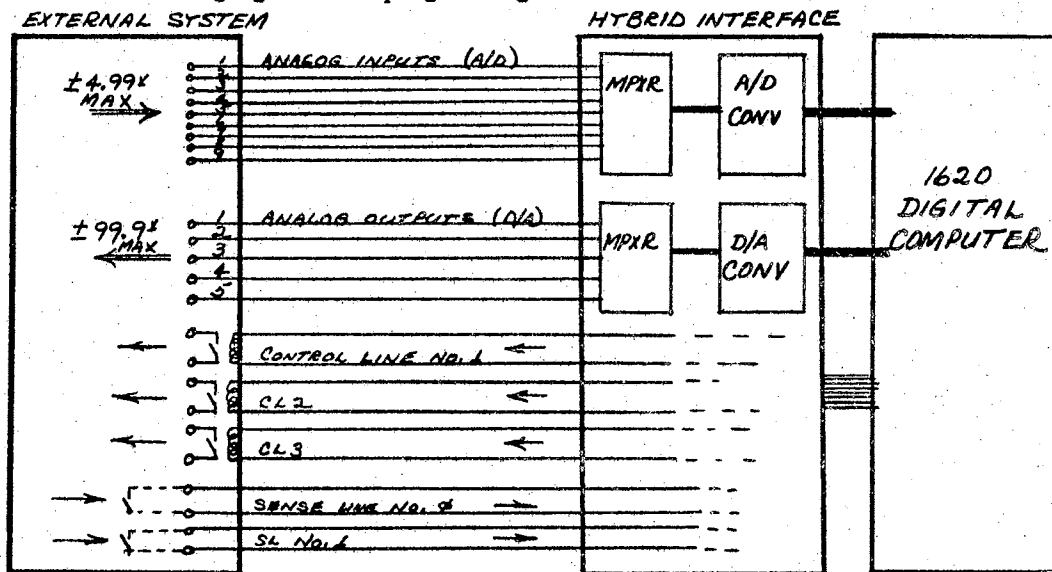

Figure 1. Diagrammatic representation of the hybrid features.
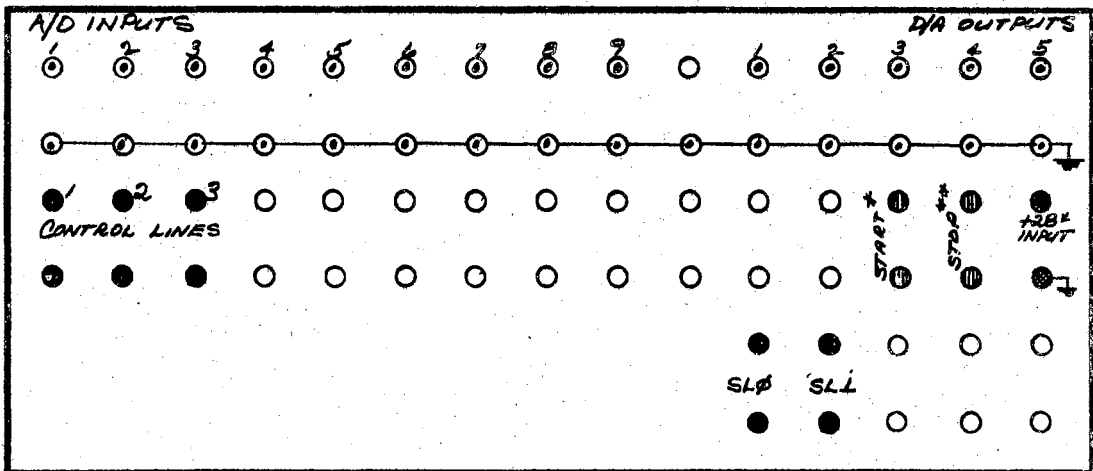
(1)

TABLE XIII (Continued)

Figure 2. Hybrid Interface Terminal Panel

* Closing this pair of terminals momentarily will start the 1620 computer.

** Closing this pair of terminals momentarily will stop the 1620 computer. This is "Instant stop".

If the alternate control line operation is to be used, then a +28 volt dc power source must be connected to the indicated terminals.

(2)

TABLE XIII (Continued)

ANALOG INPUT DATA CHANNELS

Each one of the analog input data channels can accomodate a signal range of $\pm$ 4.99 volts. A voltage in excess of 4.99 volts, when read into the 1620, will cause the program to abort and produce a "check stop".

A desired channel can be read by the Fortran statements,

        CALL GETADI(NCHAN,IDATA)   or   CALL GETADF(NCHAN,DATA)

    where

NCHAN is a fixed-point constant or variable name representing the number(1-9) of the channel to be read. IDATA is any legitimate fixed-point variable name representing the actual data being read and being entered into core memory. Due to the nature of the design of the A/D converter, the absolute value of the output of the converter will be twice that of its input.

