NsG 597

Northwestern

The Corralitos Observatory Astronomical Television System

Design Considerations

The television system described in this report was intended to permit operation of an image orthicon tube with as stable performance as possible, and with the highest resolution compatible with field operation. These requirements led to the following major design objectives:

1. The period of time during which an image is accumulating as a stored-charge pattern on the target should be free of magnetic disturbances from the sweep fields; therefore, the sweeps must be stopped before the photocathode is turned on and started again after the end of an exposure.

2. Image spreading after exposure and before the end of the subsequent readout frame should be minimized by providing for cooled operation of the camera.

3. Defocussing of the image section in "standard" operation (continuous exposure and consecutive readouts) should be avoided by using beam blanking rather than blanking by pulsing the target mesh negative. Beam blanking introduces a white reference-level instead of black, but it also means that clamping, which must be done during the retrace periods in order to maintain the signal DC level, is accomplished during a time when there is no beam noise present to cause the clamp level to wander.

4. Achievement of the highest visual resolution with easily manageable bandwidths in the video amplifiers plus the requirement for alternating exposures and readouts in one mode of operation lead to an incompatibility between optimum scanning rates for best visual presentation and for best photographic resolution. Thus both the horizontal

sweep speed and the number of lines per frame must be independently adjustable so as to allow these two conditions to be optimized empirically. This conclusion leads in turn to a requirement for the ability to switch control of sweep speed, beam current, and target voltage between two sets of controls so that the visual monitor may be viewed continuously at the optimum settings, and the photographic monitor may be operated with a different set of scanning parameters when a picture is to be recorded. Setup of the photographic, or Take, mode thus adds the requirement for a mode switch that allows the system to be operated continuously in the Take mode for setup.

5. The relatively slow frame-rates implied by alternating sweeps and exposures, and by the use of only 10 megacycles of bandwidth in the video amplifiers, imply that the visual monitor be equipped with a long-persistence screen to help reduce flicker. In order to display as much information as present or future image orthicons can produce under optimum conditions the photographic monitor must use a high-resolution; i.e., short-persistence, phosphor; also, the highest-resolution cathode ray tubes are of rather small size and must be underscanned to avoid excessive pincushion distortion. All these considerations led to the use of two monitors rather than one.

6. The desirable feature that this system be capable of use at low light-levels as well as for high-resolution work required that background interference in the video signal be held as low as possible. The shading circuits must, therefore, not introduce any unwanted noise, and the sweep circuits, particularly in the camera but also in the monitors, must not produce high-voltage flyback spikes or ringing in the horizontal deflection circuits.

7. Maximum linearity of the output presentation is required to maintain optimum resolution over the entire field. Also, the absolute linearity of the camera scan should be as high as possible so that the scanning speed and thus the effective beam current per element be constant over the whole field. The same requirements for constant discharge current lead to a sweep generator design in which the sweep amplitude is fixed by reversing the scan at fixed upper and lower voltage levels rather than depending on gain stability. The same technique eliminates the problem of DC drift in the integrators.

8. Overall stability requirements for camera-tube electrode voltages and of sweep waveform amplitudes call for well-regulated power supplies for all critical voltages.

System Configuration

The system consists of five major units: the Camera Unit, the Sweep Control Chassis, the Camera Control Chassis, the Photographic Monitor, and the Visual Monitor. In addition there are regulated power supplies mounted in available space, an A-scope for examination of the video waveform and for troubleshooting, a digital voltmeter indicating all image orthicon electrode voltages, some power supply voltages, position of the Cassegrain telescope secondary mirror and the position of the camera relative to its mount, and camera and dome temperature.

Camera Unit: The deflection assembly is mounted in a Netic-co-Netic shield which in turn is suspended with plastic blocks inside an insulated enclosure. Around the shield is wound a copper tube which is the expansion volume for a Freon-22 cooling system; the compressor unit is mounted under the dome. The whole camera is contained in an aluminum tube about eight inches in diameter and 18 inches long. The rear section is constructed so that the preamplifier plugs directly into the image orthicon socket, while the deflection and beam-blanking circuits are mounted on printed-circuit boards in shielded compartments around the central hole. The camera unit is mounted on ball-bushing ways and is driven along the optical axis by a motor-operated screw having a helipot readout giving position to the nearest hundredth of an inch.

The deflection circuits are direct-coupled to the deflection coils, and are of the type which compare the coil current, sampled with a small resistor, with the input sweep waveform. Strong correction is continuously applied to any error. The sweep current is always proportional to the sweep input voltage to within better than 1%.

The video preamplifier contains a high-speed capacitance-cancelling connection which reduces the output capacitance of the image orthicon about tenfold; gain of the preamp is 3.25, the effective transfer impedance being 130,000 ohms. Equivalent input noise current is about 15 nanoamperes. The preamplifier drives a 75-ohm video cable, separate from the camera cable.

<u>Sweep Control Chassis</u>: The principal groups of circuits on this chassis are the sweep generators, the shading and blanking waveform generators, the exposure control circuitry, and the Look-Take switching circuitry.

The sweep generators consist of analogue integrators. A constant current applied to the input of the horizontal integrator causes its output to rise linearly, until an upper-voltage-detector is activated. At this point the input current is switched to cause the output to integrate negatively. When the integral reaches the lower voltage detection threshold, the current is once again switched forward. The retrace current is always the same; the forward-trace current is derived from 1% resistors, switched from the front panel by the "Microseconds per Line" thumbwheel switches. Provision exists for injection of external synchronizing pulses, but the Horizontal Sweep Generator free-runs in normal operation.

The vertical sweep generator is identical in operation except that the forward-trace current consists of constant-amplitude, constant-width pulses generated during each horizontal flyback period. These pulses are coupled to the input of the vertical integrator through 1% resistors switched by the "Lines per Frame" thumbwheel switches on the front panel. The vertical separation between lines is thus independent of how often the horizontal sweeps occur or how long they take, and so, therefore, is the number of lines per frame. Since the vertical scan must always begin with a horizontal flyback pulse, there is no jitter in line-position. The start of a vertical frame may be delayed by injection of a synchronizing signal, but this provision is not used in the present system.

Each sweep generator feeds a set of line-drivers which provide low-impedance sweep waveform outputs at unity gain for the two monitors and for the external input of the A-scope. They also provide sweep signals to the Vertical and Horizontal Size and Position Control, thus allowing front-panel adjustment of camera sweep size and DC position. The same scanning waveforms are fed into a Shading Generator board which provides a combined vertical and horizontal shading signal under front-panel control.

A "Mode" switch on the front panel allows the system to be operated in three ways: (1) Free-running, with continual exposure and continual repetition of scans; (2) the "Look-Take" mode, in which sweeps alternate with exposures, and depression of a "Take" button can produce one readout frame under altered scan conditions with the photographic camera open; and (3) a "Take" mode in which the second set of scan controls is continually in effect for setup of the photographic monitor.

In the "Free-run" mode the sweep circuits are active but the exposure control boards are essentially out of the circuit. In the other two modes, the exposure control group operates.

In the "Look" mode the start of a vertical flyback is triggered by a flip-flop in the Delay 1 circuit and activates clamping circuits in both sweep generators. When each sweep voltage reaches zero during the flyback, a feedback current passes through forward-based diodes and prevents the sweep generator output from going more negative. The sweep cycles are suspended as long as the clamps are operative.

As the clamps are activated, a delay (Delay 1) is started; this is front-panel adjustable from about 20 milliseconds to 2 seconds. During this delay nothing at all happens because its purpose is to permit spacing of very short exposures, as for instance when one is doing time-lapse photography.

At the end of the Delay 1 cycle the Precision Delay is initiated and power is applied to a mercury-wetted reed relay that connects the image orthicon photocathode to the "Image Focus" voltage source (in the "Free-run" mode this relay is continually energized). The Precision Delay consists of an analogue integrator, the input current to which is switchable to three significant figures by precision resistors on a thumbwheel switch ("Exposure") through a range from one millisecond to 99.9 seconds. The integrating capacitor may be switched through four decades by the exposure range switch located on the front panel.

The Precision Delay cycle terminates when the integrator output voltage reaches a fixed level. At termination an end-of-exposure pulse is generated, the exposure relay is de-energized, and the end-of-exposure pulse enters the "Look-Take" board. If the "Take" button has not been depressed, this pulse is routed to Delay 1, turning off its input flip-flop. The clamps are removed from the sweep generators, completing their flybacks and generating one full forward scan; at the end of the forward scan the Delay 1 flip-flop is once again turned on, and the cycle repeats.

If the "Take" button has been depressed, several things happen. First, two relays are immediately energized, thereby transferring control of sweep speed and lines per frame to a duplicate set of thumbwheel switches and resistors. At the same time a voltage reaches the Target and Beam Switch board, and a duplicate set of Target Voltage and Beam Current controls comes into effect: this is necessary to compensate for a change in sweep speed and hence a change in effective scanning charge per picture element (strictly speaking, the video gain should also be switched, but this was not done in this system). The switching takes place at the beginning of Delay 1. At the end of the following exposure the end-of-exposure pulse now is routed to Delay 3 instead of reaching Delay 1 to reset its flip-flop.

At the start of Delay 3 power is applied to a relay which opens the Nikon camera shutter. Delay 3 has a small range of front-panel adjustment, and serves to let shutter vibrations die away before a readout takes place. At the end of Delay 3 a reset pulse is sent to the Delay 1 flip-flop, and the flybacks commence. In the "Take" mode the inverted "vertical pulse", present during forward scan as a negative voltage, is connected by the changeover relays to the Delay 3 board with the effect that as soon as the last half of the flyback is completed, taking only 1.5 milliseconds, the vertical pulse substitutes for the Delay 3 output in keeping the camera shutter open. The "Take" mode automatically terminates when the next vertical flyback starts, the "Look-Take" flip-flop being turned off by it; the relays open, the Nikon camera shutter closes and the film automatically advances, and the system returns by itself to the "Look" mode.

If the "Take" button is held down, or if the system is operating in the "Take" mode, the Nikon shutter will open at the beginning of every Delay 3 interval and remain open for the readout frame. Delay 1 may then be used to space the exposures, the minimum allowable spacing being set by the speed with which the Nikon film can be advanced to the next frame or about 1/2 second.

Camera Control Chassis: The camera cable connection is located at the back of this chassis; the front panel holds all camera electrode voltage controls, the switch for the digital voltmeter input connections, controls for alignment and focus coil currents for the camera, and calibration controls for camera and telescope optical-focus readouts.

All the normal image orthicon controls are present, the target and beam controls being present in duplicate for the "Look" and "Take" modes. In addition, all five dynode voltages are controlled by front panel knobs so that they may be used either to maximize weak signals or as video gain controls for large signals. The fine adjustment for the multiplier anode voltage is on this panel, as is a fine control for focus coil current. All controls are monitored by the digital voltmeter, and a pair of rear-projection readout devices displays a legend showing which voltage or current is being indicated by the voltmeter. The readouts are useful when the room is darkened or when one is not in a position to read the selector switch markings.

The Camera Control Chassis carries the voltage-divider resistors that set the ranges of the various controls, as well as the exposure relay and the photographic camera relay. All signals from the Sweep Control Chassis come to the Camera Control Chassis before proceeding to the camera. The video amplifier is located on this chassis, in a small "Minibox" with BNC input and output connections. This choice was dictated by the fact that the more logical Sweep Control Chassis location already contained more circuitry than anticipated.

Visual and Photographic Monitors: Electrically, these units are nearly identical. The chief differences are that in the Visual Monitor, a 10-KV modular power supply run off line voltage is used for a 10-inch tube while in the Photographic Monitor a 20-KV modular power supply of the same type is powered from a constant-voltage transformer and a Variac, and operates a five-inch precision CRT.

The deflection coils were selcted so that identical sweep drive circuitry could be used, both pairs being the same as the Camera deflection circuits. The video amplifiers have a gain of about five in each unit to produce the necessary 7-volt signal (low-drive CRTS were used) for each. The gain of the visual monitor video amplifer was trimmed to produce similar displays on the two monitors; a satisfactory picture on the photographic monitor results in a satisfactory picture on the visual monitor, this being the normal order of priority.

Since in either the "Look-Take" mode or the "Take" mode the sweeps are stopped for the duration of delays 1, 2, and (in "Take" mode) 3, it is necessary to blank both monitor beams to prevent burning the phosphors while the sweeps are stopped. The video signal, although it is clamped to a white reference voltage, is arbitrarily dropped to zero during the flybacks by a signal injected after the clamps (all DC coupling after the clamps). This drop is normally enough to provide blanking during continuous sweeps but is not enough when the sweeps stop entirely. Therefore, the horizontal deflection-current feedback signal, which is just like the sweep waveform voltage, is differentiated, and an unblanking circuit which is located in each monitor only allows the beam current to turn on during a forward horizontal sweep. Stopping the horizontal sweeps for any reason, then, results in biasing the electron guns to cutoff in both monitors. These unblanking circuits are also the sweep-failure fail-safe circuits since they operate from the resistor which samples the horizontal deflection coil current. Loss of vertical sweeps for considerable periods (no experiments concerned with maximum periods have been carried out, for obvious reasons) will not result in damage to the screen.

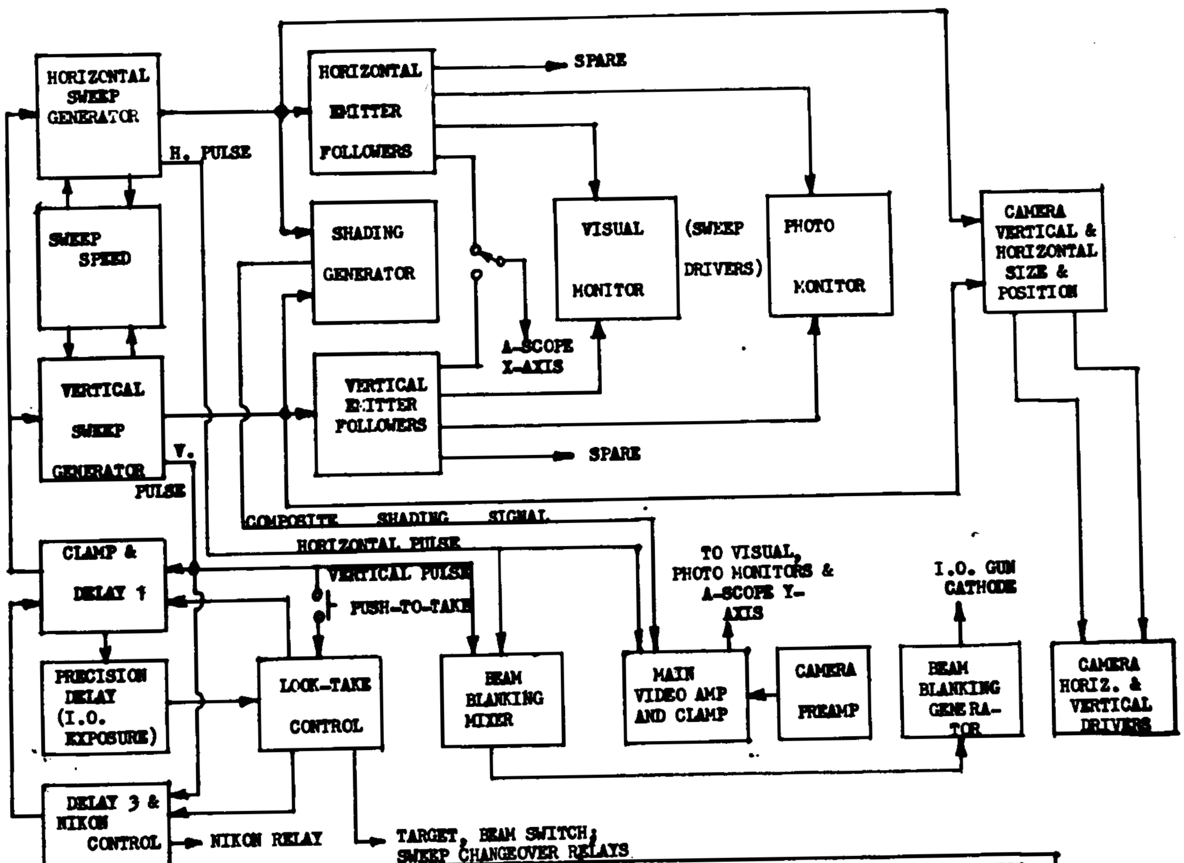
If either the -150 volt supply which provides the negative voltages for control of brightness or the +14-volt supply which powers the positive half of the photographic monitor sweep and also provides the blanking potential to cut off the CRT, should fail at the same time that the sweep circuit fails, then the fail-safe feature of the unblanking circuit would not work. Therefore, two relays are incorporated in the Photographic monitor chassis, one being activated by the presence of -150 volts and the other by presence of +14 volts. The 150-volt relay contacts are in series with the +14-volt relay coil while the +14-volt contacts are in series with the focus current supply for the CRT. If there is failure of either of these voltages, the photographic monitor loses its focus, resulting in a spot too large to burn the screen. This multiple failure is multiply unlikely, so only the $400 precision CRT is protected in this way—the $50 visual CRT will have to take its chances.

