NRL REPORT 3999

TELEVISION RECORDING PROJECT

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September 25, 1952

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WASHINGTON, D.C.

ABSTRACT

The need for recording apparatus suitable for storing televised information has been evident as the number of applications to military operations has increased. A study has been made of the elements of a suitable recording system, and a start has been made toward producing an embodiment of current ideas for this equipment. In this report are discussed the factors dictating the choice of video-amplifier characteristics, camera-tv signal synchronization, recording rate, and possible future alternatives to the present film-recording technique.

PROBLEM STATUS

This is an interim report on one phase of this problem. Work on other phases of the problem is continuing.

AUTHORIZATION

NRL Problem R01-11
RDB Projects NE 020-923, NE 021-409,
and NE 021-422

Manuscript submitted June 4, 1952

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INTRODUCTION

The transmission and reception of information by television techniques occur at such a rate that it becomes humanly impossible to perceive and interpret the entire information content. It is recognized of course that the observation process at the receiving point is in itself a selective sampling dependent upon what is of particular interest to the observer. In visually presented material with multiple-interest content, observation of the composite picture can and does result in overlooking or failing to recognize some significant points of interest. There is need in such a system for a nonselective memory device which will enable recall or playback at a rate commensurate with the observers' ability to use the important information originally transmitted.

The storage problem, certainly as old as commercial television programming, is not completely solved at the present time. A great deal of thought has been given to ways and means of meeting the requirements. Military television applications can be expected to place more stringent performance limits on recording systems than may be considered acceptable commercially.

STORAGE METHODS

Fundamentally there are two processes used in storing information; the first is what may be called short-term; the second is more or less long-term and permanent. In the first classification fall the various Haeff memory tubes, the Graphecon tube, the dark trace tubes ("Skiatron" variety) and delay lines – all of which, except in the case of certain of the memory tubes, afford only a limited number of playbacks or a limited storage time. The permanent storage media are chiefly magnetic tape, photographic film, and discs, which, depending upon recognition of their specific limitations, serve to store information for indefinite periods of time and permit repeated playbacks without intolerably compromising the quality of the information originally stored.

Consideration of the problem of utilizing the large amount of information transmitted in a television signal leads to the conclusion that a permanent means of recording the information must be devised if completely random playback intervals and number of important interest-objects are permitted. The use of magnetic tape for storing video information has been proposed and is understood to be under intensive investigation for application to commercial television programming. At present, however, the most satisfactory method of permanently recording video information is photographic.

The choice of film as the recording medium imposes certain restrictions upon the associated apparatus. Some of these can be met by available equipment or by known processes which can be combined in possibly a unique form to perform the new operations. To overcome other limitations imposed by the film process may require considerable development of new devices. Specifically, the starting and stopping of the film at the high rates imposed by the 1/30-second frame time of commercial television pictures required the development of a pull-down motion for cameras which operated more than twice as fast as the standard motion picture camera mechanism. Analysis of the requirements for recording television signals presented at 30 frames per second reveals that a shutter opening of 288 degrees per frame must be used, start and finish of the complete pull-down cycle being accomplished in the remaining 72 degrees per frame. It is imperative for highest quality of reproduction that the camera and television system be synchronized; otherwise what is known as "shutter bar" interference occurs. This interference is in the form of a black or white bar which gradually drifts across the recorded picture as the phase difference between the two systems changes.

SYNCHRONIZATION METHODS

One approach to solving the problem of synchronization is to eliminate the camera shutter and pull-down mechanism, driving the film past the lens at a constant speed. The television picture is then presented in the form of a varying brightness line on the cathode-ray tube. However, this technique cannot be used with interlaced fields, such as is the case with commercial tv signals; other means of synchronization are necessary. Military applications of television may be expected not to have common power frequencies, and synchronous camera motors at two or more different points will not necessarily be "in step" with the tv signal without auxiliary means of phasing. Selection of a means of synchronizing the camera operation with that of the tv presentation can be based upon either of two principles. The camera driving motor can be phased manually or automatically with the tv presentation by utilizing the synchronizing pulses transmitted with the video information, or the camera cycle can be utilized to control the tv presentation on the cathode-ray tube in such a fashion that it produces light and exposes the film only when a rigidly prescribed set of conditions have been met.

MINIMAL REQUIREMENTS FOR RECORDER

In March 1950, representatives of the Laboratory, Code 832 of the Bureau of Ships, and the Naval Photographic Center met to outline tentative standards for a film recording system capable of meeting future military needs.

The following requirements for the electronic presentation were agreed upon as either essential or desirable:

1. Positive or negative picture presentation,

2. Reversed horizontal sweep for either positive or negative picture presentation,

3. Electronic indication of camera focus,

4. P-4 phosphor on monitor screen, preferably on removable desk-type unit,

5. Oscillograph c presentation of vertical or horizontal video information,

6. Provision of a control signal for film driving-motor synchronization,

7. Interlaced or noninterlaced sweep, and

8. Recording rate of 15 frames per second.

No provision was to be made for simultaneously recording sound (on film or otherwise) or for photography in color of color television. However, it was further understood that the recording system should be sufficiently flexible to be used with eventual 819-line television systems. The low frame rate chosen represented a compromise, anticipating the eventual replacement of a standard 170° camera which was to be made available during the interim by a high-speed camera being developed by the Naval Photoscience Laboratory.

WORK ACCOMPLISHED – DISCUSSION

Video Amplifier Design

The maximum video frequency signal in an 819-line television system is very nearly 15 megacycles. (See Appendix A.) For a 525-line system, the maximum frequency is slightly more than six megacycles. These are theoretical limits where the reference checkerboard object is reproduced by sine-wave variations in light output at the cathode-ray presentation tube. The video amplifier should be capable of accepting a frequency spectrum two or three times greater than this maximum in order that complex waveforms can be amplified without appreciable distortion. Thus if the 15-megacycle bandwidth of the 819-line system is used as a design basis, it means that the present 525-line tv signals could be reproduced with considerably better fidelity than is possible with an amplifier having barely adequate bandwidth. Studio equipment generally is designed for 10-megacycle bandwidth, but television receivers, as well as the intermediate links, often do not pass more than a 4-megacycle band.

The first work attempted in this program consisted of an appraisal of the various types of video amplifiers. For video amplifiers up to 4 megacycles, series- and shunt-peaked plate circuits enjoy wide favor, and considerable has been written about proper design techniques. By very careful design and a liberal use of low-gain stages, it is possible to extend the range of this type of amplifier to 10 megacycles. The difficulties of adjusting the peaking coils for maximum response, the uncertain stability of this adjustment over long periods of time, and the tube requirements to extend the range to 15 megacycles seemed to warrant consideration of other types.

The use of feedback between a pair of resistance-coupled amplifier tubes to broaden the pass band of the amplifier has been suggested by various workers.[1,2] A typical circuit appears as Figure 1. Several amplifiers based on principles outlined in Reference 2 were designed and checked. It was readily possible to produce a 4-tube amplifier having a flat response out to 15 megacycles at a gain of 20 to 25 db, but it appeared improbable that sufficient voltage could be obtained to drive a cathode-ray tube from this type of amplifier.

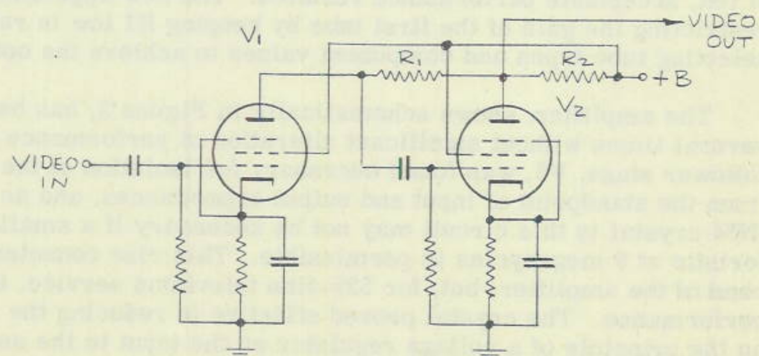

Figure 1 - Typical broad-band feedback amplifier

1 Wheeler, H. A., "Wideband Amplifiers for Television," Proc. IRE 27:429-438, July 1939

2 Mulligan, J. H., Jr., and Mautner, L., "The Steady-State and Transient Analysis of a Feedback Video Amplifier," Proc. IRE 36:595-610, May 1948

The 5WP11 c-r tube, which is to be used in this equipment, requires a total signal drive of approximately 40 volts peak swing from visual cutoff for maximum high-light brightness. It is estimated that the maximum signal input level to the video amplifier from a camera or from the video detector of a television receiver will be about 1 volt peak-to-peak, although it may be considerably less in some cases. Thus the gain of the video amplifier should be at least 40 or 32 db. The difficulty in obtaining the higher gain at this time was due to the impossibility of utilizing the full gain of one feedback stage—at an input level up to one-half volt—to drive a second stage capable of accepting a large grid voltage swing. If two transconductance tubes were used in the first pair, relatively low transconductance tubes, having a longer grid base had to be used in the second pair. Therefore, for the time being, the feedback amplifier was set aside, and the distributed-line amplifier[3] was investigated.

This type of circuit can be used to amplify unusually wide bandwidth signals, but it is rather difficult to design one to accept low-frequency signals, say below 200 kilocycles, and at the same time to amplify to its extreme upper frequency limit, which can be above 200 megacycles. The driving voltage requirements are very low, the grids of all stages are effectively in parallel, and one or two volts swing is ample.

An amplifier of this type was designed which acceptably passed the vertical sync pulses (at 60 pps) and was flat out to 15 megacycles, giving a uniform amplification of 45 db from a 0.15-volt rms signal. The output was capacitively coupled to either the grid of the cathode of the c-r tube, a d-c restorer added, and a very good picture obtained. The input stage of the amplifier was a feedback pair. Coupling the output of this portion of the amplifier into the relatively low impedance of the "distributed amplifier" 720-ohm grid line proved awkward unless a cathode follower was used and additional biasing arrangements were made. This made the amplifier undesirable from an operating standpoint; voltage supply variations made for instable frequency response also. (For reference purposes, the circuit of this amplifier is included as Figure 2.)

Further attention was again directed to the feedback amplifier, and owing largely to a new line of thinking by an associate, Mr. Julio Barbera, a six-tube feedback amplifier having a frequency response essentially flat from 30 cycles to 10 megacycles and down 1 db at 12 megacycles was developed. In accordance with the treatment of feedback amplifiers outlined in Reference 2, the ratio of the two plate-load resistances (R1 and R2 in Figure 1) should be equal to or greater than 1.

In the first work done with this circuit it was found that when R1 was greater than R2 and the same type of tube was used for both V1 and V2, the high gain available from a nominal 0.5-volt or more input to the first stage drove the second stage to saturation, with adverse effects upon the signal amplitude and phase. If the input were reduced by a factor of ten, acceptable performance resulted. The new approach to the problem consisted of restricting the gain of the first tube by keeping R1 low in relation to R2 and carefully selecting tube types and component values to achieve the optimum performance.