EXAMPLE 1: Suppose the analog data on channel 4 is +3.24 volts. This data will be read into core memory with the value 648 by either of the following instruction sequences.

        N = 4   or simply
        CALL GETADI(N,KVOLT)   CALL GETADI(4,KVOLT)

After the instruction has been executed, the value of KVOLT in memory is 648 .

The A/D conversion and storage system was designed to work convienently with an analog system whose range is $\pm$ 99.9 volts. A voltage in the 99.9v system would always have to be fed through a 20:1 voltage divider before being connected to an A/D channel input terminal. Thus, the voltage of 48.6 would be read into memory as the integer 486 . Once the data has been read into memory under a known variable name, then it can be used in any legitimate way in the program just as though it had been read in on a card.

The statement

        CALL GETADF(NCHAN,DATA)

will cause the channel no. NCHAN to be read as before, except that the analog data voltage will now be converted, read and stored in core memory as a floating-point data value having the name, DATA, in this case.

EXAMPLE 2. The analog data on channel 1 is -63.8 volts and is fed through a 20:1 voltage divider before being connected to the A/D input terminal. The program statements

        I = 1
        CALL GETADF(I,SIGNAL)   or   CALL GETADF(1,SIGNAL)

will cause channel 1 to be read, and the data value stored in core memory under the name, SIGNAL, will be -63.8 . Only one analog data channel can be read at a given time.

(3)

TABLE XIII (Continued)

ANALOG OUTPUT CHANNELS D/A

An integer, fixed-point quantity(range of $\pm$ 999) or a floating-point quantity(Range of $\pm$ 99.9), stored in core memory, can be called to be converted from digital to analog and put out as an analog voltage on any one of five output lines.

EXAMPLE 3.   The data called LUMP is stored in core memory and has the value -753 . The instructions

          N = 2
          CALL PUTDAI(N,LUMP)   or   CALL PUTDAI(2,LUMP)

will cause an analog voltage of -75.3 volts to appear on D/A output channel no. 2.

EXAMPLE 4.   The data called VOLTS4 is stored in core memory and has the value 29.5 . The instructions

          K = 4
          CALL PUTDAF(K,VOLTS4)   or   CALL PUTDAF(4,VOLTS4)

will cause an analog voltage of 29.5 volts to appear on D/A output channel 4.

When an output is instructed to appear on a given D/A output, then any output on the last previously used output line will begin to decay. The rate of decay will depend upon the amount of loading.

CONTROL LINES

The control lines are for the purpose of allowing the 1620 digital computer to turn ON and OFF circuits in the external system by programmed instructions. The hybrid terminal only has three control lines at the present; however, it is possible to add logic giving over 100 more such control lines.

The actual nature of a "control line" is a set of contacts(SPST-NO) that can be closed or opened by appropriate Fortran instructions. The contacts may be used to operated any circuit in the outside system as long as the contacts rating is not exceeded.   The rating is 200 volts maximum, 500 ma, noninductive.

A given set of contacts are closed or "SET" by the Fortran instruction

          CALL SETCL(N)

where N is a fixed-point variable name or integer constant and may have the value 1, 2, or 3.

The instruction for opening or "RESETTING" a control line is

          CALL RSETCL(N)

(4)

TABLE XIII (Continued)

The physical result of "SETTING" a control line can be changed from that of the preceding description to one of causing a voltage of +28 volts to appear on the top switch contact terminal. This alternate scheme can be put into operation by operating a slide switch on the equipment. The reason for this mode of operation is that the analog computer that normally used with the hybrid channel has mode relays that require +28 volts.

SENSE LINES

These are two "SENSE LINES" with the identification numbers O(zero) and 1. A sense-line is "SET" by placing a short-circuit across the terminals of the line which physically terminate at the external system.

The condition of a sense-line can be tested by a computer instruction and the flow of the computer program can be made to branch depending on the condition of the sense-line. The Fortran program instruction for testing the condition is

        CALL TESTSL(NLINE,L)

NLINE is a fixed-point variable name or constant and will be O(zero) or 1, the identification number of the sense-line. L is a fixed-point name of a quantity stored in core memory. Its value will be 0 or 1 depending upon the condition of the sense-line being tested. If the sense-line being tested is SET, then the stored value of L will be 1 . If the sense-line is OFF, then the value of L is 0.

Thus, at some later point in the program, the following instruction can be used.

        $IF(L)n_1,n_2,n_3$

where n_1, n_2, and n_3 are statement numbers as usual in the Fortran IF statement. Since L will have the value O(zero) or +1 , then branching of the program can be controlled by the condition of the sense-line. n_1 can just be made the same as n_2 for convienence since it becomes a dummy number in this application.