Each monitor has its own Vertical and Horizontal Size and Position controls, plus a Brightness control to operate grid number one (video drive is cathode-coupled) and a Focus control to vary the output of a regulated focus supply.

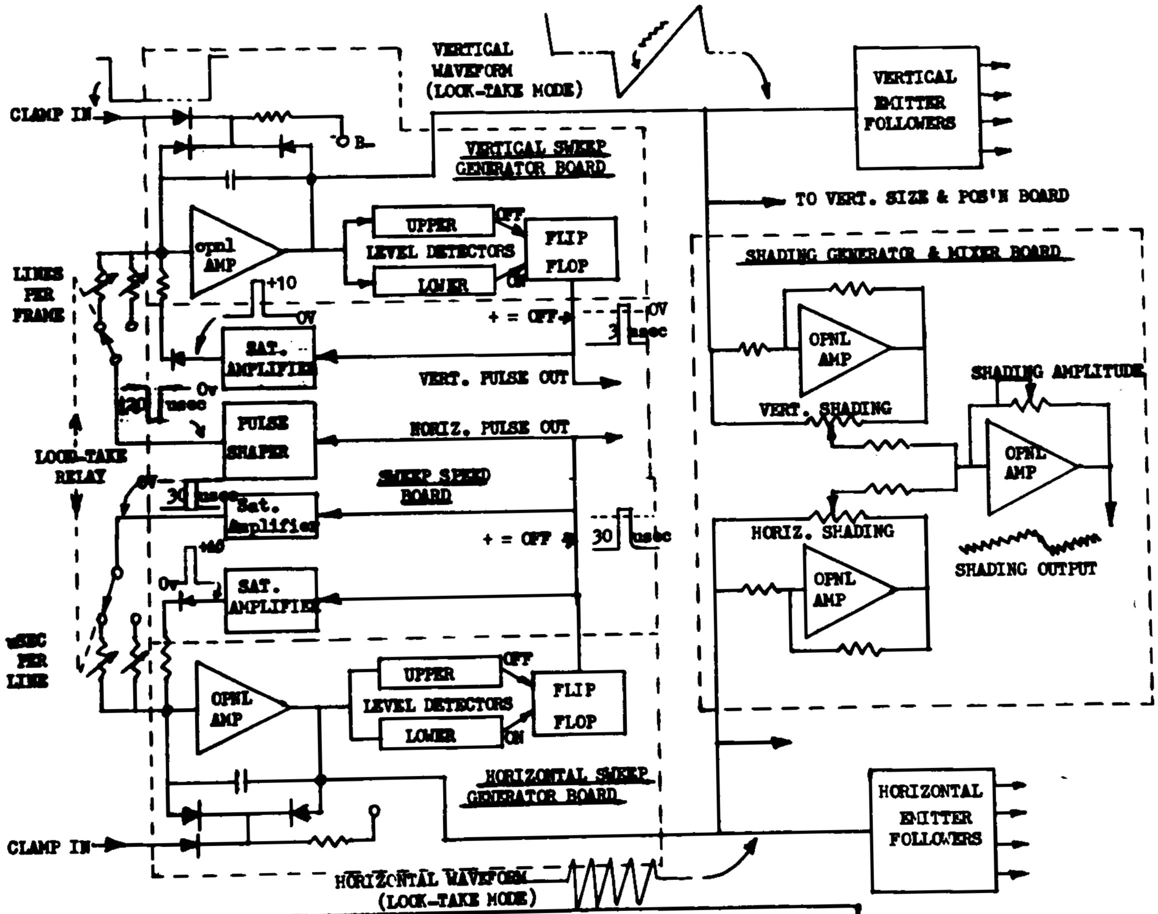
The Nikon camera is mounted in front of the Photographic Monitor on an aluminum frame, its position being adjustable by a handcrank-driven screw.

By choosing the proper combination of camera distance and image size, the pincushion distortion inherent in the precision CRT electron optics can be accurately compensated, over the entire field, by the barrel-distortion introduced when the Nikon camera lens is mounted on its close-up extension rings. The optimum picture size is about 2-1/4 inches square, permitting a maximum of 2250 scan-lines to be resolved since the screen will resolve 1000 lines per inch. Without further system refinements it is unlikely that more lines than this will be required.

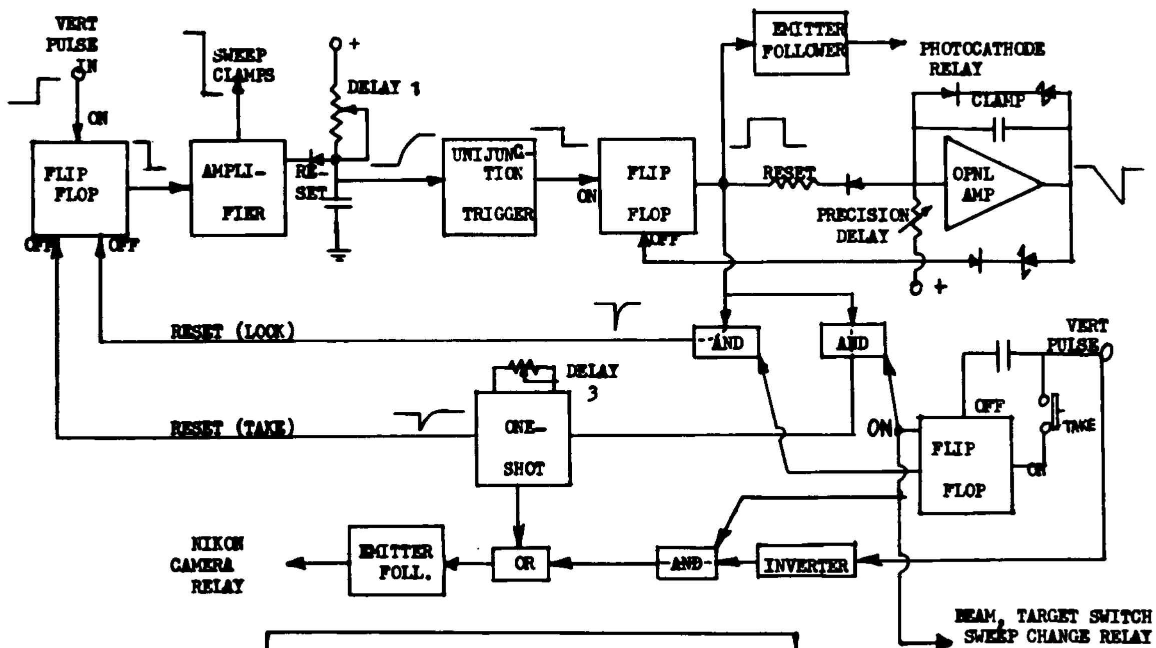
The recording camera has an electrically-operated back holding 250 exposures of 35-mm film, double-frame picture size. The square picture format allows space on each frame for inserting time and other information. When Plus-X film is used and when there is sufficient picture brightness for the f/4.5 aperture to be used, about 1500 scan-lines can be fully resolved by the camera; response would be down about 50% at 2250 lines.