The amplifier, shown schematically in Figure 3, has been successfully duplicated several times without significant alteration of performance characteristics. The cathode-follower stage, V3, was found necessary for isolation of the two feedback stages, both from the standpoint of input and output capacitances, and as an impedance charger. The IN34 crystal in this circuit may not be necessary if a small rise in amplification characteristic at 9 megacycles is permissible. This rise connotes a phase shift within the pass band of the amplifier, but, for 525-line television service, this does not adversely affect performance. The crystal proved effective in reducing the overshoot, apparently operating on the principle of a voltage regulator on the input to the second feedback pair. This amplifier will produce a 45-volt peak-to-peak output with 1-volt peak-to-peak input, which is adequate for use with the 5WP11.

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3 Ginzton, E. L., Hewlett, W. R., Jasberg, J. H., and Noe, J. D., "Distributed Amplification," Proc. IRE 36:956-969, Aug. 1948

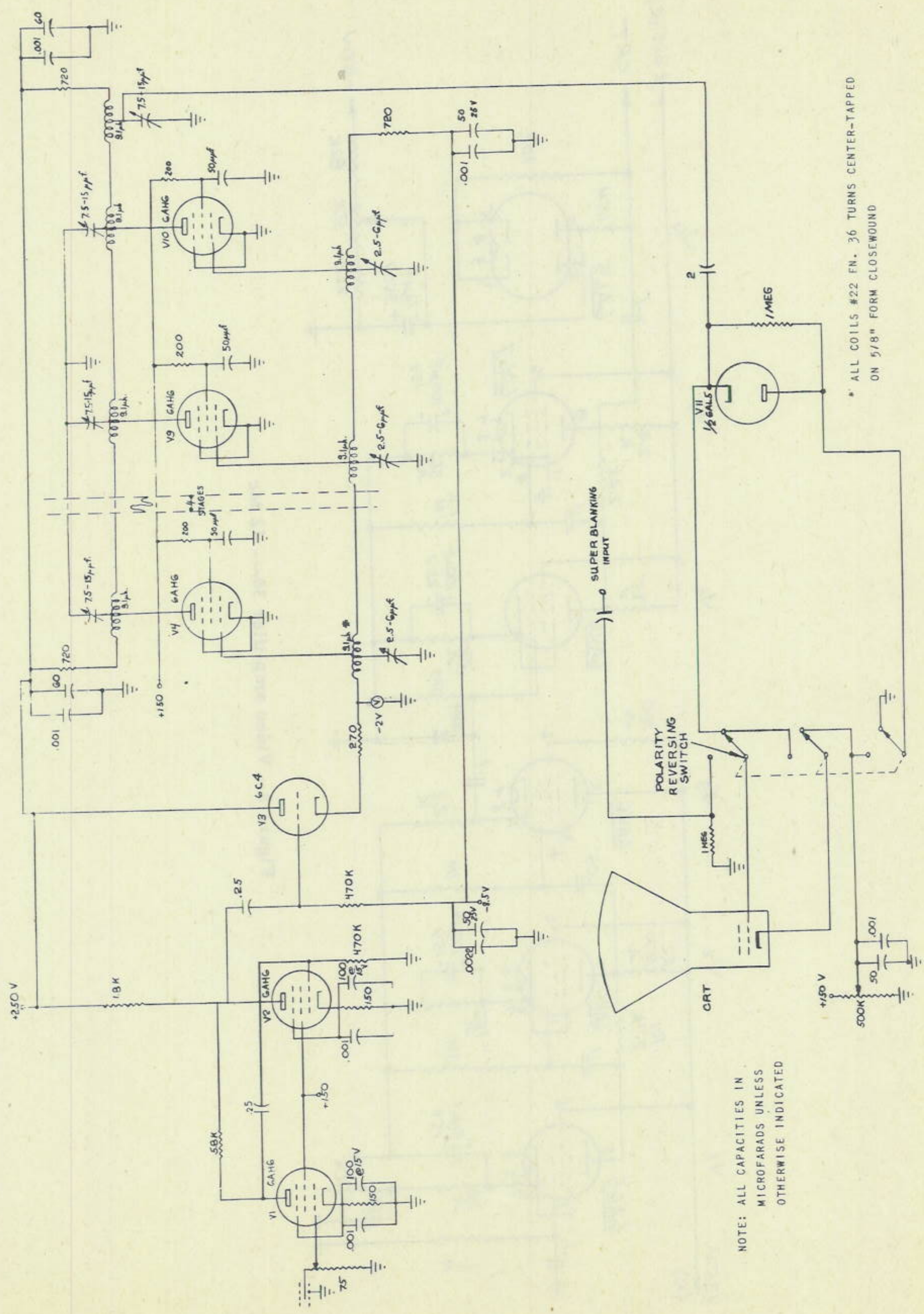

Figure 2 - Distributed line video amplifier

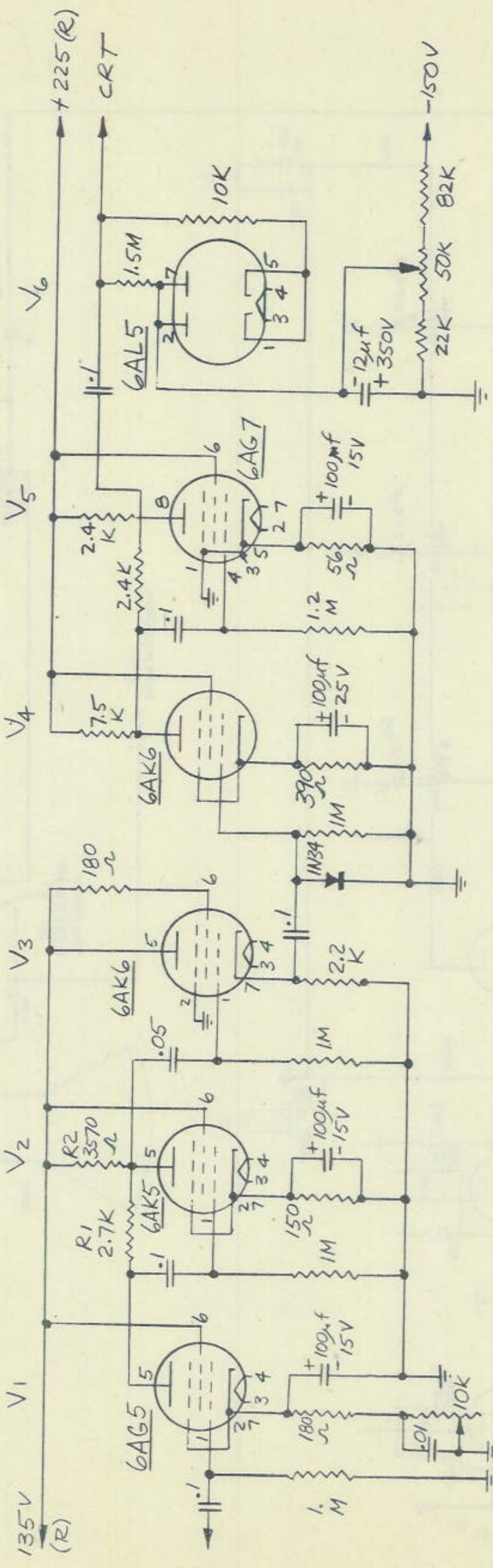

Figure 3 - Video amplifier 30~ - 12 Mc

In view of the probability that the recorder will be principally used with 525-line systems for some time, this amplifier will be used. The bandwidth is adequate, although insufficient of course for an 819-line system. Figures 4 and 5 show the low-frequency and high-frequency amplitude response characteristics of this amplifier.

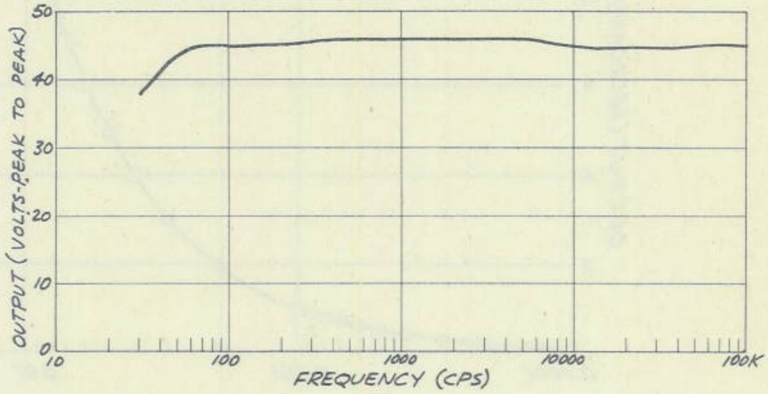

Figure 4 - Video amplifier low-frequency response input - 1 v peak-to-peak

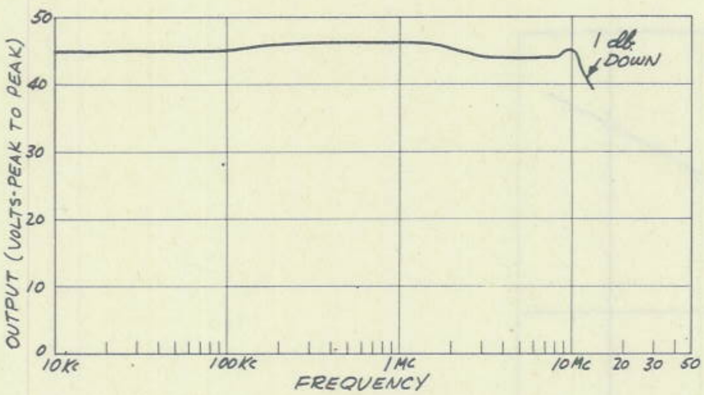

Figure 5 - Video amplifier high-frequency response input 1 v peak-to-peak

Gamma Adjustment Amplifier

The most commonly used camera tube, the image orthicon, has a typical response characteristic as shown in Figure 6. By adjustment of the lens opening, tube parameters, and ambient lighting, the operating point on the tube characteristic is first set so that white light produces the saturation value of output current; then the beam current is reduced slightly so that actual saturation does not occur. The light output from the 5WP11 as a function of grid driving voltage is shown in Figure 7. By straightforward graphic techniques, the over-all brightness transfer characteristic of the tv system can be determined, if idealized transmission networks intervene. Such a characteristic is shown in Figure 8.