***

APPENDIX B

CALIBRATION OF THE IMAGE INTERROGATOR

During the course of operation of the image inter-
rogator there is but one adjustment that needs to be made,
and this is the video threshold level. This adjustment is
described in Chapter V and should not be considered a point
of instrument calibration.

The only remaining adjustments are of the current mag-
nitudes going into the pulse resettable integrators when
they are turned "on". These integrators should be set such
that the outputs are the same for any given window size, if
the window is over a "white" area of the image. The
calibration computer program shown in Table XIV, is used
for this calibration.

Calibration Procedure

1. Remove the gate input to the integrator
   control circuitry board.

2. Set the channel monitor setting to channel 2
   of A/D converter.

3. Load the calibration program (all sense
   switches "OFF").

4. Continue pressing the remote "START" button
   until a reading of approximately 500 is shown
   on the A/D indicator lights.

TABLE XIV

CALIBRATION PROGRAM FOR THE PULSE RESETTABLE INTEGRATORS

```
‡‡JOB

‡‡FORX

C     THIS PROGRAM IS USED TO CALIBRATE THE VIDEO INTEGRATORS.
C             IF SENSE SWITCHES 1 AND 2 ARE OFF
C           THEN WINDOW AREA INCREMENTS UP
C             IF SENSE SWITCH 1 IS ON
C           THEN WINDOW SIZE IS MAINTAINED CONSTANT
C             IF ONLY SENSE SWITCH 2 IS ON
C           THEN WINDOW AREA REVERTS TO MINIMUM SIZE
C             IF ONLY SENSE SWITCH 1 IS OFF
C           THEN END OF JOB
      COMMON  IDUM,IB,IT,IR,IL
      PAUSE
    8 I=1
    5 IB= 10*I
      IT=-10*I
      IL=-10*I
      IR= 10*I
      DO 10 K=1,3
   10 CALL WINDOW
      CALL PULSE5
    1 CALL WINDOW
      CALL GETADF(4,R)
      IF(R-50.0)      1,1,2
    2 CALL GETADF(2,P)
      CALL GETADF(3,Q)
          IF(SENSESWITCH7)120,120
  120     CONTINUE
      IF(SENSE SWITCH 1)     5,4
    4 IF(SENSE SWITCH 2)     7,6
    6 I=I+1
      PAUSE
      GO TO 5
    7 IF(SENSE SWITCH 3)     9,8
    9 CONTINUE
      END


00658 CORES USED
19979 NEXT COMMON
END OF COMPILATION
EXECUTION
```

5. Turn Sense Switch 1 to "ON" on the computer.

6. Adjust either or both constant current sources until the readings on A/D channels 2 and 3 are the same.

7. For other manipulations of the window size, consult the comment cards in Table XIV.

APPENDIX C

OPERATING PROCEDURE FOR VIDEO-COMPUTER SYSTEM

The following set of instructions covers the entire video-computer system and should not necessarily be considered as a replacement for the instructions for operating the computer and television gear (which are furnished by the manufacturers).

1. Turn on the A/D and D/A converters with the switch at the top of the electronics panel (Figure 31). Allow one hour for warm-up. Do not turn this equipment on or off if the computer is in the "AUTOMATIC" mode (a CHECKSTOP will result).

2. Turn on the main power switch on the digital computer console (Figure 32).

3. Turn the three plate voltage switches on the center panel of the Dage control console to "OFF" (Figure 33).

4. Turn on the television equipment with the main control console breaker switch which is located below the shelf of the control console, on the left side (Figure 30).

5. If the CAMERA switch on the lower center portion of the center panel of the control console is off, then turn it on.

6. Turn on the oscilloscope (if it is to be used) and allow it to attain thermal stability.

7. Verify that both power supplies for the image interrogator are on, each has a power indicator lamp.

8. After approximately thirty seconds of control

console warm-up time, the plate switch or plate switches for the appropriate camera or cameras should be turned on.

9. Focus the camera on the desired subject.

10. Set the video threshold level; either with the oscilloscope (see Page 75) or by trial and error.

11. Turn the mode selector on the A/D convertor to manual, and the channel selector to "2". Push the manual button. Switch the channel selector to "3" and push the manual button. Repeat the procedure for channel 4. Turn the mode selector back to the operate mode. This procedure removes illegal BCD numbers from the output buffer register of the A/D converter.

12. As soon as the "POWER READY" light on the IBM 1620 console comes on, the "START-STOP" button on the disc-drive unit should be pushed.

13. Load the main scanning program (Table IX) or an alternative image interrogator controlling computer program.

14. The system operation should now be automatic (in the control of the digital computer).

15. The only turn-off rule is that the disc-drive be turned off prior to the turning off of the digital computer.

VITA

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