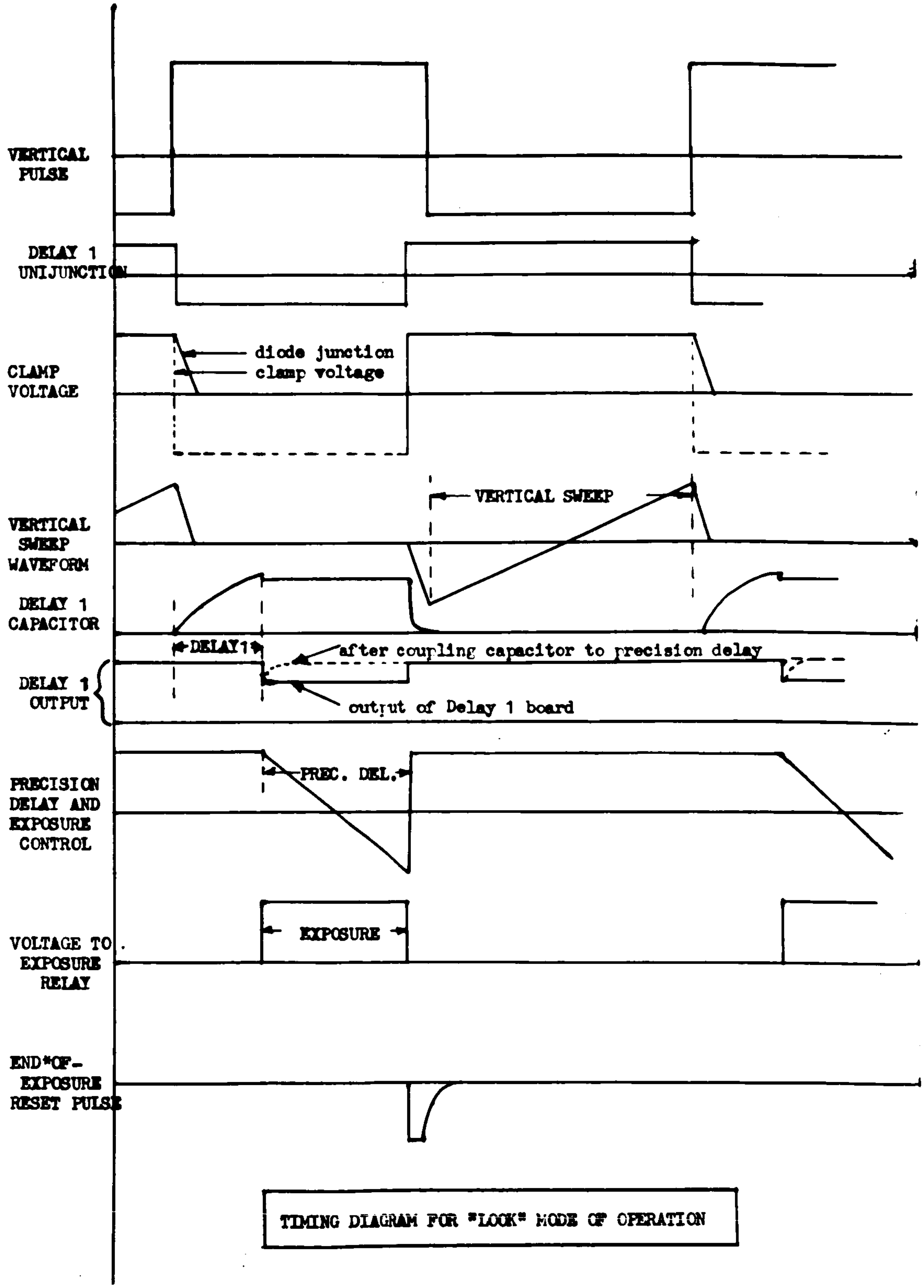
BLOCK DIAGRAM : SWEEPS AND SIGNALS, CONTROL CONSOLE, MONITORS, AND CAMERA



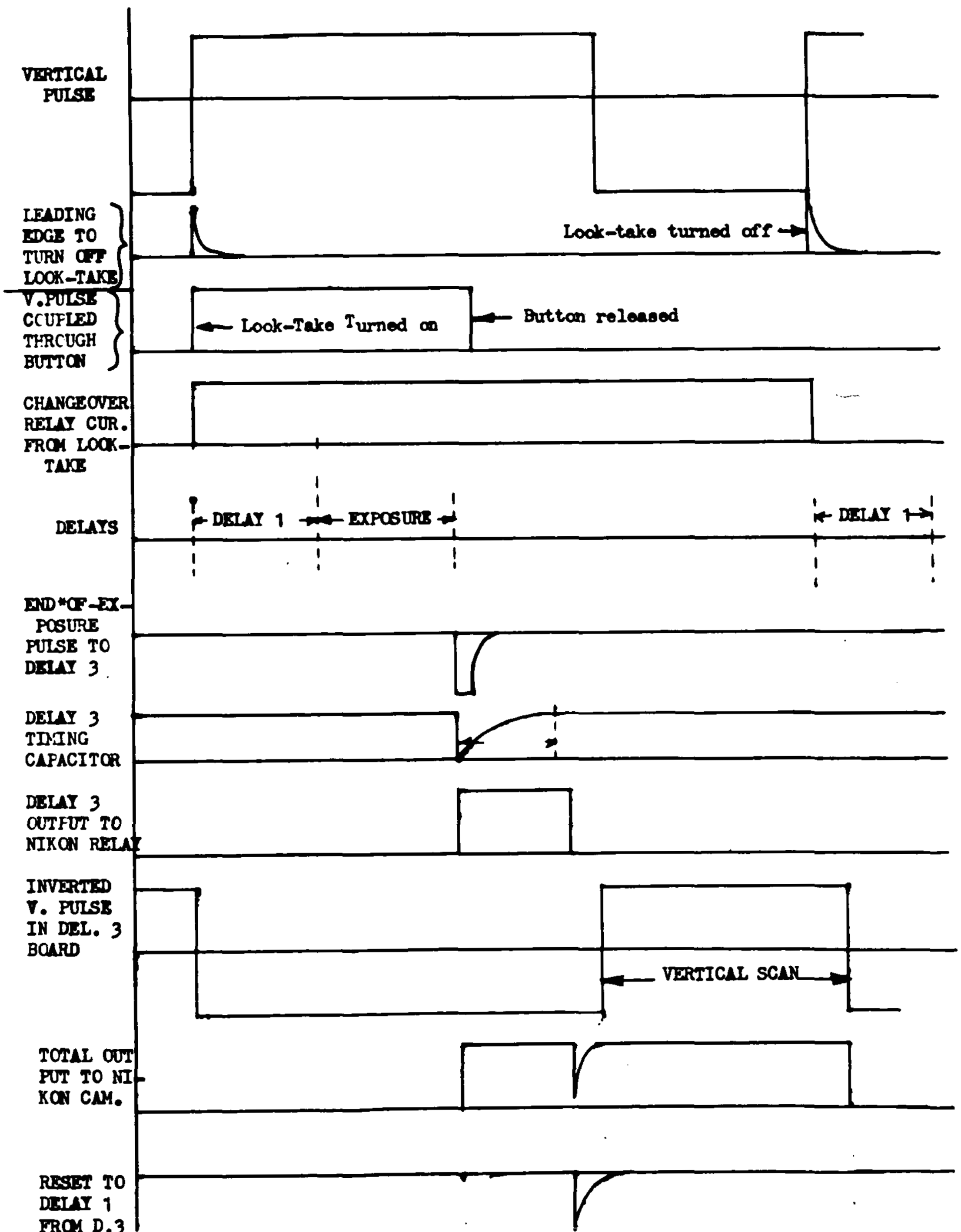
BLOCK DIAGRAM : SWEEP CONTROLS AND SHADING GENERATORS



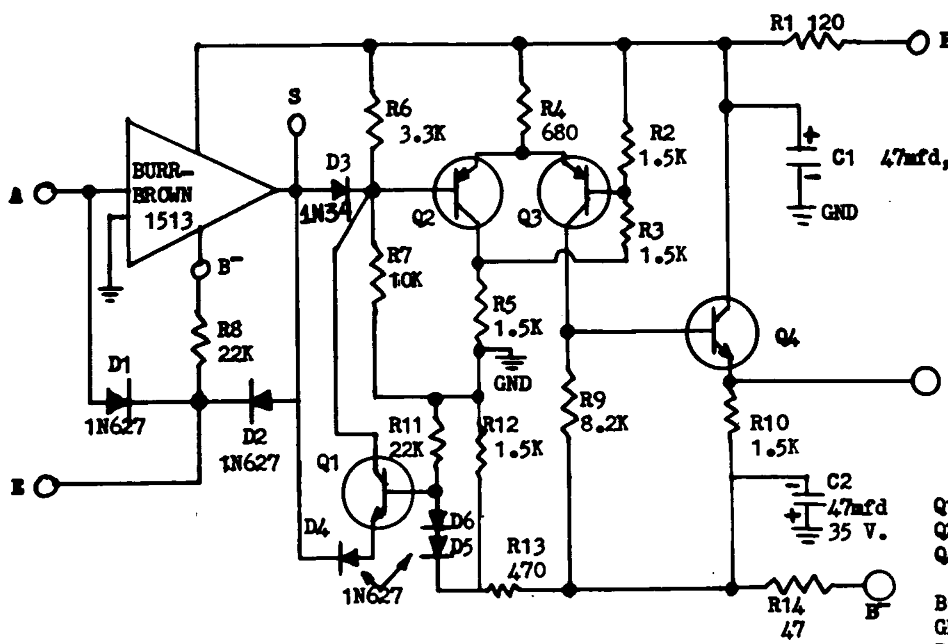
BLOCK DIAGRAM : DELAYS AND EXPOSURE CONTROL



TIMING DIAGRAM FOR "LOOK" MODE OF OPERATION



TIMING DIAGRAM FOR "TAKE" MODE OF OPERATION



Q1 - 2N3565
Q2,Q3 - 2N2189
Q4 - 2N3646 or 2N706A

B+ - Pin P
GND - Pin M
B⁻ - Pin K

VERTICAL SWEEP GENERATOR

BOARD 1: VERTICAL SWEEP GENERATOR

FUNCTIONS: To provide the vertical sweep drive waveform, and to provide the vertical pulse waveform.

CIRCUIT OPERATION: During the forward vertical sweep, 12-microsecond current pulses during horizontal flyback enter at Pin A, the input to the operational amplifier. Across the operational amplifier, from S to A, is connected the integrating capacitor. A stairstep waveform appears at pin S, positive-going.

When the stairstep reaches the level at which diode D3 begins to conduct, the flip-flop consisting of transistors Q2 and Q3 is turned off: Q1 ceases to conduct and Q2 begins to conduct. The voltage on the base of Q4 rises from the negative supply voltage to about +6v. This is the "vertical pulse" used in various other places in the circuit.

The vertical pulse goes to the Sweep Speed board where it is amplified and diode-connected to a resistor that injects a positive current into the input of the operational amplifier on this board. Thus, as soon as the vertical pulse goes positive, the output of the operational amplifier begins to go rapidly negative. If there is no positive voltage at point E (normally held close to B+), then D2 will conduct; and when the output reaches zero, D1 will conduct, preventing the operational amplifer output from decreasing further: this is the sweep clamp.

If point E is positive, or if the voltage is restored to a positive potential, the output of the operational amplifier will continue to drop below zero. When it reaches a sufficiently negative voltage, D4 will start to conduct, turning on Q1; the collector current from Q1 goes to the base of Q2 where it turns Q2 on and Q3 off. The vertical pulse thus drops back to a negative potential, and the retrace current from the Sweep Speed board is turned off. The next horizontal flyback period will produce a current pulse into the integrator, beginning the forward vertical scan again.

D5 and D6 are silicon diodes to temperature-compensate the drop in D4 (which prevents reverse breakdown in Q1) and the base-emitter diode in Q1. R12 and R13 comprise a voltage divider adjusted to give equal positive and negative swings of the output sweep waveform. The drop across the germanium diode D3 compensates for temperature changes in the base-emitter diode of Q2.

PIN CONNECTIONS:

- A - connected to junction of timing capacitor and Look-Take relay that selects which particular set of lines-per-frame resistors is in effect
- E - clamp voltage input from Delay 1 board
- K - B^-
- M - Ground
- P - B^+
- S - connected to high end of timing capacitor and input to Vertical Emitter Follower Board
- Z - Vertical Pulse output connected to Sweep Speed board, beam-blanking generator on Beam and Target Switch board, one changeover relay contact, Look-Take board, Delay 1 board, Delay 3 board

R1,2,3,4: 1K

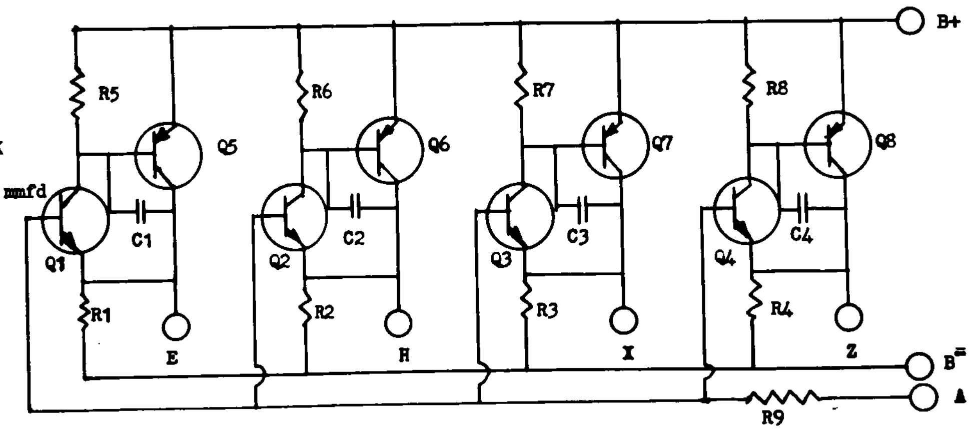
R5,6,7,8: 2.2K

C1,2,3,4: 500 mmfd

Q1,Q2
Q3,Q4 : 2N3565

Q5,Q6
Q7,Q8 : 2N3638

R9: 560



VERTICAL COMPOUND EMITTER FOLLOWERS

HORIZONTAL COMPOUND EMITTER FOLLOWERS

BOARDS 2 and 5: COMPOUND EMITTER FOLLOWERS

FUNCTIONS: To provide four low-impedance outputs for each of the two sweep generator boards. Gain is very nearly 1, and output impedance is on the order of 10 ohms.

CIRCUIT OPERATION: The input waveform enters Pin A, and goes through an RF isolating resistor, R9, to all the bases of Q1, Q2, Q3, and Q4. Transistors Q5, Q6, Q7, and Q8 provide strong negative feedback to the emitters of the lower transistors; the capacitors are necessary to prevent the feedback pair from oscillating.

Because of the strong negative feedback the upper four transistors are vulnerable to short-circuits from output to ground. Failure of these circuits should always lead to an immediate search for a short circuit to ground or B^-.

The four outputs are at pins E, H, X, and Z.

PIN CONNECTIONS: Vertical:

- A - receives waveform from Vertical Sweep Generator, Pin S.
- E - output to BNC No. 1, Visual Monitor Vertical Sweep cable.
- H - output to BNC No. 2, Photographic Monitor Vertical Sweep cable.
- X - output to BNC No. 3, Output to A-scope external vertical input (through switch).
- Z - output to Vertical and Horizontal Size and Position Board, Pin E.
- K - B^- (same for horizontal)
- M - Ground (same for horizontal)
- P - B^+ (same for horizontal)

Horizontal:

- A - receives waveform from Horizontal Sweep Generator, Pin S.
- E - output to horizontal BNC No. 1, Visual Monitor Horizontal Sweep cable.
- H - output to horizontal BNC No. 2, Photographic Monitor Horizontal Sweep cable.
- X - output to horizontal BNC No. 3, A-scope external horizontal input (through switch)
- Z - output to Vertical and Horizontal Size and Position board, Pin U.

R1, 2, 5, 8, 13, 14, 17, 19, 20, 21 = 10K

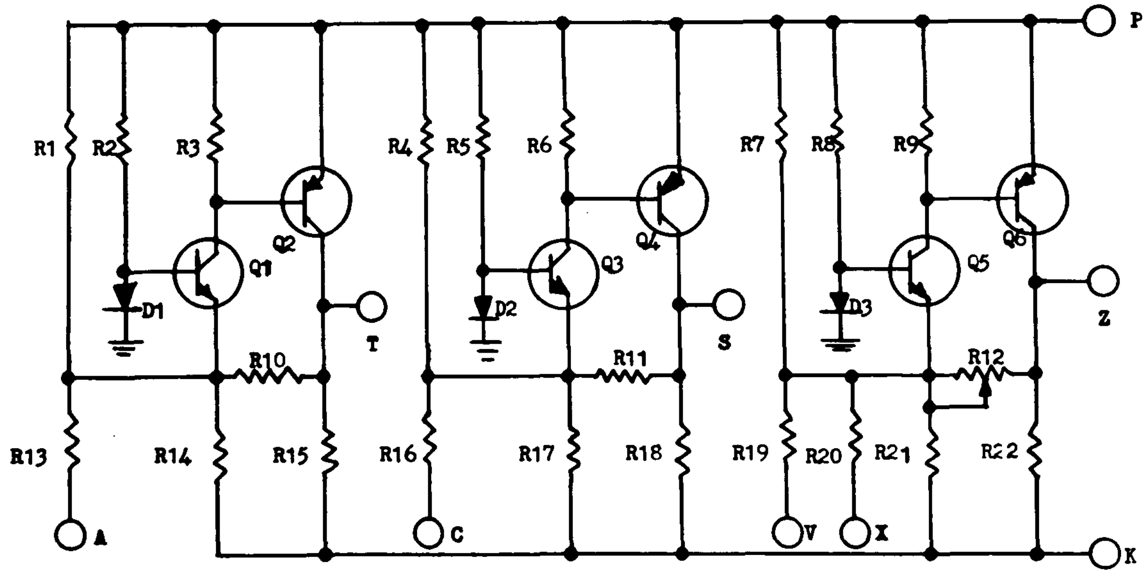
R3, 6, 9 = 1.8K

R4 = 12K

R7 = 27K

R10,11 = 2.7K
R12 = 5K Trimpot
R15, 16, 18, 22 = 2.2K

D1, 2, 3 = 1N627
Q1, 3, 5 = 2N3646 or 2N706A
Q2, 4, 6 = 2N3638 or 2N2189



SHADING GENERATOR AND MIXING AMPLIFIER

BOARD 3: SHADING GENERATOR AND MIXING AMPLIFIER

FUNCTIONS: To generate two waveforms like the sweep waveforms, but uniformly adjustable from maximum positive to maximum inverse phase, through zero, and then to mix the resulting signals additively to provide a composite shading signal.

CIRCUIT OPERATION: Three operational amplifiers are used consisting of transistors Q1 and Q2, Q3 and Q4, and Q5 and Q6.

Looking at the first amplifier, we see that Q1 and Q2 constitute a complementary feedback pair, negative feedback being connected from the collector of Q2 through R10 to the emitter of Q1. The potential at the emitter of Q1 will be approximately zero voltage with the diode D1 in the base circuit nearly compensating the base-emitter diode drop of Q1: this is also the temperature stabilization for the stage.

R1 is selected so that with the input pin A grounded and, the shading potentiometers centered, the voltage at pin T is zero. If Q1 is changed, R1 must be adjusted.

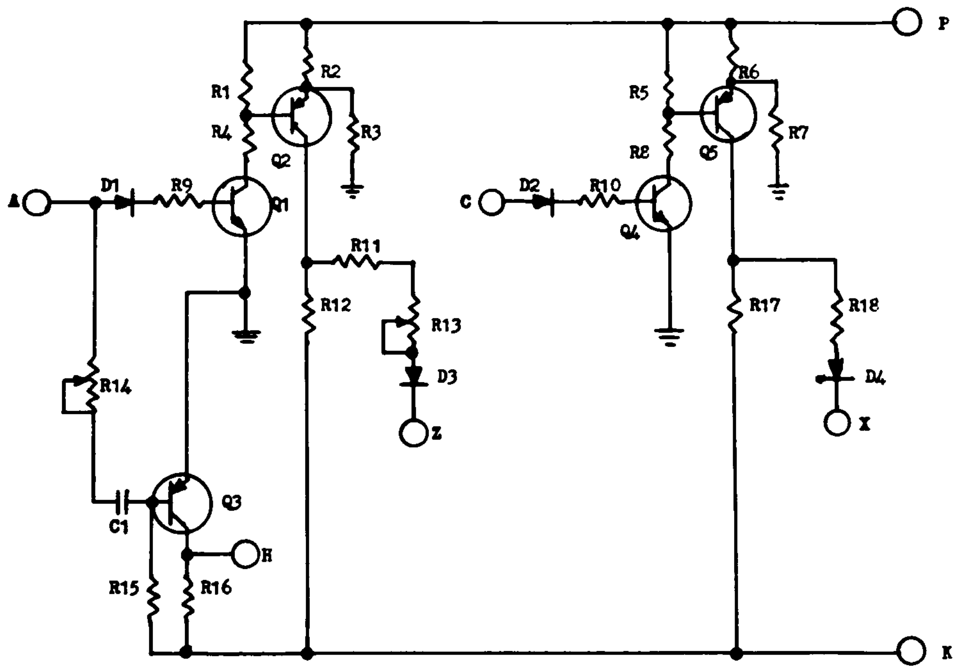
When this stage is balanced for zero voltage at T, the output voltage will depend on the current injected into the emitter of Q1 through R13 from pin A. Pin A receives the sweep waveform, and the inverted waveform appears, with about 1/3 the amplitude, at pin T. From pin A to pin T, externally, the shading potentiometer is connected, with a resistor in series with one side to give equal shading voltage on either side of zero as the pot is moved through its full range.

The second amplifier (Q3 and Q4) is the same as the first; the sweep waveform is applied at pin C and its inverse appears at pin S. The zero-trimming resistor is R4.

The two wipers of the vertical and horizontal shading controls are connected to two input resistors to the last stage, R19 and R20. Since the emitter of Q5 is held at ground potential by the negative feedback connection through R12, the currents from R19 and R20 sum, and flow through the potentiometer almost without distortion. At pin Z appears the composite shading signal, adjustable by means of changing R12. This signal has a DC level of approximately zero volts, and R12 is adjusted to give just enough range of shading to meet the system needs.

PIN CONNECTIONS:

- A - Vertical sweep waveform from pin Z, Vertical Emitter Followers and one side of vertical shading potentiometer.
- C - Horizontal sweep waveform from pin Z, Horizontal Emitter Followers and one side of horizontal shading potentiometer.
- K - B^-
- M - Ground
- P - B^+
- S - Remaining end of Horizontal shading potentiometer.
- T - Remaining side of Vertical shading potentiometer.
- V - Wiper of horizontal shading potentiometer.
- X - Wiper of vertical shading potentiometer.
- Z - Shading output to pin 16 of amphenol 20-pin connector, and thence to shading input of video amplifier.



R1, 5, 10 = 2.2K
R2, 6 = 100 ohms
R3, 7 = 3.9K
R4, 8 = 4.7K
R9 = 10K
R11 = 47K
R12 = 6.8K
R13 = 10K Trimpot
R14 = 20K Trimpot
R15 = 33K
R16 = 1K
R17 = 6.8K
R18 = 5.6K

C1 = 470 pf

D1,2,4 = 1N627
D3 = T.I. 10

Q1, 4 = 2N3646
Q2, 3, 5 = 2N3638

SWEEP SPEED AND RETRACE CONTROL

BOARD 4: SWEEP SPEED AND RETRACE CONTROL

FUNCTIONS: To produce the retrace current required for both sweep generator circuits, and to generate a constant-duration, constant-amplitude pulse during each horizontal retrace period for stepping the vertical sweep voltage upward during forward scan.