It is evident that brightness differences along a uniformly graduated grey-scale test wedge would be exaggerated toward the white end, and compressed toward the black end. When film characteristics are superimposed upon this nonlinearity, particularly in going through a negative-positive photographic process, the distortion of brightness relationships may become intolerable. Although appreciable compensation for these distortions can be effected in the development of the negative film, or the exposure of the positive

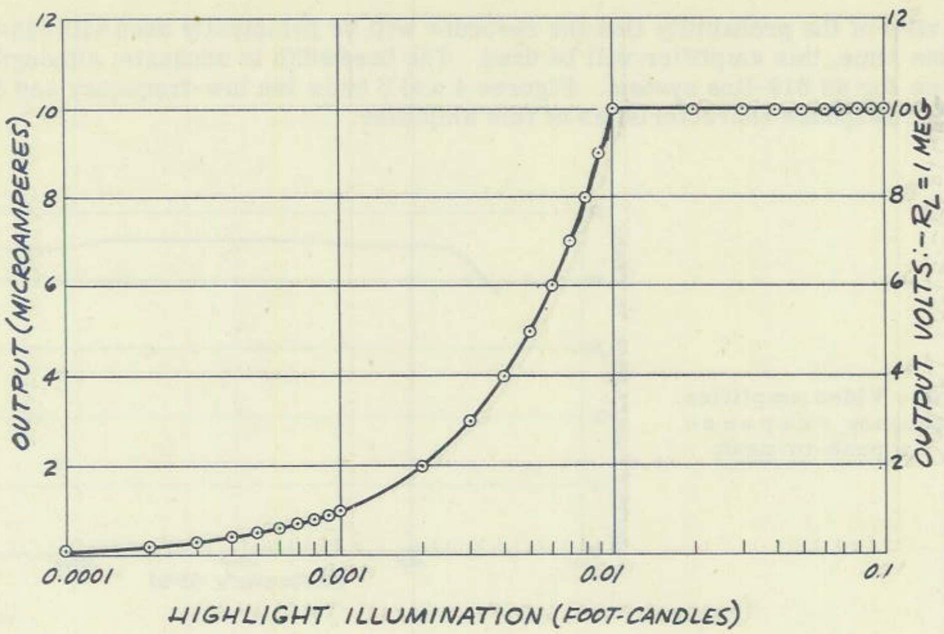

Figure 6 - Response of 5820 image Orthicon (RCA tube handbook)

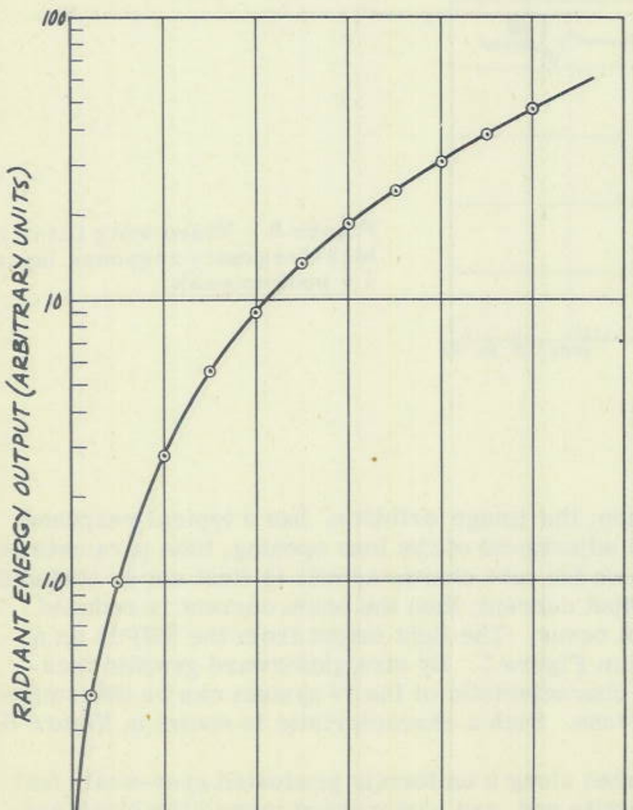

Figure 7 - 5WP11 characteristics (RCA tube handbook sheet 92 cm 7105)

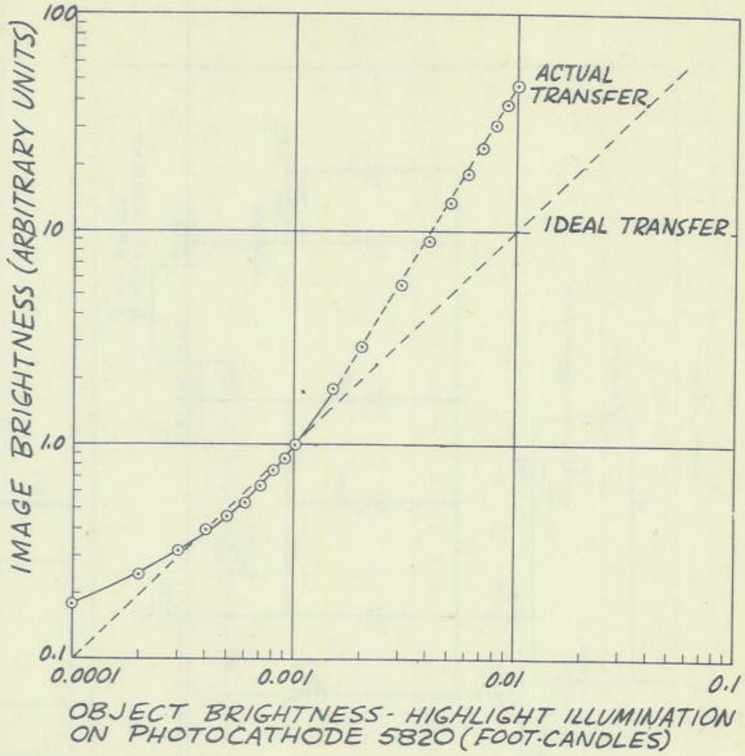

Figure 8 - Transfer characteristics 5820 image Orthicon to type 5WP11 c-r tube

print, it is possible to adjust the electrical transfer characteristics of the video amplifier to give an immediately perceptible improvement in the quality of the picture. Schade[4] and others[5,6] have demonstrated that the apparent resolution capability of a television system can be improved if the quality – i.e., naturalness – of the picture is improved. The so-called gamma-control amplifiers provide a means of increasing the contrast range of a given picture by means of a gain characteristic proportional to the applied signal voltage. The level at which the nonlinear operation is introduced can be made adjustable to suit the conditions. Several circuits capable of this type of operation were investigated and the circuit shown in Figure 9 gives the widest range of control of those considered.

Incorporation of this circuit into the video amplifier is desirable in order to provide the best possible subject material on the face of the cathode-ray tube being photographed. The light transfer characteristics of the image-orthicon to type-10FP4 c-r tube are similar to those appearing in Figure 8, except for a difference in slope and an absence of compression of black information. This similarity permits subjective determination of picture quality by observation of the monitor with the assurance that the reproduction on the 5WP11 c-r tube will be very nearly the same for recording on film.

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[4] Schade, Otto H., "Image Gradation, Graininess and Sharpness in Television and Motion Picture Systems-Part I," Journal of Motion Picture & Television Eng. 56:137-177, Feb. 1951
[5] Oliver, B. M., "Tone Rendition in Television," Proc. IRE 38:1288-1300, Nov. 1950
[6] Townsend, C. L., Goodale, E. D., "The Orthogam Amplifier," RCA Review XI:399-410, Sept. 1950

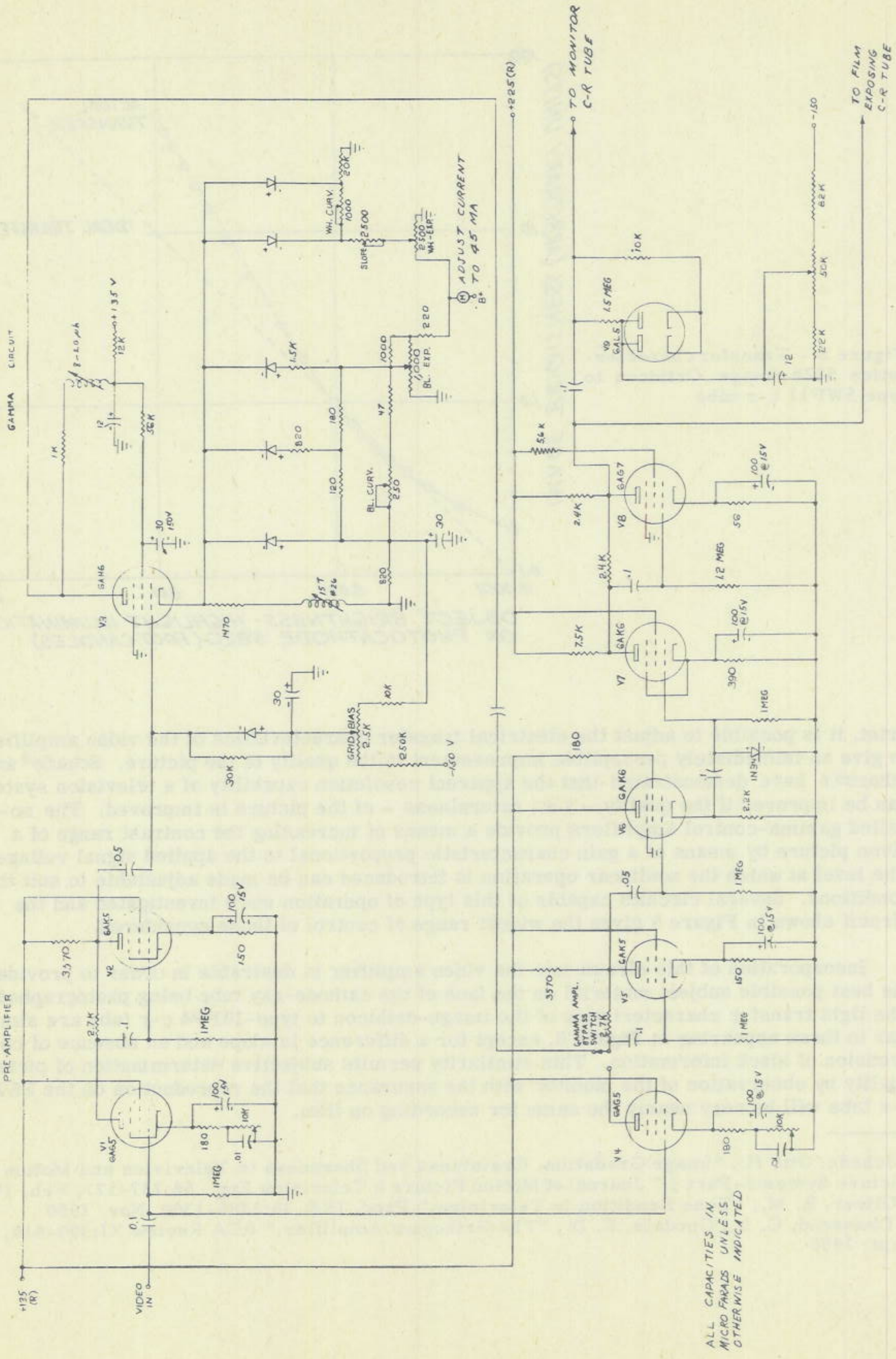

Figure 9 - Preamplifier, gamma control, and video amplifier

Electronic Shutter

It has been found desirable commercially to retain the 24-frame-per-second rate for motion picture recording and projection, chiefly because of the problems imposed by the necessarily intermittent motion of the film past the lens. Thus, in relation to the 30-frame-per-second tv rate, this slower cycle of operation means that some loss of televised information must be expected in the recording process. Special cameras having a 288^0 open shutter can be synchronized with the television frame rate to drop one-half a field every third field, so that four motion-picture frames are recorded for every five television frames. Standard cameras having a 170^0 open shutter and run at slightly less than 30 frames per second would record one complete field, but lose the second interlacing field, and the line structure of the television image would become apparent. If run at 15 frames per second, the interlaced television picture would be recorded, but every other television frame would be lost. Any of these methods of operation require extremely careful design and finishing of the mechanical shutter in order that the "shutter bar" effect is eliminated.

Gillette[7] and associates proposed the use of counter circuits to time the exposure of the film by blanking and unblanking the c-r tube under conditions controlled by the camera, thereby eliminating the mechanical shutter. Careful study was made of this technique. It offers several advantages over the alternative of having the camera synchronized by the tv signal. Primarily it eliminates an elaborate electromechanical synchronization network with consequent modifications of the camera drive. The shutter "opening" time can be adjusted for any type of camera, and can be changed rapidly and simply to operate with almost any tv line and frame rates which may be adopted for specialized military applications. The accuracy of the timing of events can be made high (in the order of 0.5 microsecond in a 50-microsecond interval and shutter-bar effects completely avoided.

The circuit of Figure 10 is based on that of Gillette with minor alterations as dictated by the particular operating conditions in the recorder. The operation of the circuit depends upon a noise-free horizontal synchronizing signal which has been derived in this equipment from the composite video signal by means of a gated separator circuit. The separator circuit will be described later. The negative-polarity horizontal sync pulses are amplified by V1 and diode-coupled into the first stage of the binary counter by means of a 6AL5 dual diode, V2. Each succeeding pulse operates on one or the other side of the first counter tube, producing a square-wave output at the plate of V3B. By using diode interstage coupling, only the negative-going portions of the square wave are effective in triggering the adjacent counter stage. The stability of the circuit is improved by this form of isolation from noise.

By means of the switches in the circuits of the reset diodes (V24 through V28) the counter can be set to indicate any number of pulses from one to 1024. This indication is in the form of a negative-going pulse at the cathode of V22A which couples to the plate circuit of the stop-coincidence stage, V23A. This stage is arranged so that horizontal sync pulses are continuously applied to the grid circuit of V23A through V22B, keeping V23A in a nonconducting state and V23B conducting. For a 525-line picture the counter is set to indicate an output from V21B after 524 pulses have been counted. The 524-count pulse stops conduction in V23B, transferring it to V23A, but the next horizontal pulse on the grid of V23A immediately transfers conduction back to V23B. The result, at the plate of V23B, is a positive-going pulse of approximately 53 microseconds duration which is used to trigger the shutter gate generator V31. Although this pulse could be differentiated and only the negative-going portion applied to V31, it was found that inverting the pulse in V29 improved the operation of the shutter multivibrator. The d-c voltage appearing at the plate of V31A is applied to the first anode of the cathode-ray tube. This voltage, during the time the film

[7] Gillette, F. N., King, G. W., White, R. A., "Video Program Recording," Electronics 23:90-95, Oct. 1950

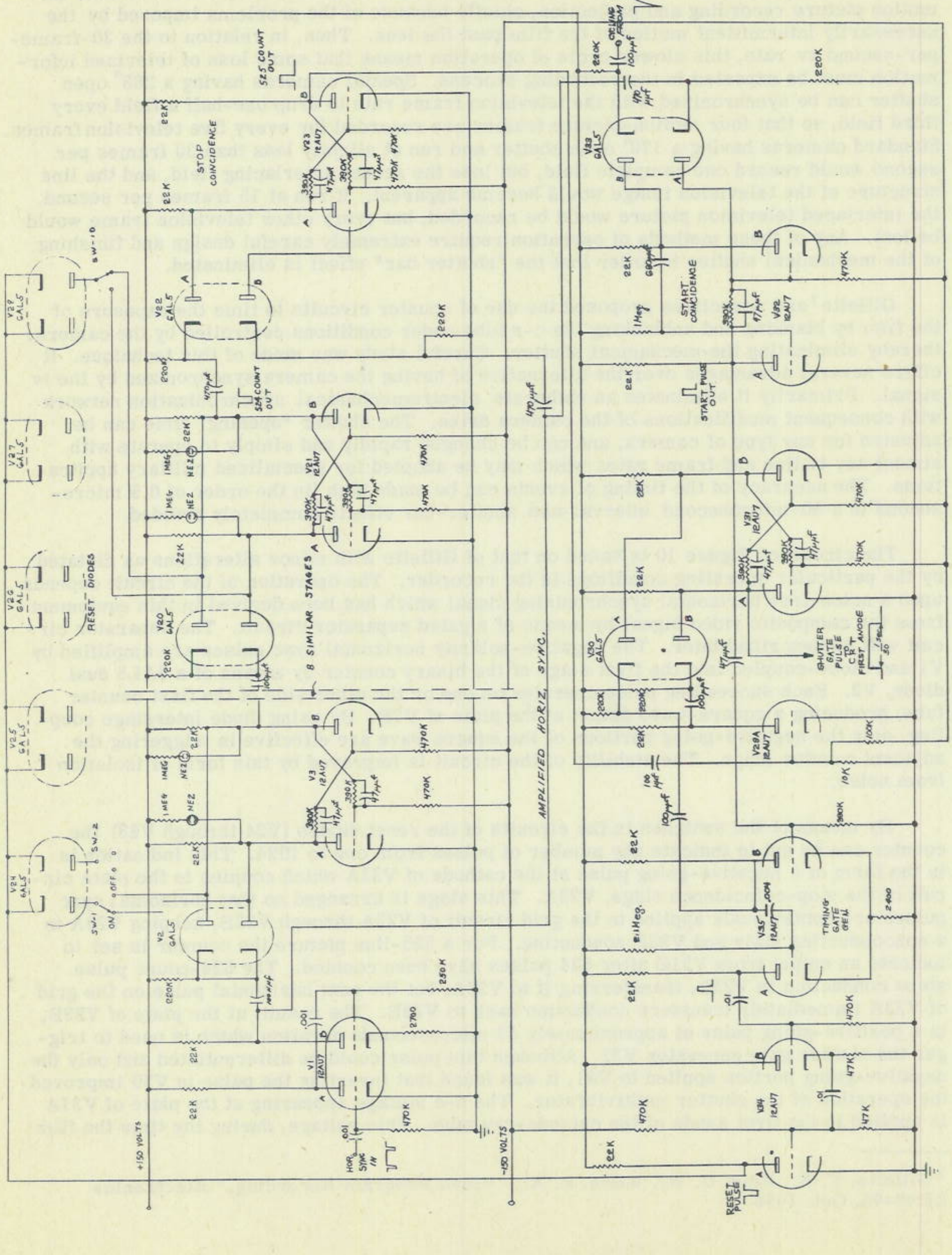

Figure 10 - Electronic shutter generator

is being exposed, is that of the B supply, which in the present configuration is 150 volts, but which can be increased if necessary. During film pulldown, the plate current of V31A causes an appreciable reduction in this potential which, in conjunction with a given fixed bias on the c-r tube, suffices to cut off the c-r beam current and blank the tube.

To control the start of the film exposure, a separate group of multivibrators is used whose final output is coupled through V30A into the shutter multivibrator, V31. The start-coincidence circuit of V32 is activated by a negative-going pulse derived from a circuit controlled by the motion-picture camera. The pulse is produced at the completion of film pulldown and supplied through V33B. V32 is a delay multivibrator, stable only when the "A" section is conducting. The time constant in this grid circuit provides a delay in the return to a stable condition after triggering. The duration of the delay is a function of the amplitude of the pulse derived from the camera, the amplitude of the horizontal sync pulses applied to V33A, and the supply voltage, as well as of the time constant in the grid circuit. These variables are reconciled to produce a delay equivalent to the time of two or three horizontal lines (150 μsec) before the circuit returns to the stable position. The delay is introduced in this circuit primarily to insure control of film exposure by a particular horizontal pulse following the "ready" pulse produced by the camera. This same horizontal pulse actuates the binary counter stages, initiating the desired count cycle. The delayed pulse from V32 is applied to the timing-gate generator, V35. This stage is also a delay multivibrator which performs two functions. The input section, V35B, is normally cut off. The output of V32 is amplified and inverted by V35B and applied to the shutter-gate generator through V30A. V35A generates a positive-going pulse which is coupled into V34 one-half of which functions as a cathode-follower providing a low-impedance driver for the diode reset-control tube, V34A. The negative-going pulse from V34A, when applied to the paralleled cathodes of V24 through V28, effects an erasure of whatever count may be present in the counter and starts a new counting cycle coincident with unblanking the c-r tube beam by the shutter gate generator.

Especial attention must be paid to maintain symmetry between stages when wiring the switches (SW-1 to SW10) controlling the plates of the reset diodes to facilitate setting for a desired count. A method for setting the count is described in Appendix B.

The large number of tubes required for this circuit can possibly be reduced by replacing the dual-diode interstage coupling by a cathode-follower coupling. The cathode-follower technique, if satisfactory, would reduce the total tube complement by at least five. Further tube reduction, based on this method of coupling, may not be possible in the four coincidence circuits, where complete blocking of positive polarity pulses is essential. The substitution of 6AN7 quadruple-diodes in the reset circuit would reduce the number of 6AL5 diodes by two, but an extra tube type is added. The performance of this latter type of circuit has not been determined: only a start on drawing the circuit diagram has been possible up to the present time.

Sync Separator Circuit

It has been stated previously that a noise-free horizontal sync pulse is necessary to operate the counter. In view of the probability that a composite video signal would be more frequently available than an independent sync, it was necessary to investigate suitable means of separating sync from video information. Allied with the problem of synchronization is that of controlling or correcting the frequency of the horizontal-sweep generator. Accordingly, various types of automatic frequency control circuits were considered. The circuit of Figure 11, combines both functions to a high degree, and has proved satisfactory in preliminary tests under severe noise conditions.