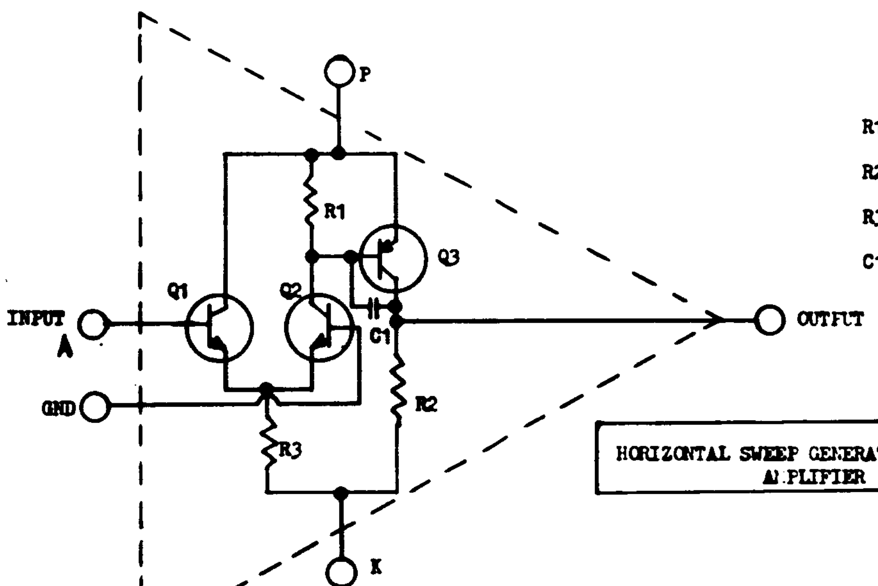
CIRCUIT OPERATION: Q1 and Q2 comprise a direct-coupled amplifier receiving the horizontal pulse from pin A. When this pulse goes positive, diode D1 conducts (it prevents breakdown of Q1 and loading of the vertical pulse generator while the pulse is negative); and Q1 turns on to saturation, R4 limiting the current into the base of Q2 which also saturates. When the collector of Q2 saturates, retrace current reaches the input of the horizontal sweep generator via R11, R13, and D3; D3 prevents R11 and R12 from affecting the horizontal sweep generator during forward scan.

At the beginning of the horizontal pulse, R14 and C1 couple the leading edge of the pulse to the base of Q3, turning Q3 off. Q3 remains off until C1 discharges enough to let the current from R15 enter the Q3 base again. Thus the Q3 collector current drops abruptly to zero for a short period (about 12 microseconds; the horizontal pulse is about 30 microseconds long) and then rises quickly to a few tenths of a volt below ground, the Q3 saturation voltage. This is the pulse which is integrated in the vertical sweep generator to cause the forward stairstep scan to appear.

The potentiometer R13 adjusts the horizontal retrace period independently of the forward scan rate; R14 adjusts the calibration of the number of lines per frame by varying slightly the duration of the output pulse at H. The second amplifier consisting of Q4 and Q5 is essentially the same as the Q1-Q2 amplifier; its output provides the retrace current for the vertical sweep generator.

PIN CONNECTIONS:

- A - Horizontal pulse input from Horizontal Sweep Generator, Pin Y
- C - Vertical pulse input from Vertical Sweep Generator, Pin Y
- H - forward scan pulses to relay contact which selects the lines-per-frame resistors
- K - B^-
- M - Ground
- P - B^+
- X - Retrace current to Input of Vertical Sweep Generator, Pin A
- Z - Retrace current to Input of Horizontal Sweep Generator, Pin A.



R1 - 4.7K

R2 - 2.2K

R3 - 10K

C1 - 150 pF

Q1, Q2 - 2N3565

Q3 -2N2189

HORIZONTAL SWEEP GENERATOR, OPERATIONAL AMPLIFIER

HORIZONTAL SWEEP GENERATOR
Circuit same as vertical sweep except for resistor values and R-10 detail

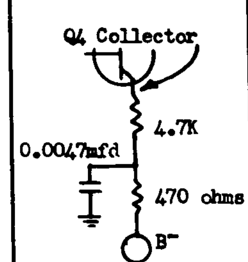
Circuit Values:

Refer to V. Sweep Gen.

R1 - Not used
R2 - 12K
R3 - 6.8K
R4 - 2.2K
R5 - 2.7K
R6 - 18K
R7, 8, 11 - 22K
R9 - 8.2K
R10 - see detail
R12 - 1.5K
R13 - 560 Ohms
R14 - Not used

C1, C2 - Not used
Transistors and Diodes identical to those on Vert. Swp. Gen. Board

R10 Detail



BOARD 6: HORIZONTAL SWEEP GENERATOR

FUNCTIONS: To produce a linear horizontal sweep drive waveform, and to provide the horizontal pulse waveform.

CIRCUIT OPERATION: This circuit is the same as that for the vertical sweep generator except for different resistance values (chosen to minimize loading on the operational amplifier) and a different operational amplifier, designed for higher-speed operation than the Burr-Brown unit could produce.

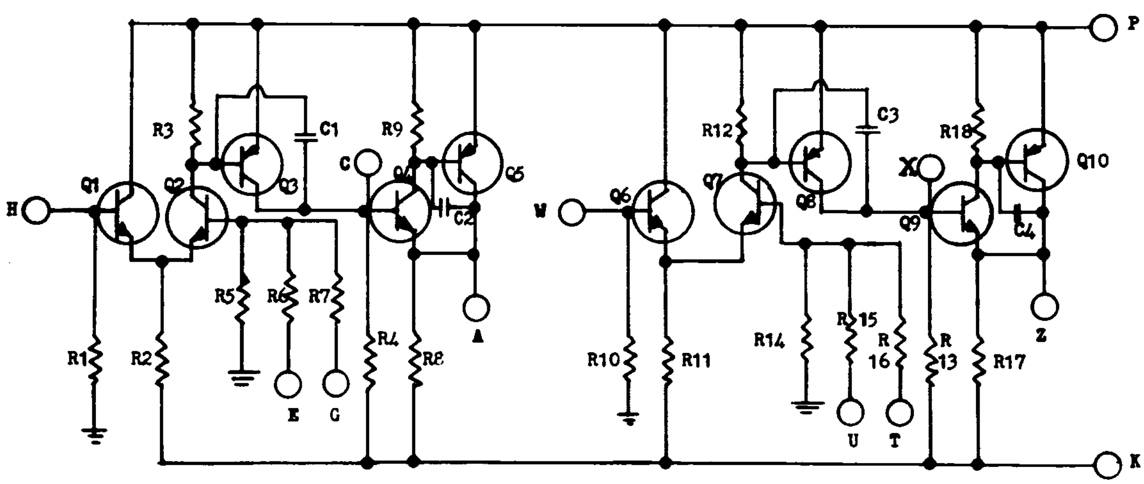
During forward scan generation this operational amplifier receives a steady input current instead of a series of pulses; the output, therefore, is a smooth ramp instead of a stairstep. The principle of operation is exactly like that of the Vertical Sweep Generator, upper and lower voltage levels being detected and used to switch on a flip-flop which in turn, via the Sweep Speed board, switches the current entering the integrator. This current flows through the "Microseconds per line" resistors, being interrupted by a separate saturating amplifier stage (see "Auxiliary Circuits") during horizontal retrace time so that this retrace time will not vary with changes in duration of the horizontal sweeps.

The operational amplifier for this sweep generator consists of Q1, Q2, and Q3, as shown on the diagram labelled, "Horizontal Sweep Generator, Operational Amplifier." Q1 and Q2 comprise a differential amplifier, with Q3 giving additional current amplification. Since the total current amplification is about 10,000, it is implied that very nearly all of the integrating current will flow through the integrating capacitor and very little into the base of the high-gain transistor Q1. Resistor R1 is adjusted (selected) for minimum base current into Q1 consistent with maintaining a full voltage swing at the output.

The nature of the sweep generator circuit makes unnecessary any painstaking DC balancing of the operational amplifier. Capacitor C1 adjusts the high-frequency rolloff of the amplifier for stability.

PIN CONNECTIONS:

- A - Input to operational amplifier, connected to one end of timing capacitor and common contact on one side of sweep changeover relay.
- E - Clamp input from Pin U, Delay 1 Board
- K - B-
- M - Ground
- P - B+
- S - Output of operational amplifier, connected to other end of timing capacitor and Pin A, Horizontal emitter followers.
- Y - Horizontal pulse output, to Horizontal Flyback Cutoff circuit switches, beam blanking generator on Target and Beam switching board, video amplifier, Sweep Speed and Retrace Board.



R1, 10 - 2.2K	R6 - 8.2K	R15 - 12K	Q1, 2, 4, 6, 7, 9 - 2N3565
R2, 11 - 4.7K	R7 - 6.8K	R16 - 12K	Q3, 5, 8, 10 - 2N3638
R3, 12 - 1.2K	R8, 17 - 820 ohms		
R4, 13 - 4.7K	R9, 18 - 1K	C1, 3 - 330pF	
R5 - 1.8K	R14 - 2.2K	C2, 4 - 180pF	

HORIZONTAL AND VERTICAL SIZE AND POSITION
(CAMERA)

BOARD 7: VERTICAL AND HORIZONTAL SIZE AND POSITION CONTROL (CAMERA)

FUNCTIONS: To provide vertical and horizontal sweep waveforms to the camera unit, variable with respect to amplitude and DC level.

CIRCUIT OPERATION: Transistors Q1, Q2, and Q3 form one operational amplifier, and Q6, Q7, and Q8 form a second. From pin H (input) to pin A (output) is connected the Vertical Size potentiometer; from pin W (input) to pin X (output) is connected the Horizontal Size potentiometer, both connected as rheostats. The 2.2K resistor to ground at each input (H and W) supplies DC ground reference to one differential input of each amplifier, and constitutes part of the voltage-division network for determining size, the other part being the "S13e" potentiometer on the front panel.

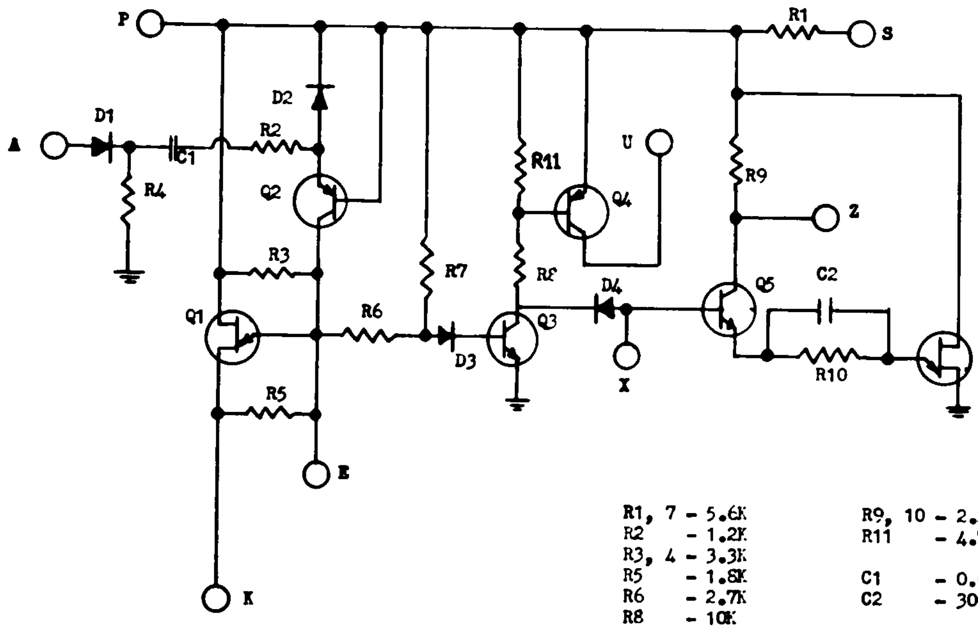
Into pin E comes the vertical sweep waveform, and into U, the horizontal waveform. Both are reduced in size by a voltage divider (R6 and R5, and R15 and R14) to limit the maximum amplitude of waveform. Pin G goes to the wiper of a potentiometer connected from B+ to B- (Vertical Position), and Pin T goes to the wiper of a similarly connected potentiometer (Horizontal Position); these are the position controls, which bias the operational amplifiers positive or negative.

The outputs of the two operational amplifiers (pins C and X) go to two compound emitter followers like those on the compound emitter follower boards. The outputs of these circuits drive the horizontal sweep (Q9, Q10) and the vertical sweep (Q4, Q5) in the camera unit through long coaxial cables. Again, these outputs, being of low impedance, are vulnerable to short-circuits, the principal victims of an overload being Q5 and Q10, possibly followed by Q4 and Q9.

Capacitors C1, C2, C3, and C4 adjust the high-frequency rolloff of the various feedback amplifiers to prevent oscillation.

PIN CONNECTIONS:

- A - Vertical sweep output to camera, Vertical BNC No. 4
- C - One side, vertical position pot; also test point for output of vertical operational amplifier
- E - Input from pin Z, Vertical Emitter Follower board
- G - Wiper, Vertical Position potentiometer
- H - Vertical Size pot, wiper
- K - B-
- M - Ground
- P - B+
- T - Wiper, Horizontal Position potentiometer
- U - Input from Horizontal Emitter Follower Board, pin Z
- W - Wiper, Horizontal Size potentiometer
- X - End, Horizontal Size potentiometer
- Z - Horizontal Sweep output to camera, Horizontal BNC No. 4



NOTE: Consider Uni-junction basing as if PNP transistor

R1, 7	- 5.6K	R9, 10	- 2.2K	Q1,6	-2N2624 (Unijunction)
R2	- 1.2K	R11	- 4.7K	Q2, 4	-2N3638
R3, 4	- 3.3K	C1	- 0.01 mfd	Q3	-2N3646
R5	- 1.8K	C2	- 300 pF	Q5	-2N3565
R6	- 2.7K				
R8	- 10K				

CLAMP AND DELAY ONE

BOARD 8: CLAMP AND DELAY ONE

FUNCTIONS: To clamp the vertical and horizontal sweeps to zero during flyback, and to generate a pulse output a variable time after the initial positive rise of the vertical pulse.

CIRCUIT OPERATION: The leading edge of the rising vertical pulse, just at the beginning of the vertical retrace time, is capacitively coupled to the emitter of Q2. The resulting current pulse is coupled through the collector of Q2 to the emitter of the unijunction transmitter without imposing a DC load or a capacitive load on it. The emitter voltage of Q2, normally lower than the firing point due to the DC level derived from R3, R5, R6, and R7, rises high enough to trigger the unijunction. The emitter-to-base-one voltage then drops nearly to zero, carrying the emitter voltage nearly to B- potential.

Before Q1 fires, R7 brings the anode of D3 positive enough to conduct and keep Q3 turned on; therefore, Q4 is on and the voltage at U is nearly B+; in this condition the clamps on each sweep generator, to which U is connected, are inactive.

The Q3 collector is diode-coupled to the Delay 1 timing capacitor, which is externally connected from X to ground. The Delay 1 potentiometer, also external, goes from this same point to pin S through a 5.6K limiting resistor to B+. Q3, however, holds the capacitor discharged to within about 0.9 volts of ground.

When the unijunction fires, its emitter drops in potential, turning off Q3. This allows Q4 to turn off, and the voltage at U drops along with the vertical sweep voltage to zero, where the diodes across the sweep timing capacitors stop the sweep: the vertical pulse, therefore, remains positive since the sweep voltage cannot drop to the negative potential required to turn it off.

When Q3 is turned off, its collector voltage rises quickly to B+, disconnecting diode D4 and allowing the external timing capacitor to charge through the external Delay 1 potentiometer toward B+. Q5, an emitter follower, has no current flowing in it until its emitter voltage is high enough to trigger Q6, the second unijunction.