The circuit embodies a 6BN6 gated-beam tube connected as an amplifier of the video signal with sync-positive polarity. The bias on grid 3 is adjusted so that in the absence of

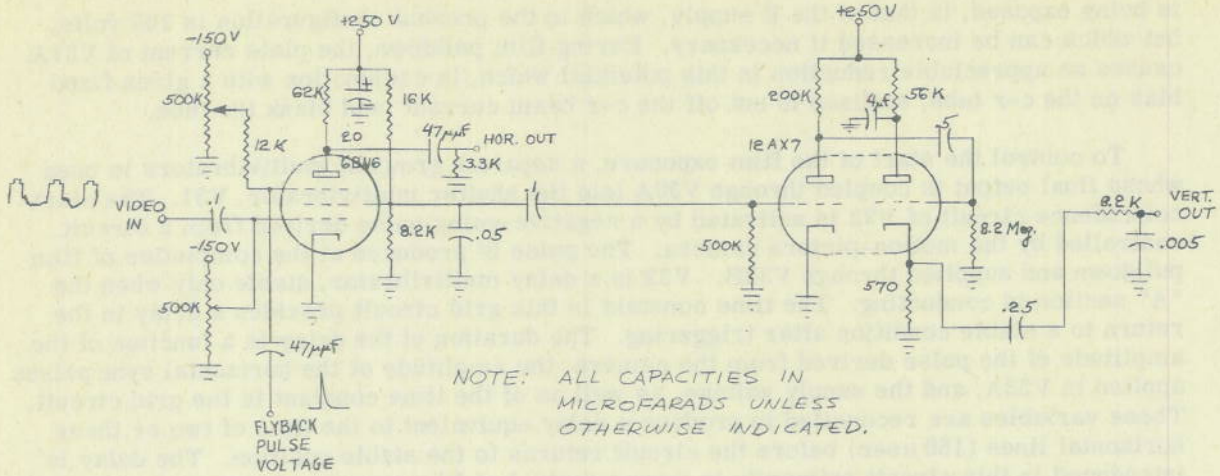

Figure 11 - Sync separator

a pulse derived from the horizontal-flyback voltage, no output is available from the plate circuit. The presence of the flyback pulse at the same time as the sync-pulse portion of the video permits plate conduction, and a negative-going pulse at the horizontal rate is produced. This is completely free of video information and, after differentiation, can be applied directly to the grid of the horizontal-sweep multivibrator. The bias on grid 1 is adjusted to keep the screen current at a value within the rating of the tube and to permit passage, primarily, only of the sync peaks. This mode of operation was found most satisfactory for efficient separation, and it improved the noise immunity. High amplitude positive-going noise pulses occurring at times other than during the sync-pulse interval, when the gating pulse is present on grid 3, do not appear in the plate circuit. It was found that a satisfactory vertical pulse could be recovered from the screen circuit if the output was integrated, clipped, and amplified in the 12AX7 tube as shown in Figure 11. The separated sync voltages from this circuit are sufficient to operate the counter circuit, and to synchronize the horizontal and vertical sweeps for the c-r tubes.

Viewing Monitor

A 10 FP4 c-r tube has been used as a monitor of the signal to be photographed. Conventional sweep circuits are used; these appear in Figure 12 for reference. The high second anode voltage available from the voltage-doubler supply improved the picture quality significantly.

Film Exposing C-R Tube

A sweep chassis for deflecting the 5WP11 c-r tube used for exposing the motion picture film has been developed using conventional circuits and components as shown in Figure 13. It will be noted that a gated sync-separator has been incorporated in this circuitry as well as in that of the monitor. It is probable that one can be eliminated by the use of cathode-follower distribution for the vertical and horizontal sync pulses derived from a single separator stage. Deflection components produced by the General Electric Company are more effective in this application than those of other manufacture. The high voltage necessary for the second anode of the 5WP11 is produced by an r-f supply which operates independently of the horizontal sweep. There is danger of damaging the c-r tube in the event of loss of horizontal or vertical sweep when this type of supply is used, and some

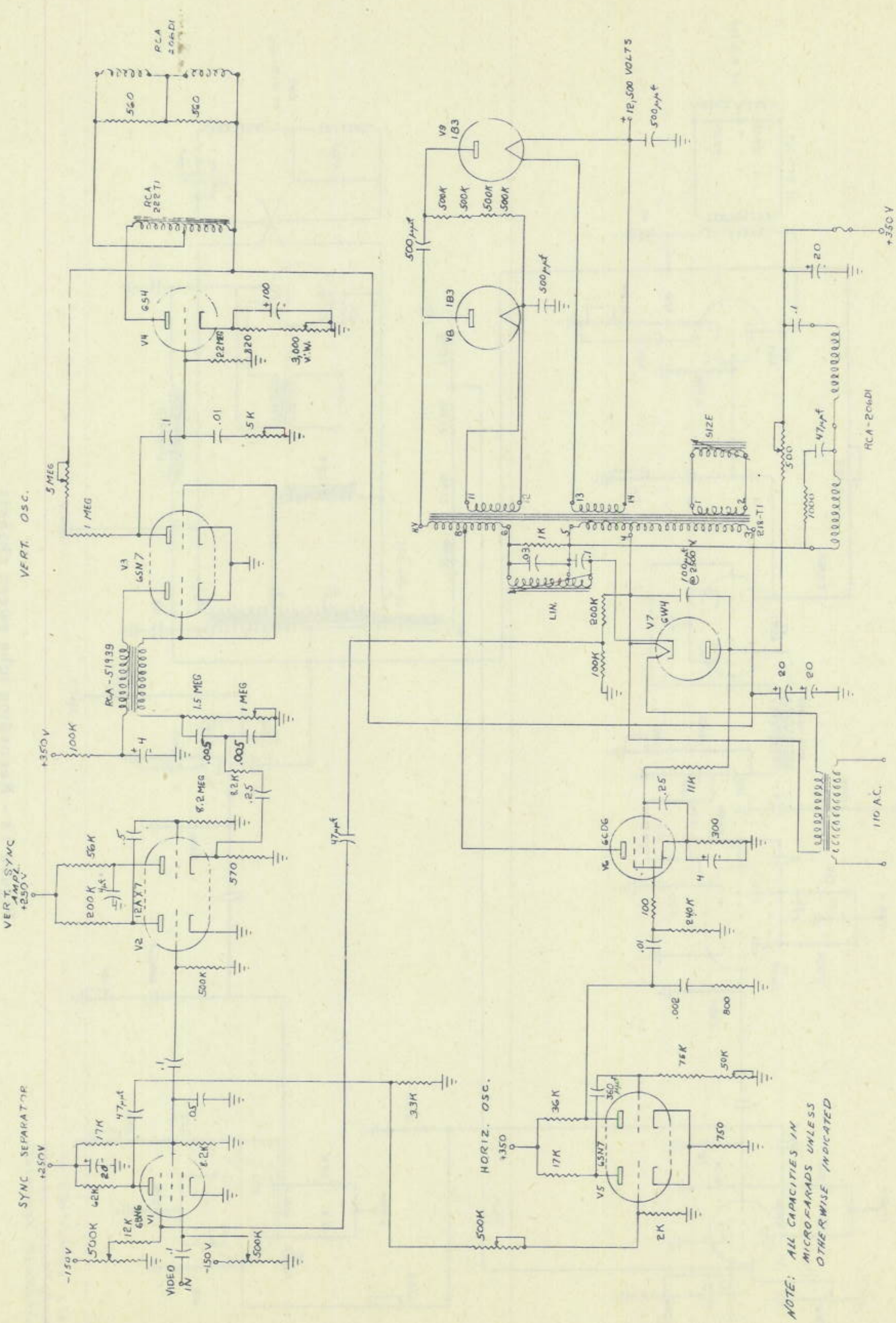

Figure 12 - Monitor sweep chassis

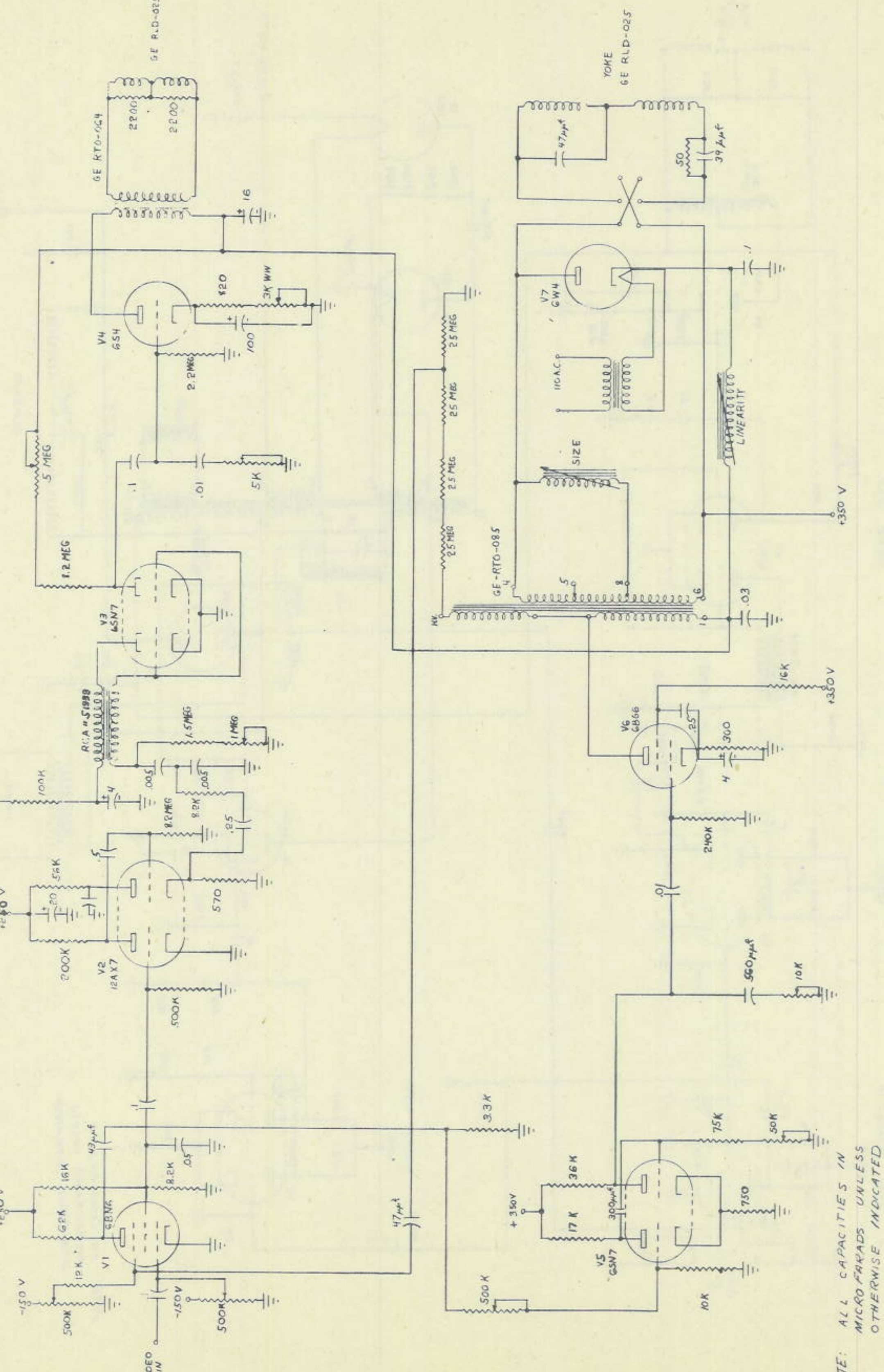

Figure 13 - Recording tube sweep chassis

thought has been given to protecting the tube by means of a circuit operating on the screen grids of the oscillator tubes. A possible circuit for this is shown in Figure 14, which will in this case protect only against failure of the horizontal sweep. A portion of the horizontal sawtooth voltage is applied to the plates of dual-diode V5 through a capacitor. The cathodes of this tube are connected to the screen grids of the oscillator tubes where the r-f bypass capacitors charge to the peak of the sawtooth voltage. This charge is utilized to supply the oscillator screen current requirements. In the event of failure of the horizontal sweep, the screen voltage will rapidly decrease to zero and oscillations cease. The feasibility of this circuit, beyond these theoretical considerations, has not been established.

When presenting a reversed image on the film-exposing c-r tube during direct positive recording, the video signal is inverted at the c-r tube by the method shown in the circuit of Figure 2. This causes the retrace lines that occur during the normal blanking interval to be intensified. To avoid their appearance on the recorded copy it is necessary to apply a blanking pulse at the horizontal rate to the grid of the 5WP11 during the time that the video signal is being injected into the cathode. This circuit, perhaps consisting of a single delay multivibrator, has not been checked as yet, but it should not present any problems in design or operation.

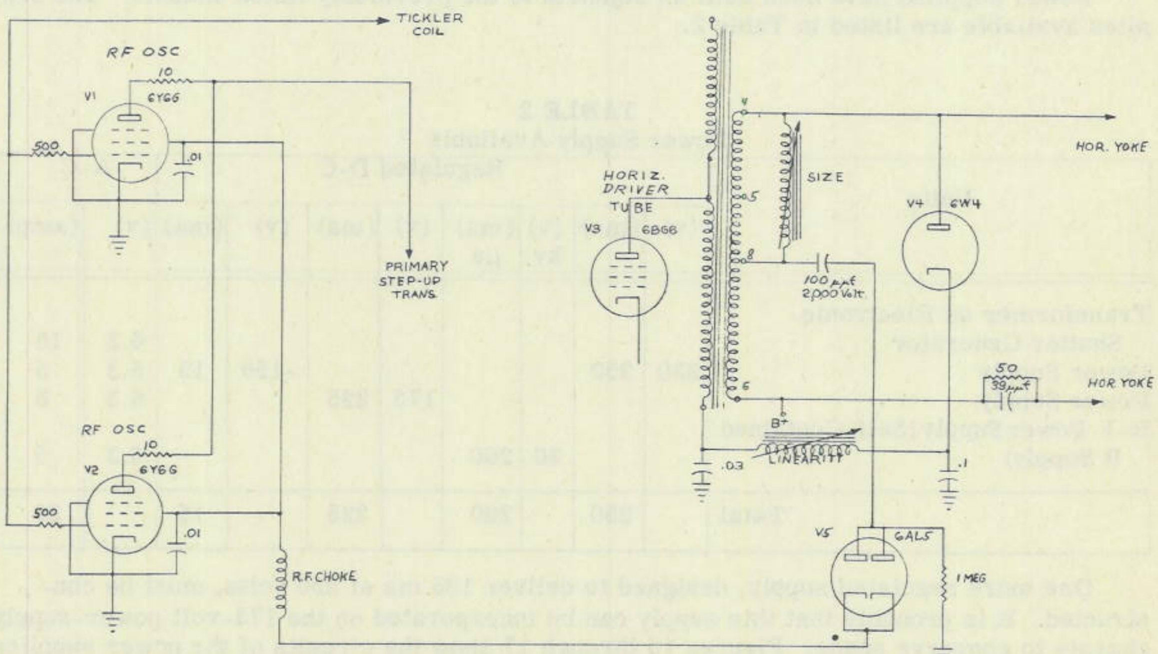

Figure 14 - R-F power supply and horizontal sweep interlock

Power Supply Requirements

The contemplated apparatus comprises 4 basic chassis, exclusive of power supplies. Their names or functions and the power requirements are outlined in Table 1.

TABLE 1
Power Supply Required

Units	Regulated D-C								A-C	
	(v)	(ma)	(v)	(ma)	(v)	(ma)	(v)	(ma)	(v)	(amp)
Electronic Shutter Generator	330		250		150	90	-150	5	6.3	10
Gamma Control and Video A			225	65	135	105	-90	1	6.3	2.65
Monitor Sweep and Sync Separator	330	135	250	20			-150	7	6.3	6.0
Film Tube Sweep Chassis	330	135	250	20					6.3	6.0
Total		270		105		195		13		24.65

Power supplies have been built as adjuncts to the previously listed chassis. The supplies available are listed in Table 2.

TABLE 2
Power Supply Available

Units	Regulated D-C								A-C	
	(v)	(ma)	(v) kv	(ma) μa	(v)	(ma)	(v)	(ma)	(v)	(amp)
Transformer on Electronic Shutter Generator									6.3	10
Power Supply	330	250					-150	15	6.3	5
Power Supply					175	225			6.3	6
R-F Power Supply (Self-Contained B Supply)			30	200					6.3	5
Total		250		200		225		15		26

One more regulated supply, designed to deliver 105 ma at 250 volts, must be constructed. It is probably that this supply can be incorporated on the 175-volt power-supply chassis to conserve space. Figures 15 through 17 show the circuits of the power supplies constructed thus far.

WORK YET TO BE ACCOMPLISHED

Electronic Focusing Accessory

The P-11 phosphor used on the film-exposing c-r tube has a maximum light output at a wavelength of 4600 Angstrom units. Visual focussing of the camera with this light is difficult inasmuch as the focal point for composite lens systems at this wavelength falls at a somewhat different point from that for longer-wavelength light; moreover, the sensitivity of the eye for blue light is down appreciably from the sensitivity to green and is reflected in lowered resolution capability. It appears desirable that a means be provided in this