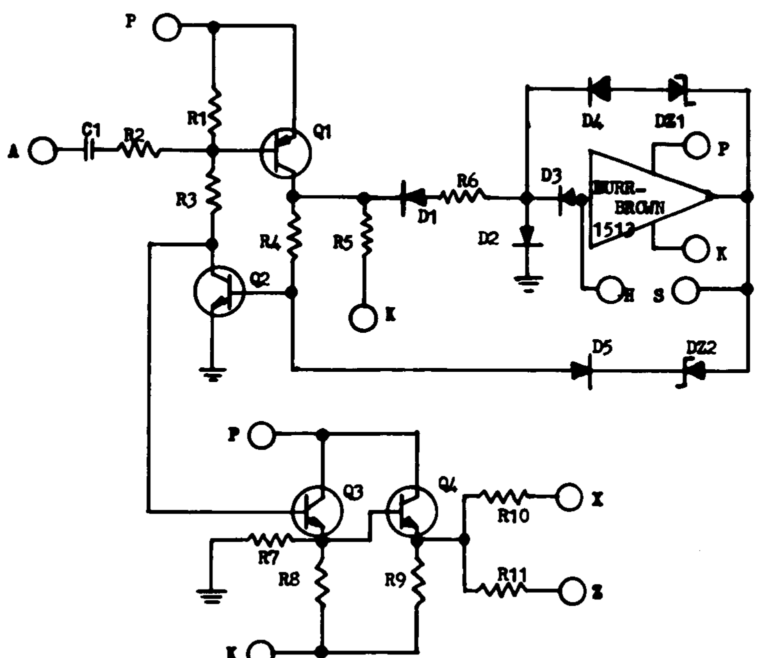
When Q6 fires, the resistance from emitter-to-lower-base drops nearly to zero, and Q5 finds the bottom end of its emitter resistor tied suddenly to ground: it conducts accordingly and its collector voltage drops abruptly due to the current flowing through R9. C2 sharpens and exaggerates the leading edge of this drop. Since very little base current is drawn when Q5 begins to conduct, the timing capacitor is not discharged enough to allow Q6 to drop out of conduction, so the circuit stays in the final state until reset.

The pulse out of pin Z, the sudden negative drop, is capacitively coupled to the Precision Delay board, initiating the exposure of the image orthicon.

A negative pulse into Pin E turns off Q1 and resets the entire board to its initial conditions: the sweeps are unclamped to finish their flyback, and the timing capacitor is discharged.

PIN CONNECTIONS:

- A - Vertical Pulse input from Pin Y, Vertical Sweep Generator
- E - Reset input from Look-Take Board and from Delay Three board
- K - B-
- M - Ground
- P - B+
- S - wiper of Delay One potentiometer
- U - Clamp inputs of horizontal and vertical sweep generators (Pin E on both)
- X - End of Delay One potentiometer, positive and of timing capacitor (other end to ground)
- Z - pulse output to Precision Delay board, pin A



PRECISION DELAY AND EXPOSURE CONTROL

R1 - 680 ohms

R2 - 1.5K

R3, 4 - 6.8K

R5,6,7,8,9,11 - 10K

R10 - 6.8K

C1 - 0.05 ufd

D1 - T. I. 10

D2,3,4,5 - 1N627

DZ1, DZ2 - 1/4M7.5Z5

Q1 - 2N3638

Q2,4 - 2N3646

Q3 - 2N3565

BOARD 9: PRECISION DELAY AND EXPOSURE CONTROL

FUNCTIONS: To turn on the image orthicon photocathode at the end of the Delay 1 interval, and to turn it off after a controlled interval.

CIRCUIT OPERATION: Q1 and Q2 constitue a complementary flip-flop which is normally off. The collector of Q1 is several volts negative so that D1 is conducting and D3 is conducting. The Burr-Brown operational amplifier output will be clamped at about +7.5 volts by D4 and DZ1, feeding current back to the input to limit the positive rise caused by the negative voltage on the Q1 collector.

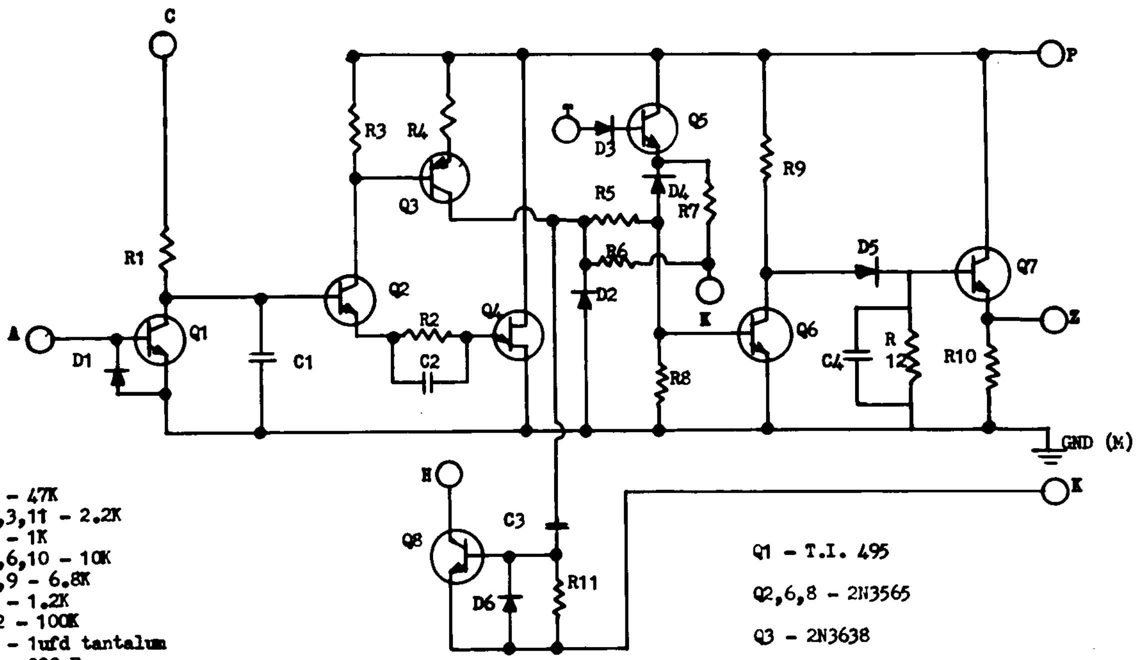
At the end of the Delay 1 period a negative-going step is applied to Pin A and, via C1 and R2, turns on Q1 and Q2. The Q1 collector rises positive disconnecting D1 and switching off the clamp D4 and DZ1. Leakage current through the back-biased D3 is minimized by the clamp diode D2.

Between H and S is connected a set of four switchable timing capacitors (the Exposure Multiplier switch), and from H to B+ there is a variable resistor switched by thumbwheel switches (the Exposure switch). These components determine the rate at which the output of the operational amplifier goes negative beginning when Q1 turns on. When the operational amplifier output reaches about -7.5 volts, diodes D5 and DZ2 conduct, turning off Q2 and hence turning the flip-flop off again.

During the time that the flip-flop is on a slightly negative voltage is present at outputs X and Z: at the end of the exposure period the Pin Z output rises positive, and this rise is what trigger the next events, controlled by the Look-Take board. The Pin X output goes to the base of a PNP transistor (see Auxiliary Circuits diagram) with its emitter tied to B+; thus, the transistor is on only during the exposure time when the Pin X voltage is zero. This transistor operates both the exposure-indicating lamp and the exposure relay itself, a mercury-wetted reed relay in the Camera Control chassis. At the end of the exposure cycle when the output of the operational amplifier reaches -7.5 volts and turns the flip-flop off, the circuit resets itself to the initial conditions.

PIN CONNECTIONS:

- A - input negative step from Pin Z, Delay One board.
- H - connection to low end external timing capacitor switch, and to low end thumb-wheel exposure resistor switches
- K - B-
- M - Ground
- P - B+
- S - high end, and switch common, for exposure timing capacitors
- X - output to base of PNP transistor for switching lights and exposure relay
- Z - end-of-exposure pulse to Pin A, Look-Take board



R1 - 47K
R2,3,11 - 2.2K
R4 - 1K
R5,6,10 - 10K
R7,9 - 6.8K
R8 - 1.2K
R12 - 100K
C1 - 1ufd tantalum
C2 - 330pF
C3 - 0.001 ufd
C4 - 0.01 ufd

Q1 - T.I. 495

Q2,6,8 - 2N3565

Q3 - 2N3638

Q4 - 2N2646 Unijunction

Q5,7 - 2N3646

All Diodes: 1N627

DELAY THREE AND NIKON CAMERA CONTROL

BOARD 10: DELAY 3 AND NIKON CAMERA CONTROL

FUNCTIONS: To open the shutter of the Nikon camera, provide a delay for vibrations to settle down, and to reset the Delay 1 board in the "Take" mode.

CIRCUIT OPERATION: The input voltage at Pin A from the Look-Take board goes positive briefly at the end of an exposure. Q1 conducts, discharging capacitor C1 in about 0.1 millisecond and turning off unijunction Q4. This in turn stops the current through Q2, turns off Q3, and turns off Q6. When Q6 turns off, the base of Q7 is biased positive and the output at Z rises; this output operates the relay that opens the Nikon camera shutter.

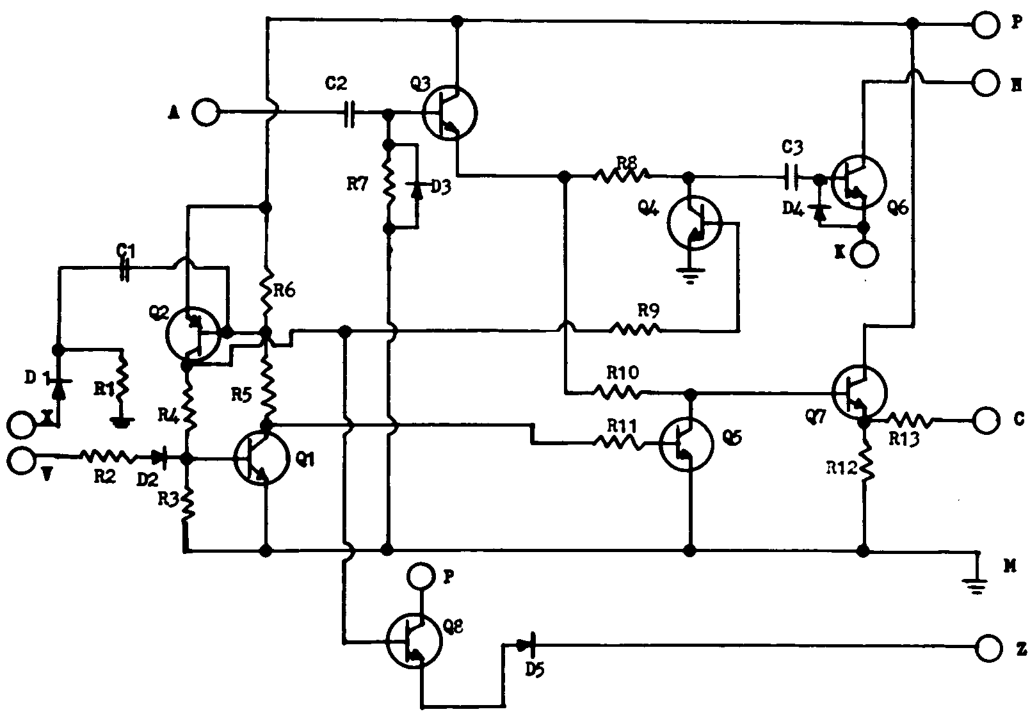
Capacitor C1 begins to charge through the fixed R1 and an external potentiometer connected from pin C to B+, the Delay 3 control. When the emitter of Q2 reaches the firing potential of the unijunction Q4, Q2 begins to draw current suddenly and Q3 is turned on. The positive going pulse is capacitively coupled via C3 to Q8, the collector of which drops nearly to the B- potential, turning off the first unijunction on the Delay 1 board and resetting Delay 1 to allow the flybacks to continue and a frame of readout to occur.

While the system is in the "Take" mode, the only time that Delay 3 is in the circuit, one contact of the changeover relays connects the vertical pulse to pin T. When Q3 turns back on after the delay and the sweep circuits are released from clamp via Q8, Q6 also turns on and brings the output at pin Z back toward zero. The RC time constant at the base of Q7, however, holds Z positive just long enough for the vertical flyback to reach its lower limit which is the point at which the vertical pulse drops negative (it has been positive since the initiation of Delay 1). Now it drops negative turning Q5 off and allowing R7 to pull the emitter of Q5 and the base of Q6 negative. Q6 is turned off again, therefore, about 1.5 milliseconds after the termination of Delay 3 so the output at Z is brought positive again holding the Nikon camera shutter open.

At the termination of the next readout frame the vertical pulse once again goes positive turning Q5 on and allowing the camera shutter to close. Normally, the changeover relays will drop out and pin T will be connected to B+ at this point if the "Take" button is not again depressed, and the Nikon camera shutter will remain closed as the Delay 3 circuit receives no further inputs in the "Look" mode.

PIN CONNECTIONS:

A - Input pulse from Pin C, Look-Take
C - Low end, Delay 3 potentiometer (other end and wiper to B+)
H - Reset pulse to Pin E, Delay 1 board
K - B-
M - Ground
P - B+
T - Vertical pulse from contact on changeover relay
Z - Output to relay for Nikon camera shutter



R1 - 220K

R2 - 4.7K

R3,6,12,13 - 1K

R4 - 8.2K

R5 - 6.8K

R7 - 22K

R8,9 - 10K

R10 - 1.8K

R11 - 100K

C1 - 0.005 ufd

C2 - 0.05 ufd

C3 - 0.05 ufd

Q1,3,4,6 - 2N3646

Q2 - 2N3638

Q5,7 - 2N3565

All Diodes: 1N627

LOCK - TAKE

BOARD 12: LOOK-TAKE CONTROL

FUNCTIONS: To switch from the "Look" condition to the "Take" condition when the "Take" button is pressed by re-routing the reset pulse to Delay 1 via Delay 3 instead of directly from the Precision Delay, and by applying power to the changeover relays and the Target and Beam switch board.

CIRCUIT OPERATION: Q1 and Q2 constitute a complementary flip-flop. Vertical pulses are always present at pin X; they are differentiated and the positive going spike is applied to turn off Q2 at its base. R1 is large so there is no negative spike at the end of the Vertical Pulse. When the "Take" button is held down, the turn-off spike occurs as usual but the DC vertical positive pulse is coupled to Q1 to turn the flip-flop on again: it will not turn off until the next positive pulse occurs at the start of the next vertical flyback and then only if the "Take" button is not still depressed.