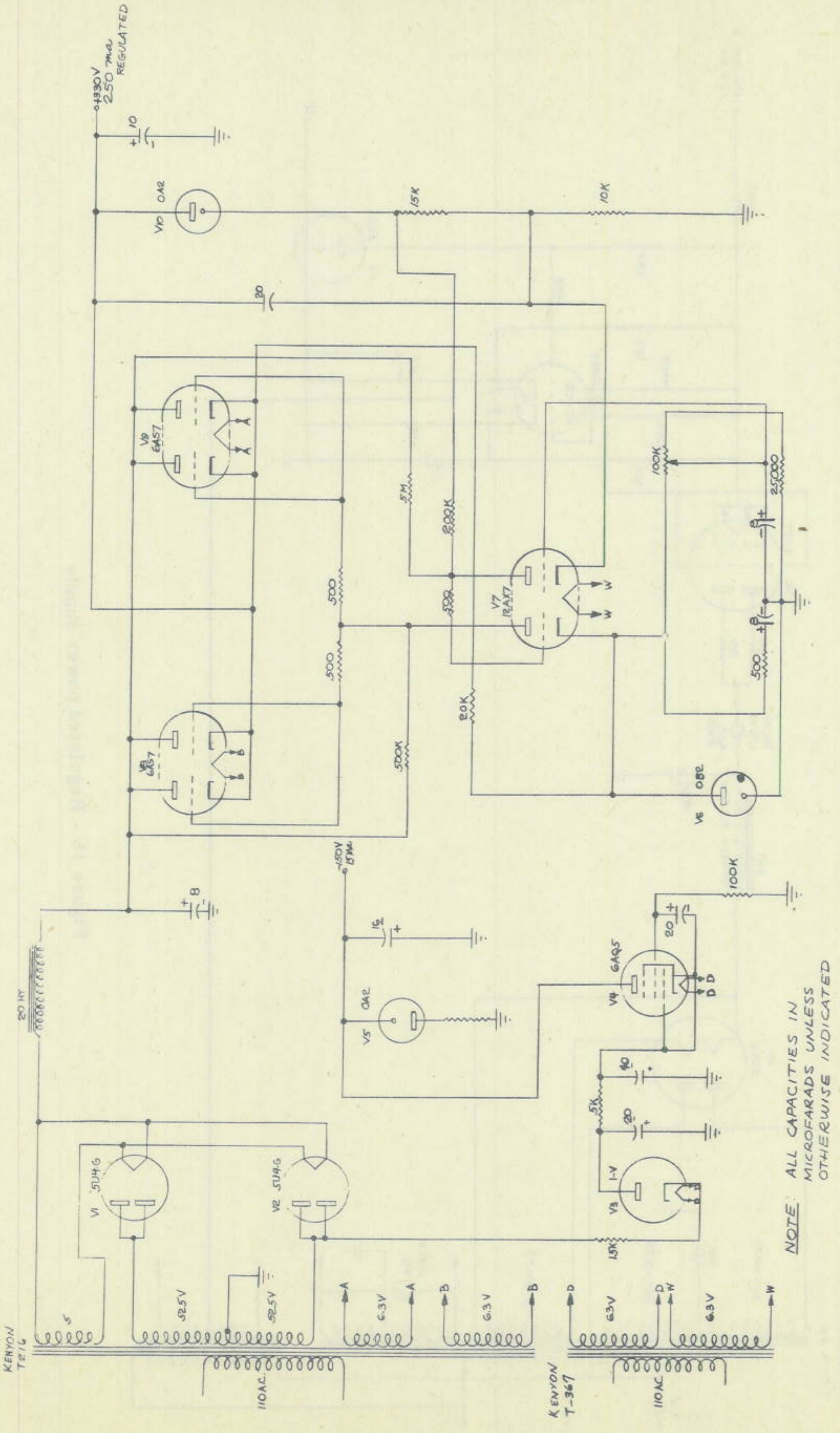

Figure 15 - Regulated power supply

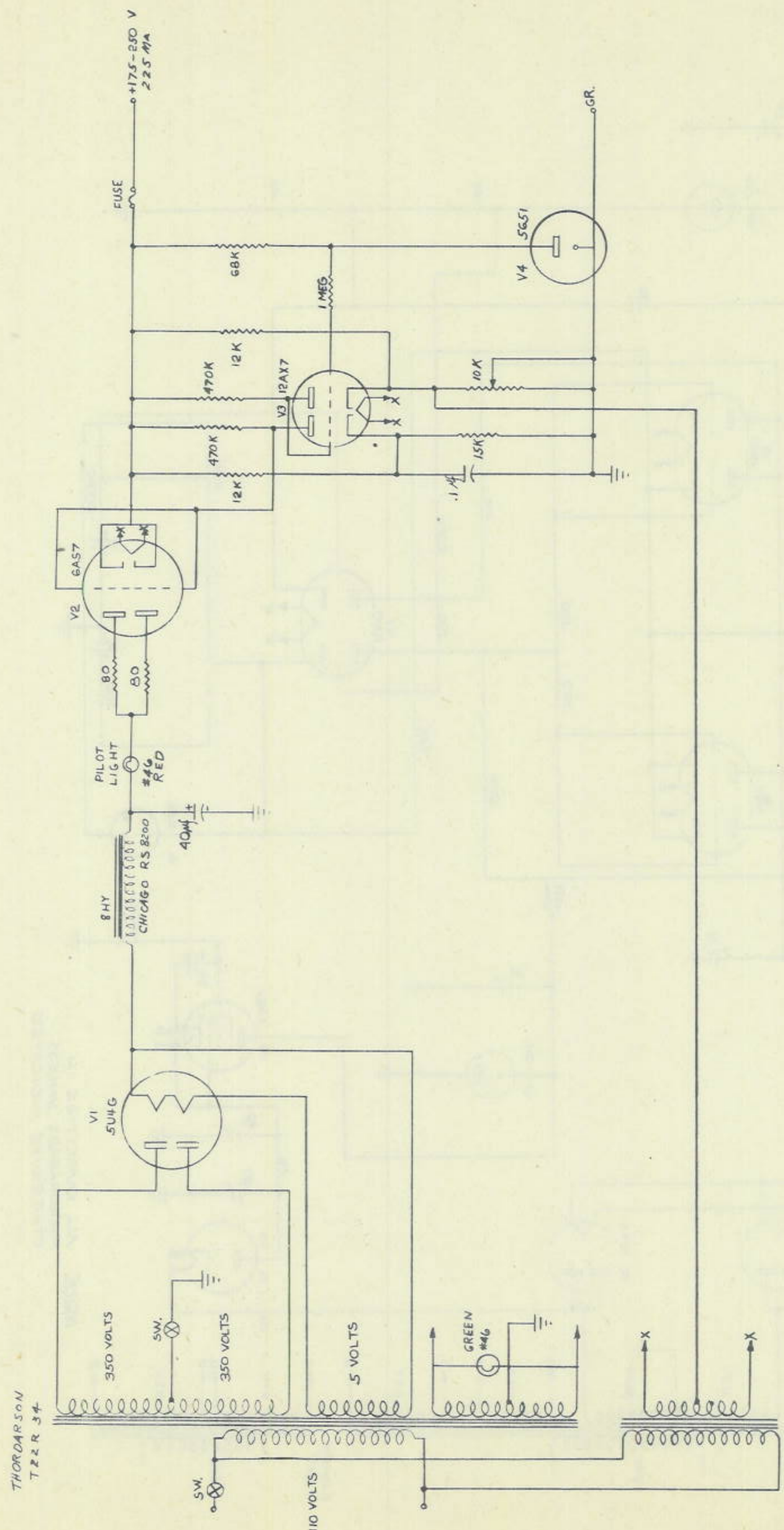

Figure 16 - Regulated power supply

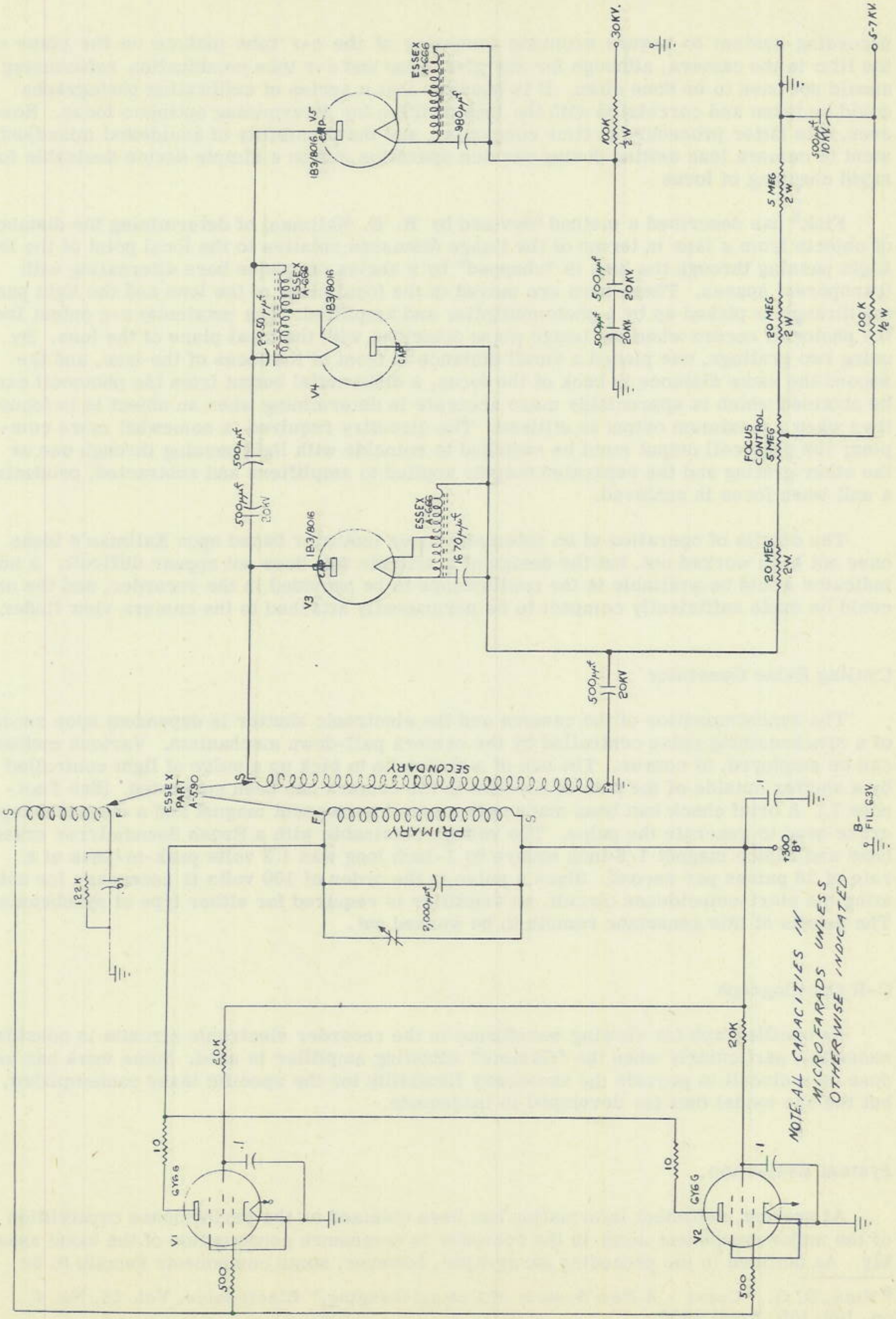

Figure 17 - R-F high voltage supply

recording system to assure accurate focussing of the c-r tube picture on the plane cf the film in the camera, although for any given lens and c-r tube combination refocussing should not have to be done often. It is possible that a series of calibrating photographs could be taken and correlated with the lens position for determining optimum focus. However, this latter procedure is time consuming, and the possibility of accidental misadjustment of camera lens setting during service operation makes a simple device desirable for rapid checking of focus.

Fink[8] has described a method (devised by H. E. Kallman) of determining the distance of objects from a lens in terms of the image distances relative to the focal point of the lens. Light passing through the lens is "chopped" by a series of opaque bars alternating with transparent spaces. These bars are moved in the focal plane of the lens and the light passing through is picked up by a photomultiplier and amplified. The maximum a-c output from the photocell occurs when the image plane coincides with the focal plane of the lens. By using two gratings, one placed a small distance in front of the focus of the lens, and the second the same distance in back of the focus, a differential output from the photocell can be obtained which is appreciably more accurate in determining when an object is in focus than when a maximum output is utilized. The circuitry required is somewhat more complex; the photocell output must be switched to coincide with light passing through one or the other grating and the separated outputs applied to amplifiers and subtracted, producing a null when focus is achieved.

The details of operation of an automatic focus indicator based upon Kallman's ideas have not been worked out, but the design of a suitable unit does not appear difficult. A null indicator would be available in the oscilloscope to be provided in the recorder, and the unit could be made sufficiently compact to be permanently attached to the camera view finder.

Cycling Pulse Generator

The synchronization of the camera and the electronic shutter is dependent upon receipt of a synchronizing pulse controlled by the camera pull-down mechanism. Various methods can be employed, of course. The use of a phototube to pick up a pulse of light controlled by a shutter outside of the path of the film in the camera has been suggested. (See Footnote 7.) A brief check has been made with a small permanent magnet and a magnetic-tape erase head to generate the pulse. The voltage obtainable with a Brush Soundmirror erase head and Alnico magnet 1/8-inch square by 1-inch long was 1.2 volts peak-to-peak at a rate of 28 pulses per second. Since a pulse in the order of 100 volts is necessary for actuating the start-coincidence circuit, an amplifier is required for either type of synchronizer. The details of this generator remain to be worked out.

C-R Oscillograph

An oscillograph for viewing waveforms in the recorder electronic circuits is considered essential, particularly when the "Gamma" adjusting amplifier is used. Some work has been done on a circuit to provide the necessary flexibility for the specific tasks contemplated, but the one model thus far developed is inadequate.

System Evaluation

At present, sufficient information has been obtained on the performance capabilities of the major component units in the recorder to commence construction of the basic assembly. As outlined in the preceding paragraphs, however, some components remain to be

[8] Fink, D. G., "Optar - A New System of Optical Ranging," Electronics, Vol. 23, No. 4, pp. 102-105, April 1950

developed. An evaluation of the performance of the recorder system must await completion of the remaining units. A block diagram of the composite apparatus appears as Figure 18.