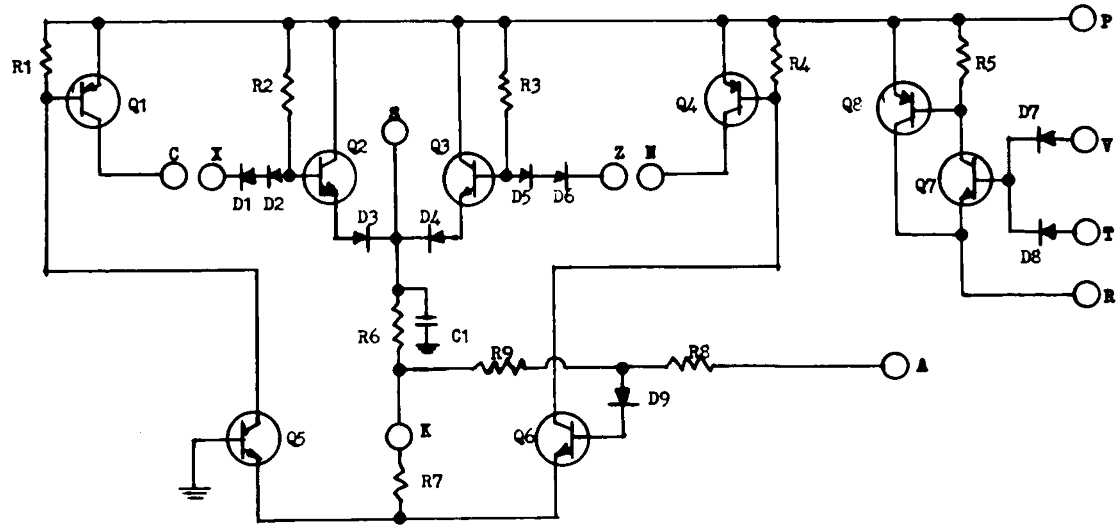
Before the "Take" button is depressed, the positive-going step at Pin A, marking the end of the Precision Delay, is differentiated: the spike is applied to R8 and R10. Q4 and Q5 act to short out the spikes, but only one can be on at a time as they are driven by opposite collectors of Q1 and Q2. In the normal condition, Q1 and Q2 are off, so that Q5 is conducting and Q4 is not: the spike, therefore, is stopped at Q5 and bypasses Q4 into the capacitive coupling into Q6. The collector of Q6 briefly comes nearly to B-, and since Pin H is connected to the unijunction emitter at the input of Delay 1, Q6 acts to reset Delay 1 immediately after the end of the Precision Delay.

After the "Take" button is depressed Q1 and Q2 remain conducting, but now Q4 conducts and Q5 is off. The spike is stopped from resetting Delay 1 but instead appears at Pin C, the output to Delay 3.

After depression of the "Take" button, Q8 is driven positive by Q2, bringing pin Z nearly to B+ potential: this is the voltage output which activates the sweep changeover relays and which enters the Beam and Target Switching board to transfer control of target voltage and beam current.

PIN CONNECTIONS:

- A - end-of-delay pulse from Precision Delay, Pin Z
- C - end-of-delay pulse output to Delay 3, Pin A ("Take" condition)
- H - end-of-delay pulse to reset input of Delay 1, Pin E ("Look" condition)
- K - B-
- M - Ground
- P - B+
- V - vertical pulse input from Pin Y, Vertical Sweep generator
- X - vertical pulse input through "Take" switch (normally open)
- Z - output power to coils of changeover relays, and plus voltage to pin A, Beam and Target Switching board



R1,4,5 - 1.8K

R2,3 - 100K

R6,8 - 6.8K

R7,9 - 10K

C1 - 0.5 ufd

Q1,8 - 2N3638

Q2,3 - 2N3565

Q4,5,6,7 - 2N3646

BEAM AND TARGET SWITCHING

BEAM BLANKING AMPLIFIER

BOARD 13: BEAM AND TARGET SWITCHING: BEAM BLANKING AMPLIFIER

FUNCTIONS: To apply voltage either to the Look Beam Control or to the Take Beam Control at the same time applying voltage to the Look Target Control or the Take Target Control, and to produce a composite blanking output waveform for driving the camera Beam Blanking board.

CIRCUIT OPERATION: In the "Look" mode pin A carries zero voltage so Q6 is off and Q5 is on. The collector current from Q5 turns on Q1 and Pin C is brought nearly to B+ potential. Pin C is connected to one end of the "Look" Beam Control potentiometer, the other end being grounded. The wiper of this potentiometer is connected to Pin X. The voltage from the Look Beam Pot is thus reproduced at the junction of D3 and D4 which is the output, at Pin S. D3 and D4 prevent reverse breakdown in Q2 and Q3 emitter followers, and D1 and D2, as well as D5 and D6, compensate both for the voltage drops and for temperature changes in the output emitter circuits of Q2 and Q3.

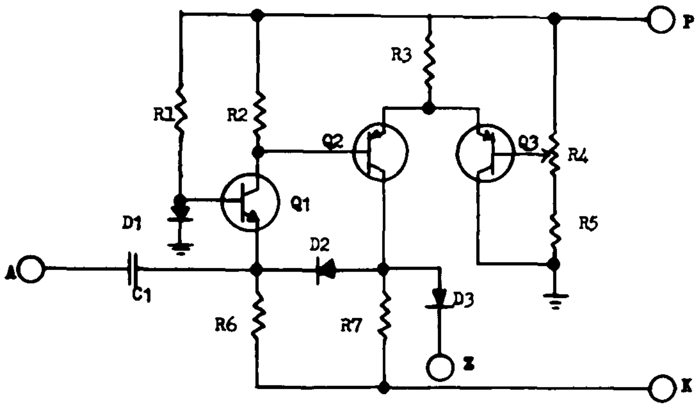
When Q1 is conducting, Q4 is not so that the "Take" Beam Potentiometer has no voltage applied to it; in fact, it has a negative voltage on it because both Beam potentiometers are connected to the high end of the two target potentiometers, the other ends of which go to B-, the wipers being diode-coupled to the target line to the camera. Q3 is not conducting and D4 is open.

While the Look-Take flip-flop is on, a positive voltage appears at Pin A turning on Q6 and turning off Q5. Now the "Take" Beam Potentiometer has voltage applied while the "Look" potentiometer does not. Q3 receives the wiper voltage from pin Z which is coupled to the output, pin S. Pin S is connected to the lower end of the Grid One potentiometer so the voltage here serves as a fine adjustment on G1.

Q8 and Q9 comprise a compound emitter-follower driving a cable up to the camera. Into pins V and T come the vertical and horizontal pulses so that the output of the emitter follower, on pin R, is positive during vertical or horizontal flyback time. This output drives the beam blanking circuit in the camera shutting off the beam during flyback.

PIN CONNECTIONS:

A - output from Pin Z, Look-Take board: zero in "Look" condition, positive in "Take" condition
C - output to Pin 9, Amphenol 20-pin connector, and thence to high side of "Look" Beam potentiometer and "Look" Target potentiometer
K - B-
M - Ground
P - B+
N - output to Pin 1, Amphenol 20-pin connector, and thence to high side of "Take" Beam potentiometer and "Take" Target potentiometer
R - beam blanking waveform to Pin 6, 20-pin Amphenol connector, and thence to lower end of G1 potentiometer
S - beam voltage to Pin 15, Amphenol 20-pin connector, and thence to lower end of G1 potentiometer
T - vertical pulse from Pin Y, Vertical Sweep generator
V - horizontal pulse from Pin Y, Horizontal Pulse generator



R1 - 12K

R2 - 2.7K

R3 - 470 ohms

R4 - 1K Trimpot

R5 - 560 ohms

R6 - 22K

R7 - 18K

C1 - 0.01 ufd

D1 - 1N627
D2 - 1N772
D3 - 1N914A (fast)

Q1 - 2N3646
Q2,3 - 2N2190

UNBLANKING AND FAIL-SAFE (BOTH MONITORS)

UNBLANKING AND FAIL-SAFE (BOTH MONITORS)

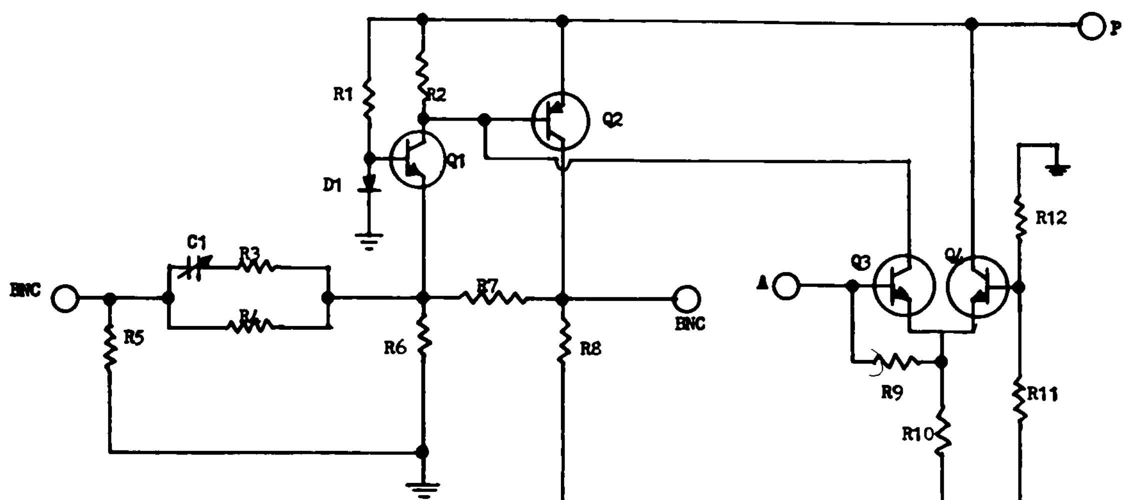
FUNCTIONS: To provide a signal for cutting off the video amplifier by forcing its output to maximum positive potential during horizontal flyback, and producing the same result in the event of loss of sweep current in the horizontal yoke, as occurs during exposures in the "Look" and "Take" modes.

CIRCUIT OPERATION: Pin A is connected to the current-sensing resistor in the horizontal sweep driver circuit. During the forward sweep capacitor C1 charges linearly yielding a constant current into the emitter of Q1. This current reduces the base current into Q2 and cuts it off (cutoff adjustment is R4). The output voltage at the collector of Q2 drops nearly to B- at all sweep speeds.

If the sweep fails, or during the flyback period, the transistor Q1 conducts and the output voltage goes positive at Z, the amount being limited by feedback through D2. As long as the output is positive the video amplifier will be driven to maximum positive output; since the CRT is cathode-driven, the CRT is cut off.

PIN CONNECTIONS:

A - input from current-sensing resistor of Horizontal Sweep Board, Pin Z
K - B-
M - Ground
P - B+
Z - output to monitor video amplifier, Pin A



R1 - 5.6 K	R7 - 2.7K	C1 - 120 pF Trim
R2 - 1.2K	R8 - 1.5K, 2W	D1 - 1N627
R3 - 82 ohm	R9 - 3.9K	Q1 - 2N3646
R4 - 680 ohm	R10,11 - 22K	Q2 - 2N3251
R5 - 75 ohm 1%	R12 - 1K	Q3 - 2N3565
R6 - 100 ohm		Q4 - 2N3646

MONITOR VIDEO AMPLIFIER AND UNBLANKING AMPLIFIER

MONITOR VIDEO AMPLIFIER AND UNBLANKING AMPLIFIER (BOTH MONITORS)

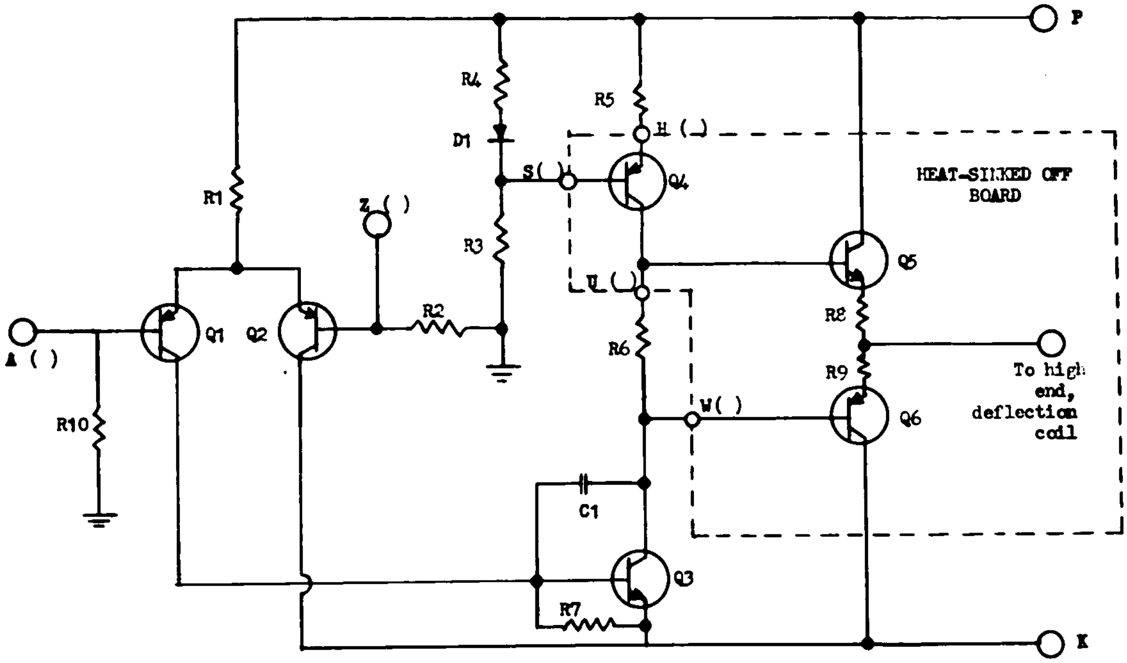
FUNCTIONS: To invert and amplify the video signal, and to amplify the unblanking voltage from the Unblanking and Fail-Safe board to cut off the CRT in the event of sweep failure.

CIRCUIT OPERATION: The video signal from the Main Video Amplifier enters the BNC connection at the left. It is coupled to the emitter of the transistor Q1, which is half of a complementary feedback pair with Q2. C1 and R3 determine the high peaking; the gain is approximately the ratio of R7/R4, or 4.0. Since five to seven volts are required to drive the CRT through a satisfactory range of brightness, the input signal required is about 1.5 volts.

Q3 and Q4 comprise an emitter-coupled differential amplifier referenced about 1 volt below ground at the Q4 base. During the forward scan pin A from the unblanking generator is negative; during flyback, or when the sweep is stopped, point A is approximately at ground potential or slightly positive, so that Q3 conducts. The Q3 collector current enters the base of Q2 turning it on to saturation. The Q2 collector and the output to the CRT cathode are thus brought to about the B+ potential, blanking the CRT. Only horizontal blanking is used since the vertical sweep waveform is not suitable for differentiation and because the CRT can operate for a considerable period with horizontal scan only without burning the screen.

PIN CONNECTIONS:

A - unblanking signal from Unblanking and Fail-Safe board, Pin Z
BNC - (left on diagram) video input from Main Video Amplifier
K - B-
M - Ground
P - B+
BNC - (right on diagram) video output to CRT cathode pin



R1 - 3.3K	R6 - 15 ohm, 1W	D1 - 1N34A	Q6 - 2N1908
R2 - 1ohm non-inductive, 10W	R7 - 1K	Q1,2 - 2N2191	
R3 - 3.3K	R8,9 - See Text	Q3 - 2N2991	
R4 - 100 ohm	R10 - 8.2K	Q4 - 2N1046	
R5 - 10 ohm, 1W	C1 - 180-330 pF (anti-oscillation)	Q5 - T.I. 1135	

HORIZONTAL YOKE DRIVER, CAMERA AND BOTH MONITORS

HORIZONTAL YOKE DRIVER (CAMERA AND BOTH MONITORS)

FUNCTIONS: To compare the current waveform through the horizontal deflection coil with the input sweep waveform, and to correct any errors.