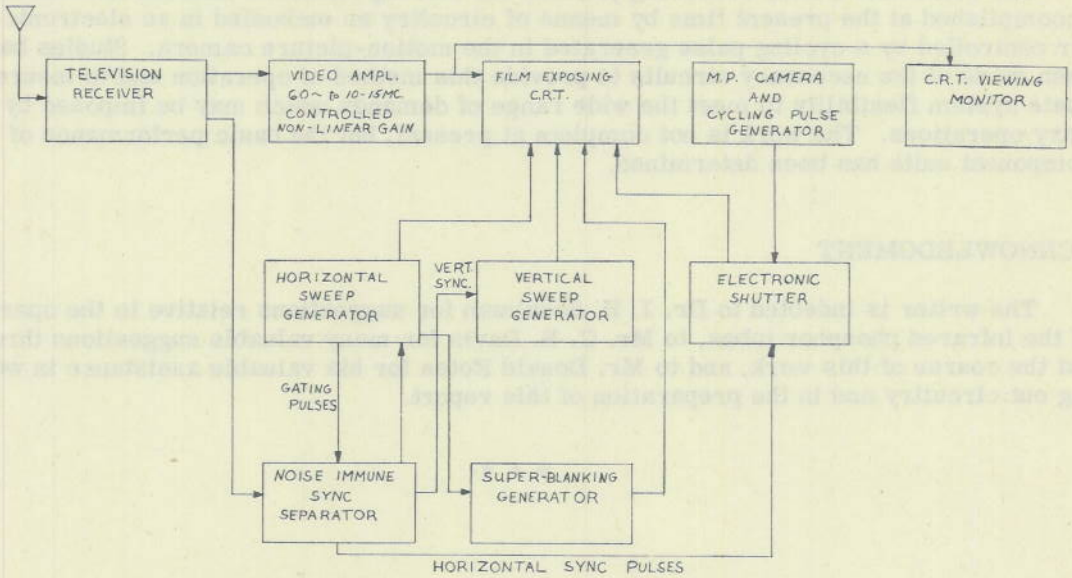

Figure 18 - Block diagram for television recording

A POSSIBLE RECORDING TECHNIQUE

The Crystal Branch of the Metallurgy Division of the Laboratory has developed two types of infrared stimulable phosphors. These phosphors are characterized by relatively slow rates of decay after excitation by cathode rays. The intensity of the trace several minutes after removal of excitation can be increased perceptibly if a pulse of infrared energy is applied to the phosphor. One of the tubes, having a calcium silicate lead manganese composition, exhibits a yellow fluorescence and phosphorescence with a retentivity characteristic which inhibits a reasonable reproduction of motion in the scene being picked up by the tv camera. Its light output when "flashed" by infrared is relatively low. It appears doubtful if this particular phosphor could be used as a short-term storage device. A second type infrared stimulable phosphor, zinc sulfide lead copper, exhibits a green fluorescence of relatively high intensity under cathode-ray excitation. Its persistence characteristic is noticeably shorter than that of the cadmium silicate, and an infrared flash against the phosphor suffices to produce a high-brightness, visible light pulse. It is possible that further development of phosphors of this type having shorter storage times could be used on a tv recording system. The decay time would have to be decreased to approximately 1 millisecond, and the trapped electrons in the excited phosphor would have to be completely freed during the tv vertical blanking interval when the infrared flash would be applied. The motion-picture film could be exposed during this interval by the flash of the infrared stimulable phosphor. Film pulldown would then be accomplished at a relatively leisurely rate during the succeeding two fields of the tv system. A considerable advantage of this system over those now in operation is that the complete television signal could be recorded instead of only 50 to 80 percent. The writing speed of the zinc sulfide type phosphor, its resolution capabilities, and its light output under infrared seem potentially adequate to such an application; but, from the brief checks which have been made thus far, more work on the storage characteristic will be necessary for successful operation in this manner.

CONCLUSIONS

The control of a film-recording process for storing televised information can be best accomplished at the present time by means of circuitry as embodied in an electronic shutter controlled by a cycling pulse generated in the motion-picture camera. Studies have been made of the necessary circuits to provide this method of operation and to insure adequate system flexibility to meet the wide range of demands which may be imposed by military operations. The work is not complete at present, but the basic performance of component units has been determined.

ACKNOWLEDGMENT

The writer is indebted to Dr. J. H. Schulman for suggestions relative to the operation of the infrared phosphor tubes, to Mr. C. B. Davis for many valuable suggestions throughout the course of this work, and to Mr. Donald Koten for his valuable assistance in working out circuitry and in the preparation of this report.

* * *

APPENDIX A

Determination of the Maximum Frequency in the Video Range

The sequential scanning processes most commonly used in television picture presentation are effected by focussed electron beams sweeping across selected target areas of the pickup or presentation tubes. In order to delineate fine structures in the scene being transmitted, high frequency modulation of the beam current must be achieved. Circuitry associated with the presentation or pickup tubes must be capable of accepting and amplifying these high frequencies.

If a checkerboard pattern consisting of black and white squares of the same size as the smallest picture element to be transmitted is used as the basis for an analysis, the waveform produced by scanning this checkerboard by an ideal scanning agent would result in a square-wave video signal. If only the fundamental of the square wave is considered, the video signal would be a sine wave of the same frequency, appreciably reducing the bandwidth requirements. This sine wave would not reproduce the picture as perfectly black and perfectly white squares of definite outline, but rather as gradually shaded areas. Although such a picture may be a poor reproduction of the original, it does re-establish the basic structure of the original picture. Therefore, a sine wave of the same fundamental frequency as the desired square wave is assumed to reproduce adequately the original checkerboard. Each square wave accommodates two adjacent picture elements of different brightness.

In order to determine the maximum frequency necessary to transmit and reproduce arbitrarily-small checkerboard elements, other factors involved in the process must be briefly considered.

Establishing the maximum number of horizontal lines which will be used in a picture immediately limits the maximum number of picture elements available in the vertical dimension of the nominally rectangular picture. Because a fraction of the available vertical sweep time must be allocated to returning the beam from the bottom of the picture to the top, not all of the horizontal lines can be used for picture presentation or scanning. A similar limit is imposed upon the horizontal sweep time available for scanning. These limits can be taken into account in arriving at an equation for determining the maximum frequency limits.

A second factor influencing the upper frequency limit is the rate at which the pictures are to be transmitted and reproduced. The time required for blanking retrace lines, which exceeds that of the actual retrace time, must be deducted from the total time available for picture transmission. This tends to increase the upper frequency it is necessary to transmit.

When the scanning beam intersects a boundary between two objects in the scene being observed, the line structure of the scanning raster imposes a discontinuity in the image signal, which, in the case of objects oriented at other than 90° with respect to the direction of scan, reduces the effective picture area. This reduction is taken into account in computing the maximum video frequency by an appropriate constant, K, termed the utilization factor.

In determining the maximum video frequency qualitatively, the following defined symbols will be used.

N = total number of scanning lines per picture

n_a = number of active lines per picture

n_i = number of inactive lines per picture

K = utilization factor

k = ratio of horizontal retrace velocity to trace velocity

q = ratio of vertical retrace velocity to trace velocity

w = width of picture area

h = height of picture area

V_h = horizontal scanning velocity

m = ratio of horizontal to vertical resolution

w/h = aspect ratio

F = frames per second (rate of picture presentation)

R = rate of transmission of picture elements

H_f = total time for one horizontal scan

The total number of lines in a picture, N, is the sum of the active and inactive lines, or,

$$N = n_a + n_i \qquad (1)$$

The active and inactive lines bear the same relationship to each other as the vertical retrace velocity does to the trace velocity. Thus,

$$n_a/n_i = q \qquad (2)$$

Substituting in (1) and solving for n_a

$$n_a = N/(1 + 1/q) \qquad (3)$$

The number of elements in a horizontal scan

$$n_h = (w/h)\, m\, K\, n_a \qquad (4)$$

Since n_a has been previously defined in (3), Equation (4) now becomes

$$n_h = (w/h)\, m K N/(1 + 1/q). \tag{5}$$

The time consumed in transmitting these elements, t, is determined by the picture width, the horizontal scanning velocity, V_h, and the total number of elements transmitted. Thus,

$$t = N(w/v_h + w/k\, v_h)\,. \tag{6}$$

But $t = 1/F$, the picture frame frequency, and, Equation (6), through substitution, becomes

$$V_h = w F N(1 + 1/k)\ , \tag{7}$$

the horizontal scanning velocity.

The time of one horizontal sweep, t_h, is equal to the width of the trace divided by the horizontal velocity, or

$$\begin{aligned} t_h &= w/V_h \\ &= w/w F N(1 + 1/k) \\ &= 1/F N(1 + 1/k)\,. \end{aligned} \tag{8}$$

The maximum rate, R, of picture element transmission is the maximum number of elements per line divided by the time in which the line is scanned. Thus,

$R = n_h/t_h$ or by substituting Equations (5) and (8) (9)

$$R = \left[(w/h) m F K N^2 (1 + 1/k)\right] \div \left[1 + 1/q\right]$$

The maximum frequency in cycles per second corresponding to this rate is one-half the value obtained in Equation (9), since one cycle corresponds to two picture elements.

The usual limits for k are between 7 and 10, and for q between 10 and 15. The utilization factor, K, is approximately 0.75 in representative television systems. Pictures are transmitted at a rate of 30 frames per second. The usual aspect ratio is 4/3; the horizontal resolution factor m is also considered 4/3. Substituting these values into (9) above and converting to frequency

$$f = \tfrac{1}{2}R = 1/2\left[4/3 \times 4/3 \times 30 \times 0.75 \times 525^2 \times (1 + 1/7)\right] - \left[1 + 1/12\right]$$

$$= 5.8 \text{ megacycles for } 525 \text{ line systems.}$$

For an 819-line system, using the same constants, the maximum frequency becomes by proportion,

$$\begin{aligned} f &= (819^2/525^2) \times 5.81 \text{ Mc} \\ &= 1.56^2 \times 5.81 \text{ Mc} \\ &= 14.14 \text{ Mc}\ . \end{aligned}$$

* * *

APPENDIX B
Method of Setting Binary Counter for a Desired Count

For a 10-stage scale-of-two counter, the maximum available count is 1024 units. By appropriate switching, which presets selected stages of the counter, the device can be made to deliver an output pulse after any desired number of input pulses up to this maximum of 1024.

The presetting of various stages of the counter, accomplished by reversing switch positions, has the effect of advancing the count by a fixed amount depending upon the switch selected. The following table lists these amounts:

TABLE 3

Switch Number	1	2	3	4	5	6	7	8	9	10
Count Advance	1	2	4	8	16	32	64	128	256	512

To set the counter to deliver an output pulse after any desired number of input pulses have been inserted into the counter, the steps outlined below should be followed.

1. Subtract the desired output count from the maximum available count;
2. From this remainder, subtract the highest power of two shown in the count advance column of Table 1 that is less than this remainder;
3. Continue subtracting successively lesser powers of two (obtained from Table 3) from each new remainder until the final remainder is one or zero;
4. The positions of the switches corresponding to the various powers of two used in Step 3 should now be reversed from the normal positions which give the maximum count of 1024.

As an example, assume it is desired to set the counter to deliver an output pulse after 524 input pulses have been received.

1. 1024 - 524 = 500
2. 500 - 256* = 244
3. 244 - 128 = 116
   116 - 64 = 52
   52 - 32 = 20
   20 - 16 = 4
   4 - 4 = 0
4. Therefore, switches 9, 8, 7, 6, 5, and 3 should be reversed.

*(256 is the highest power of two available in the counter which can be subtracted from 500.)

* * *

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