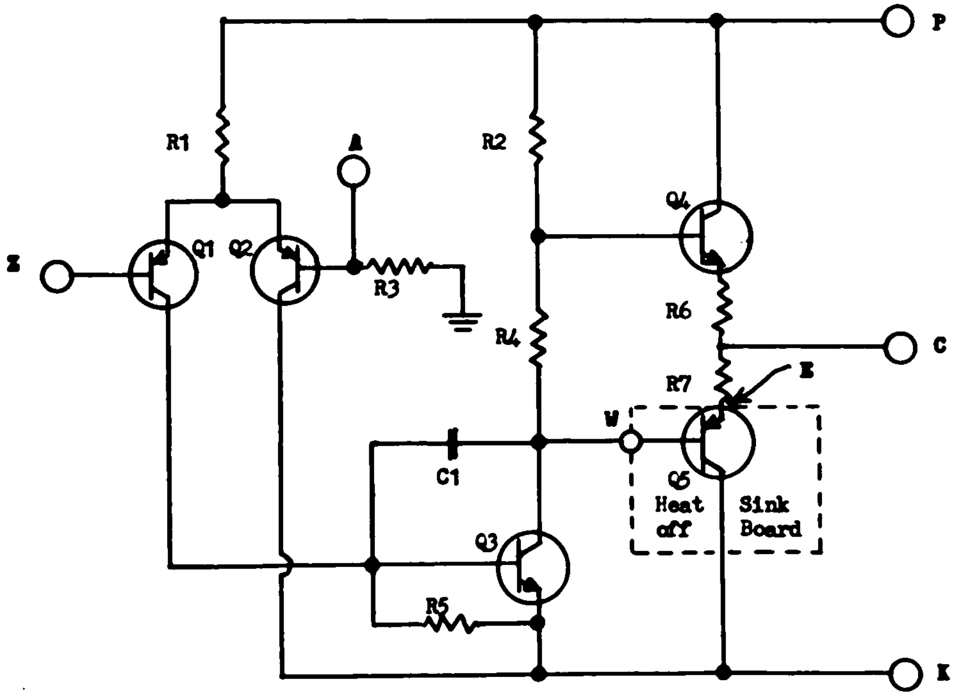
CIRCUIT OPERATION: Q1 and Q2 comprise a differential amplifier; the input sweep waveform is applied to one base and the current feedback from the yoke, sampled by a 1-ohm non-inductive resistor, to the other. The collector of Q2 carries a current proportional to the error between sweep voltage and feedback voltage: the error-current is amplified by Q3 and applied to the bases of the complementary power amplifier consisting of high-frequency power transistors Q5 and Q6. Q4 is a constant-current source for driving the output transistors positive as the Q3 collector current declines below 100 milliamps. R6 biases the output transistors to avoid crossover distortion; resistors R8 and R9 limit the current and prevent thermal runaway.

In the monitors a current of only about 2 amperes peak-to-peak is required. so R8 and R9 are 2-watt carbon resistors mounted on the board and brought out to terminals C and E for one resistor, and Y and Z for the other. In the camera which requires 4 amperes peak-to-peak of drive current the resistors are Dale 10-watt resistors heat-sinked to the camera body, and are not on the board.

The two power supplies are by-passed to a local ground at the camera with capacitors of 31,500 microfarads (plus supply) and 10,000 microfarads (minus supply); this prevents large circulating currents from generating interfering voltages between camera and console ground. In addition, extra series inductance is added to the leads from the relevant power supplies (14A200+ and PRM-24-8).

PIN CONNECTIONS NOT INDICATED ON DIAGRAM:
Parentheses indicate camera board connections

A - Horizontal Sweep waveform from Vertical and Horizontal Size and Position board, pin Z, or Horizontal Emitter Followers, pin E or H.
Z - low end, Horizontal Deflection Coil
P - B+
M - Ground
K - B-



R1 - 5.6K

R2 - 820 ohm, 2W

R3 - 30 ohm, 5W

R4 - 50 ohm, 2W

R5 - 1.8K

R6,7 - 5 ohm, 2W

C1 - 500pF

Q1,2 - 2N3638

Q3 - 2N2991

Q4 - 2N697

Q5 - 2N1046

VERTICAL YOKE DRIVER, CAMERA AND BOTH MONITORS

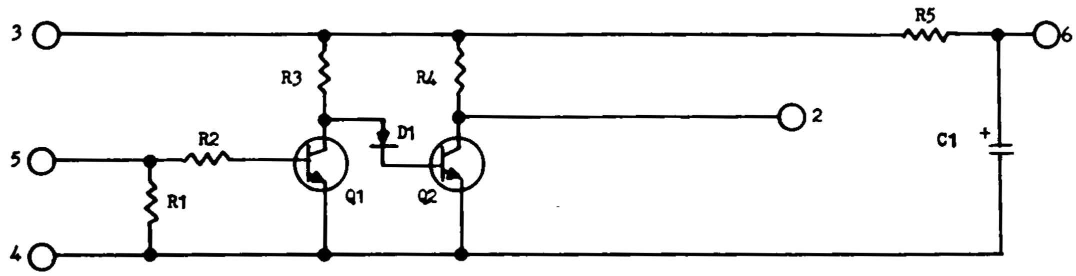
VERTICAL YOKE DRIVER (CAMERA AND BOTH MONITORS)

FUNCTIONS: To compare the vertical sweep waveform with the current in the deflection coil, and to correct any errors.

CIRCUIT OPERATION: Essentially similar to that of the Horizontal Yoke Driver except that an 820-ohm resistor is used in place of the constant-current source. Lower current transistors are used as the deflection currents required are no more than 250 milliamperes.

PIN CONNECTIONS:

A - low end, vertical deflection yoke
C - high end, vertical deflection yoke
E - emitter of heat-sinked 1046
K - B-
M - local ground
P - B+
W - base of heat-sinked 1046



R1 - 820 ohms	R4 - 2200 ohms	D1 - 1N627
R2 - 3900 ohms	R5 - 10 ohms	Q1 - 2N3565
R3 - 8200 ohms	C1 - 220 ufd	Q2 - 2N3646

BEAM BLANKING AND VIDEO POWER SUPPLY FILTER

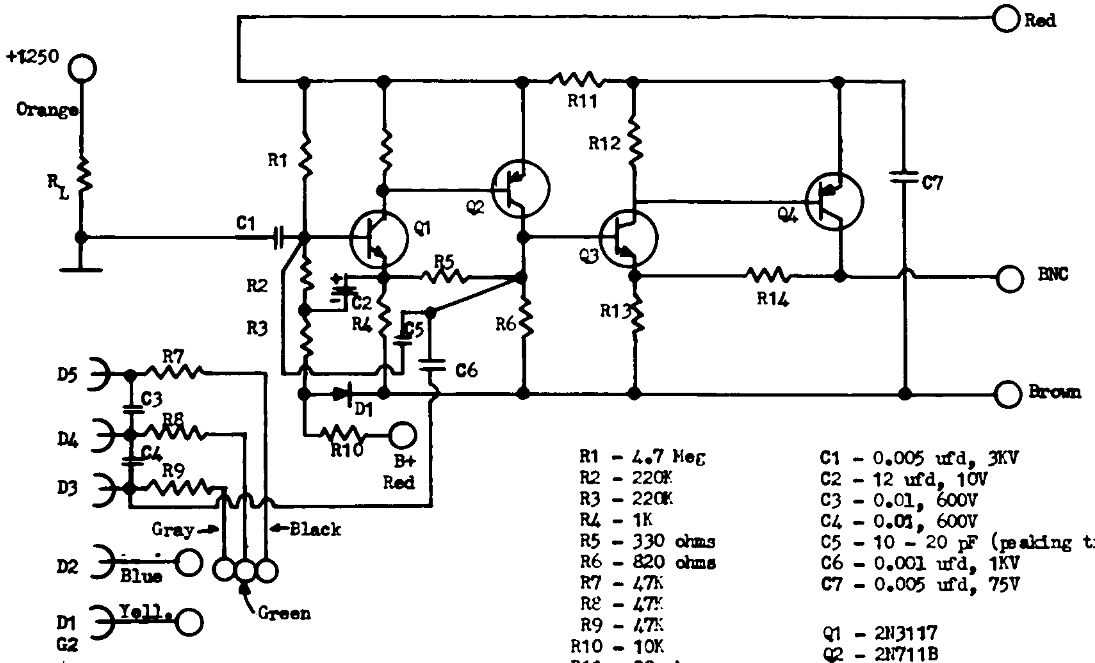
BEAM BLANKING AND VIDEO POWER SUPPLY FILTER (CAMERA)

FUNCTIONS: To amplify the composite blanking signal for application to the image orthicon electron-gun cathode, and to add filtering to the B+ power for the camera preamplifier.

CIRCUIT OPERATION: The blanking waveform is amplified by Q1 which is either cut off or saturated. Diode D1 disconnects the base of Q2 when Q1 is saturated. The collector of Q2 reproduces the input blanking waveform, but the positive (cutoff) amplitude is determined by the B+ voltage; the lower level (beam on) is the saturation voltage of Q2. R5 and C1 remove noise from the B+ line before it reaches the preamplifier.

PIN CONNECTIONS:

2 - blanking output voltage to I.O. electron-gun cathode
3 - B+
4 - Ground
5 - beam blanking input from pin R, Target and Beam Switching board
6 - B+ to camera preamplifier



R1 - 4.7 Meg
R2 - 220K
R3 - 220K
R4 - 1K
R5 - 330 ohms
R6 - 820 ohms
R7 - 47K
R8 - 47K
R9 - 47K
R10 - 10K
R11 - 22 ohms
R12 - 1.2K
R13 - 100 ohms
R14 - 150 ohms

R_L - 40K, 1%

C1 - 0.005 ufd, 3KV
C2 - 12 ufd, 10V
C3 - 0.01, 600V
C4 - 0.01, 600V
C5 - 10 - 20 pF (peaking trim)
C6 - 0.001 ufd, 1KV
C7 - 0.005 ufd, 75V

Q1 - 2N3117
Q2 - 2N711B
Q3 - 2N3646
Q4 - 2N3638

D1 - 1N627

PREAMPLIFIER AND LINE DRIVER (CAMERA)

PREAMPLIFIER AND LINE DRIVE (CAMERA)

FUNCTIONS: To amplify the signal from the image orthicon, to cancel a portion of the output capacitance of the tube, and to drive a 75-ohm line with the resulting video signal.

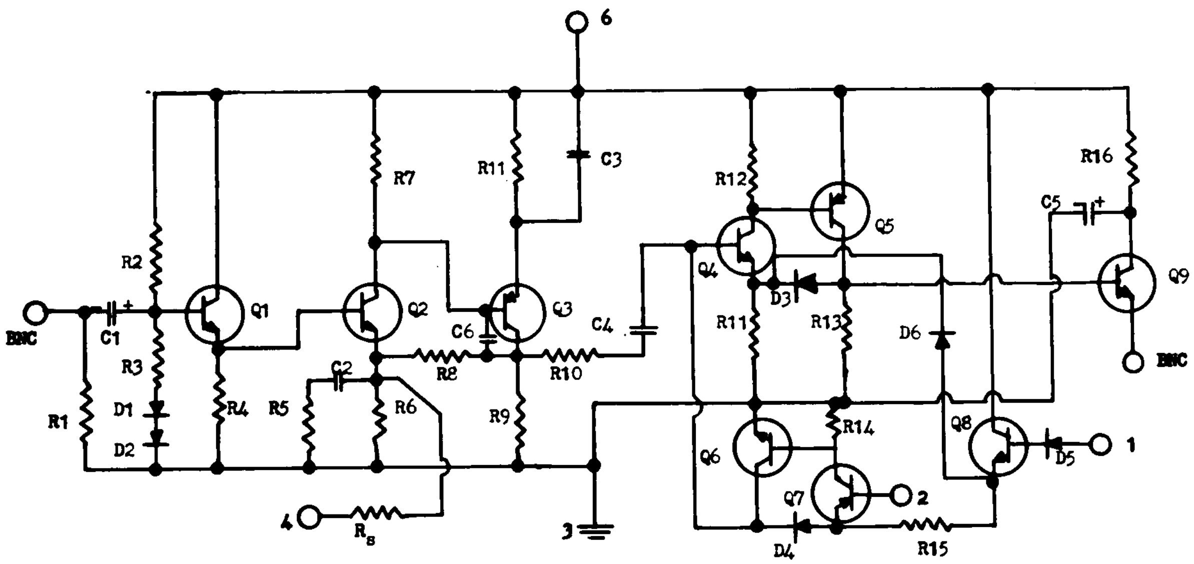
CIRCUIT OPERATION: Q1 and Q2 comprise a feedback amplifier pair, the gain being about equal to R5/(R5 + R4), or 1.3 times. C6, C4, and C3 couple the high-frequency components of the output signal back to dynodes D3, D4, and D5 with the main electrodes contributing to the output capacitance of the I.O. anode. Since the feedback is positive, a capacitance bridge is formed and much of the output capacitance is effectively cancelled. Additional trim of the cancellation effect is achieved by the small capacitor, C5, which goes from output to input of the preamp. Without an image orthicon plugged into the socket the preamplifier will oscillate because of the positive feedback.

Q3 and Q4 comprise a second feedback pair giving a gain of about 2.5 for an overall preamplifier gain of about 3.25 times. The output goes directly into a 75-ohm line separate from the camera cable.

R11 and C7 prevent feedback from the line drive stage into the first stage. The preamp itself is built into a small can mounted directly to the I.O. socket.

OUTPUT LEAD CONNECTIONS: (Including those socket leads not on diagram)

	(I.O. Pin)
Red - B+ input, from Blanking Amplifier board, pin 6	
Brown - ground and one side of filament	Pin 14
BNC - video output	
Yellow - dynode 1/grid 2	Pin 10
Blue - dynode 2	Pin 5
Gray - dynode 3	Pin 9
Green - dynode 4	Pin 6
Black - dynode 5	Pin 8
Orange - anode	Pin 7
Green-Yellow-White - grid 3	Pin 3
Purple - grid 4	Pin 2
Brown-Black-White - hot side, filament	Pin 1
Shielded lead - gun cathode from Pin 2, Beam Blanking	Pin 13
Red-Brown-White - grid 1	Pin 12



R1 - 75 ohm, 1%	R7,9 - 820 ohm	C1 - 100 ufd	Q1 - 2N3565	D1,2,5 - 1N627
R2 - See Text	R8 - 3.3K	C2 - See Text	Q2 - 2N3646	D3,4 - T.I. 10
R3 - 2.2K	R10,13 - 470 ohm	C3 - 100 ufd	Q3 - 2N2189	D6 - T.I. 10
R4,7 - 180 ohm	R11,15 - 1.2K	C4 - 0.1 ufd	Q4 - 2N3646	
R5 - 47 ohm	R12,14 - 1K	C5 - 100 ufd	Q5 - 2N2189	
	R16 - 100	C6 - See text	Q6 - 2N3646	
	R_s - See Text		Q7 - 2N2189	
			Q8 - 2N3646	
			Q9 - 2N3646	

VIDEO AMPLIFIER AND CLAMP

VIDEO AMPLIFIER AND CLAMP

FUNCTIONS: To amplify the video signal from the camera preamplifier, to clamp the signal during flyback time to a controllable DC level, and to produce an output into a 75-ohm line which is forced to zero during flyback.

CIRCUIT OPERATION: Q1 is an emitter follower driving the feedback amplifier pair consisting of Q2 and Q3. The gain of this pair is about 19, and the rise-time is measured at 0.03 microseconds with a Tektronix 535A oscilloscope having a rise-time of 0.022 microseconds. Rise-time is measured without the peaking components (R5 and C2) in the circuit. Overall gain is about 18.5 times.

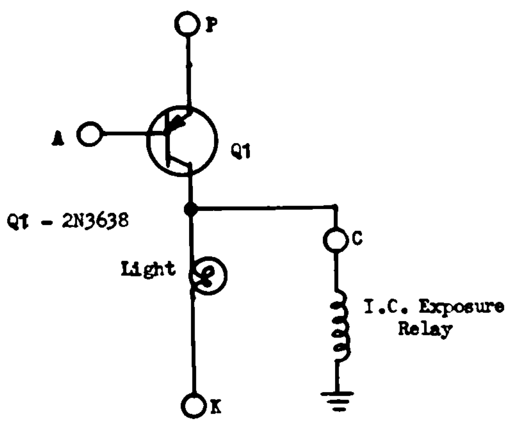
The resistor R2 is selected to give about +2 volts at the collector of Q3. Capacitor C6 is selected to be the smallest that will permit operation without ringing, overshoot, or oscillation with the peaking components connected; in a typical model it will be about 10 pf.

The peaking components for use with the preamp of this system were selected to be about 47 ohms and 0.003 microfarads, giving an RC time constant of 0.14 microseconds. This is, therefore, the approximate rise-time of the preamplifier output signal.

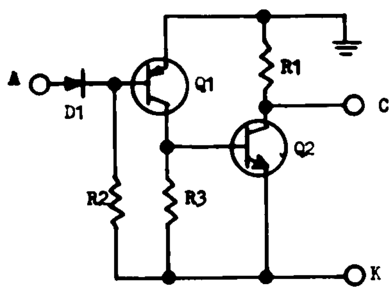
The resistor labelled "R_s" determines the amount of shading signal injected into the amplifier at the Q2 emitter. It should be selected to give the minimum shading signal required so as to minimize the possibility of noise being introduced. The shading component in the signal at the Q3 collector is approximately $R8/R_s$ times the input shading signal.

Since the signal at the collector of Q3 results from a capacitively-coupled amplification, it will have no fixed DC reference level. This level is introduced by clamping the right side of C4 to a fixed DC reference voltage by means of the clamp circuit consisting of Q6, Q7, and Q8. During horizontal flyback pin 1 is driven positive by the horizontal pulse, and the emitter-follower Q8 pulls its emitter and one end of R15 positive by the same amount. Q7 conducts when the horizontal pulse becomes more positive than the voltage at the Q7 base from pin 2 and drives Q6 into conduction. The Q6 emitter becomes tied to the Q7 emitter by diode D4 and since this point is connected to C4, C4 is either charged or discharged to the value set by the DC voltage at pin 2. This clamp is released at the end of the flyback period so that Q6 turns off and D4 disconnects; now there is no DC load on C4 except that from the Q4 base.

Q4 and Q5 comprise a feedback pair having unity gain; the feedback path, however, is through diode D3. When the horizontal pulse appears, the emitter of Q8 is tied to the emitter of Q4 through diode D6 and brings the Q4 emitter to a level more positive than the base, thus turning Q4 off. This action turns Q5 off also and with the feedback path being broken by D3, the collector of Q5 drops to ground potential for the duration of the flyback period. Thus, the video signal drops to a "blacker than black" level during flyback in spite of the fact that the clamping is referenced to the white signal level and due to the fact that the image orthicon beam current is turned off during flybacks. Q9 is an emitter follower, isolated by R16 and C5 to prevent feedback to earlier stages. This stage drives a 75-ohm line going to the monitors.



EXPOSURE LIGHT AND RELAY



R1 - 2200 ohms
R2 - 33K
R3 - 1K

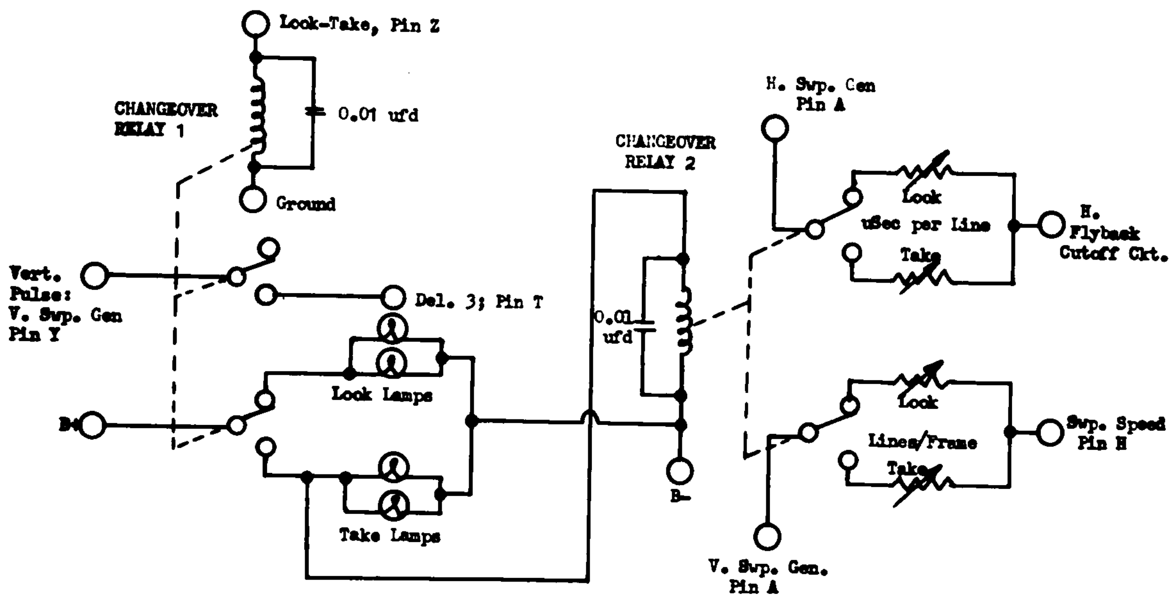
Q1 - 2N3638
Q2 - 2N3646
D1 - 1N627

HORIZONTAL FLYBACK CUTOFF

AUXILIARY CIRCUITS

PIN CONNECTIONS: Note: the numbered leads are brought out to a 7-pin header on the "Minibox" in which the video amplifier is housed. The output BNC connector is on the end of a short length of RG/59U cable so that its shield is not grounded except at circuit ground. Both circuit ground and the B+ line should be connected to the circuit approximately at the physical locations shown on the diagram in order to keep circulating currents from the last stages out of the first stage.

Pin 1 - horizontal pulse in, from Pin Y, Horizontal Sweep Generator
Pin 2 - DC level in, from wiper of DC level control (bypassed with 47 microfarads)
Pin 3 - Ground
Pin 4 - shading input
Pin 5, 7 - not used
Pin 6 - B+, from Sweep Control power supply



CHANGEOVER RELAY CONNECTIONS

AUXILIARY CIRCUITS

FUNCTIONS: To activate the exposure relay controlling image orthicon photocathode voltage and to remove scanning current from the horizontal sweep speed resistors during flyback so as to prevent changes in scanning speed from changing the flyback time.

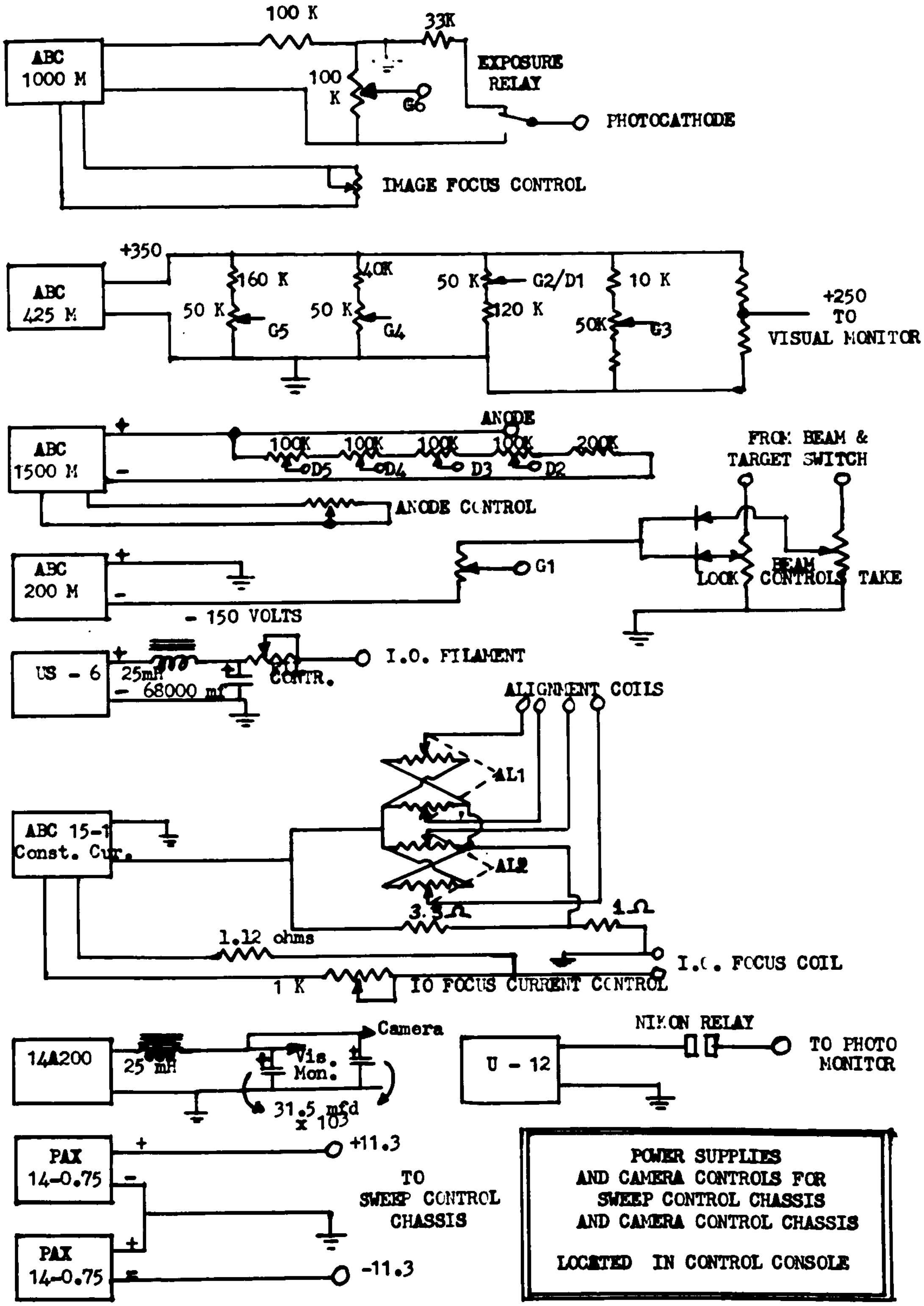
CIRCUIT OPERATION:
a. Exposure Light and Relay Circuit: This circuit is located on a terminal strip that also supports the Exposure light. Pin A receives the voltage from pin X, Precision Delay, which is positive except during an exposure. The negative drop in this voltage is coupled through an output resistor in the Precision Delay, and turns on Q1. The Q1 collector goes through a lamp bulb (24-volt type) to B-, and also through the Amphenol 20-pin connector to the coil of the mercury-wetted reed relay, the contacts of which are in series with the photocathode voltage. This relay requires a positive current to transfer its contacts and a negative current to release them: the negative current is provided by the lamp resistance. It also keeps the lamp warmed slightly (not enough to generate visible light) and improves the lamp response for short pulses.
b. Horizontal Flyback Cutoff: This circuit is located on a terminal strip next to the horizontal sweep speed switches. Point C is connected to one side of both sets of resistors. When Q1 is on, which is all the time except during a horizontal flyback pulse that enters at point A, Q2 is also on and the voltage at point C is nearly B-. When a horizontal pulse comes along, it turns off Q1, and hence Q2, and the voltage at point C rises to ground potential in a few tenths of a microsecond. Since the input of the Horizontal Sweep operational amplifier operates nearly at ground potential, this rise removes nearly all the effect of the horizontal switch setting during the flyback period.

CONNECTIONS: Exposure Light and Relay Circuit

A - input from Precision Delay circuit, pin X
C - Pin 8, Amphenol 20-in connector, and thence to I.O. Exposure Relay
D - Ground
P - B+

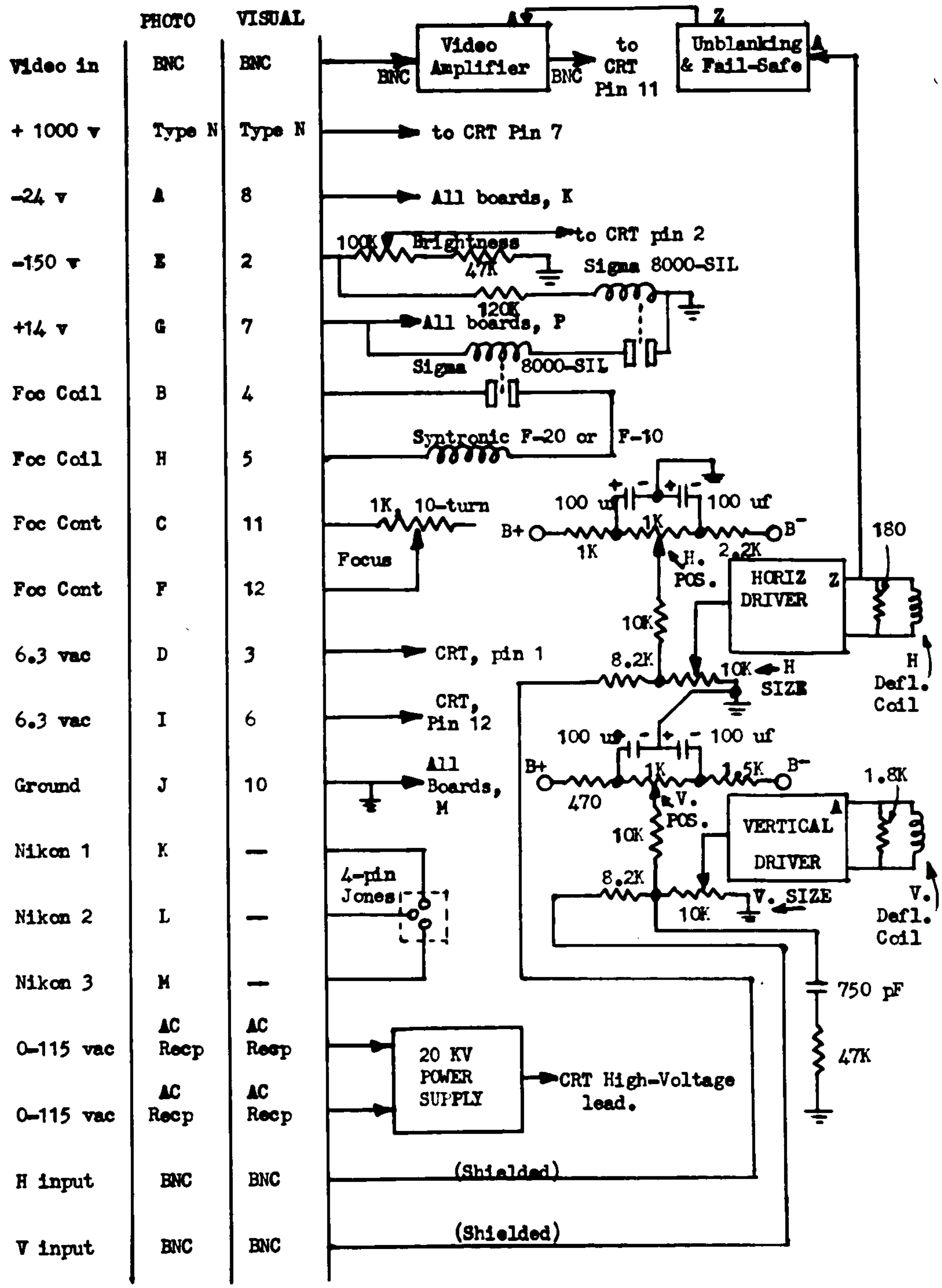
CONNECTIONS: Horizontal Flyback Cutoff

A - horizontal pulse, from pin Y, Horizontal Sweep Speed Generator
C - to one end of both sets of Horizontal Sweep Speed resistors
K - B-



POWER SUPPLIES
AND CAMERA CONTROLS FOR
SWEEP CONTROL CHASSIS
AND CAMERA CONTROL CHASSIS

LOCATED IN CONTROL CONSOLE



MONITOR INTERNAL CONNECTIONS, BOTH MONITORS

CHANGEOVER RELAY CONNECTIONS

Relay 1 is activated while the "Look-Take" flip-flop is on; that is, after initiation of a "Take" mode frame or while the "Mode" switch is in the "Take" mode. It releases on the beginning of the next vertical flyback after the button is released or the "Mode" switch is returned from "Take" to "Look-Take."

One set of contacts of Changeover Relay 1 connects the vertical pulse to the Delay 3 board in order to hold the camera shutter open during the readout period. The other contacts switch the "Look" and "Take" indicator lights (indicating which set of sweep-control switches is in operation), and switch Changeover Relay 2 on in the "Take" mode.

Changeover Relay 2 switches control of sweep speed from the "Look" thumbwheel switches to the "Take" thumbwheel switches when it is energized.