SECTION VI

ELECTRICAL OPERATION

6-1. BASIS OF DISCUSSION.

6-2. The principles of operation of the tape transport are readily divided into two main categories: control of tape motion and control of the servo mechanisms which control the length of loop in the tape storage chambers.

6-3. The explanation of circuit operation will be more clearly understood by referring to the circuit diagrams appearing in another section of this instruction book.

6-4. ACTUATOR CONTROL.

6-5. The first principle to be understood with respect to the actuator is that the direction and speed of tape motion is controlled solely by the capstans. The capstan speed, in turn, is controlled by the synchronous drive motor which receives its motive force from the ac line. Therefore, tape speed across the read/write head is a function of line frequency.

6-6. Two identical actuators for control of tape movement in the forward and reverse directions are mounted on the rear of the precision plate of the tape transport. Shafts extend to the front of the precision plate, with yokes clamped to these shafts to support the rollers and inertia brakes.

6-7. Each actuator is similar in design to a polarized relay. Two permanent magnets are used to establish the two stable conditions--ON, when the roller clamps the tape against the rotating capstan, and OFF, when the roller is pulled away from the tape and the capstan.

6-8. The actuator shaft, mounted between the two permanent magnets, has a flat reed brazed to it which serves as an armature. Flux linkage between the two magnets through this reed tends to hold it in its last set position until the opposite coil, form-wound to fit around the reed structure, is pulsed with a short burst of current to form an electromagnet. The two coils create opposing magnetic fields. Thus, one of them is always available to reverse the flux in the reed and cause the reed to flip to the other stable position. The total rotation of the reed as measured at the pole faces is only a few thousandths of an inch. The time required to shift from one position to the other is on the order of 800 microseconds.

6-9. Each actuator has one end of its pair of coils connected to a common supply point; the outer ends of these coils are connected to the anodes of thyratrons on the actuator control unit AC-400. In the discussion which follows, operation of the forward actuator K701 and its associated thyratrons V403 and V404 will be considered. The operation of reverse actuator K702 is identical for the control of reverse tape motion. (See Figure 6-1.)

6-10. Approximately 600 vdc is supplied to the coils of K701 through capacitor C107 in the PS-100 electronics power supply assembly. This voltage is applied through the actuator coils to the anodes of V403 and V404. These thyratrons cannot conduct at this time because of the dc bias applied to the grids through the center-tapped secondary winding of T408 and the isolating/decoupling resistors R415-R416 and R411-R412, and AND gate diode CR410.

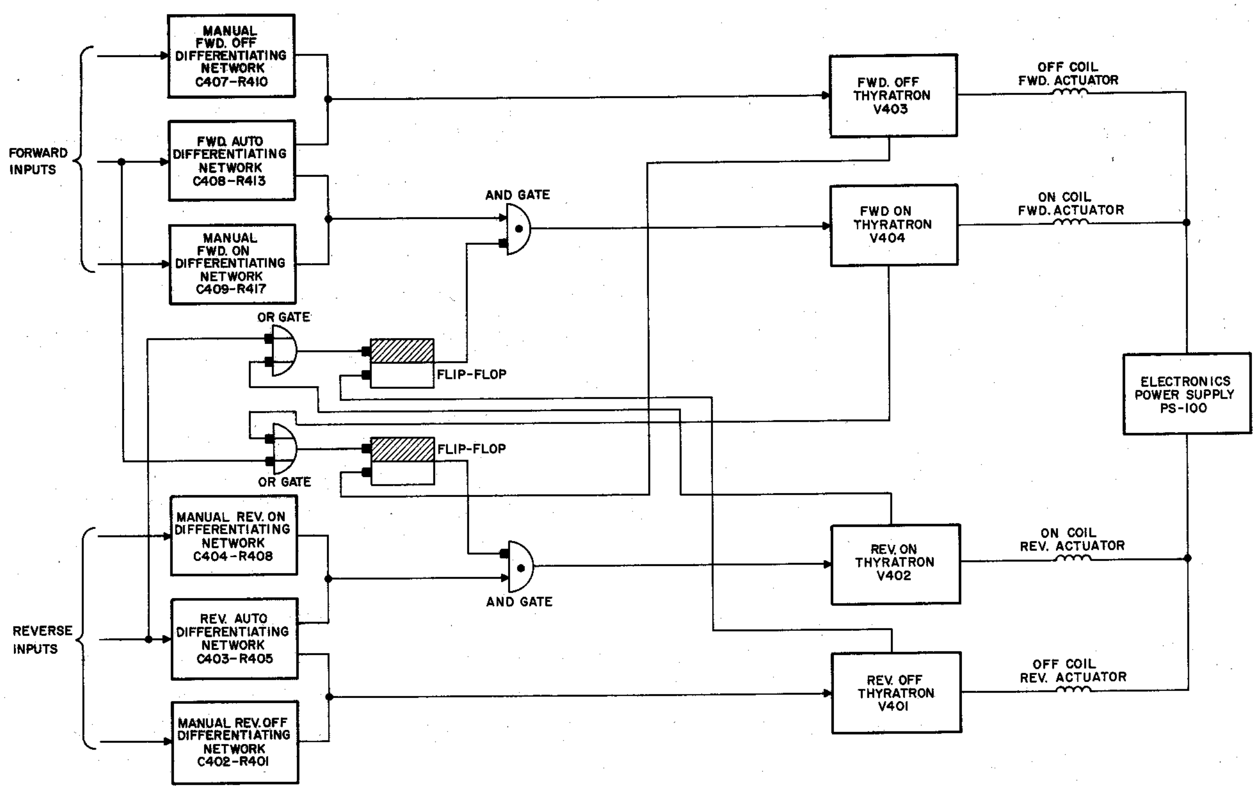


Figure 6-1
Block Diagram, Actuator Control AC-400

This negative bias is developed by half-wave rectifying 6 vac with CR401 and dropping the resultant voltage through R409. Filtering is accomplished by electrolytic capacitor C418. Capacitor C405 is used to by-pass any high-frequency transients, and Zener diode CR402 stabilizes the bias supply.

6-11. To shift actuator K701 from OFF to ON, a positive-going pulse of sufficient amplitude to drive the grid of V404 to -2 vdc or less must be provided from the control source. As the grid voltage of V404 decreases to a point sufficient to allow V404 to fire, that tube discharges capacitor C107 through the ON winding of the actuator. The amplitude of the resultant current (approximately 2 amperes peak) is sufficient to polarize momentarily the armature reed of the actuator so that it is of the same polarity as the permanent magnet which it contacts. Since like poles repel, the resulting force flips the reed to the unlike magnetic pole. With this action, the capstan roller assembly attached to the armature shaft shifts from the OFF to the ON position.

6-12. It is a fundamental characteristic of thyratrons that when conduction starts, it continues until anode voltage is removed or goes negative with respect to cathode, regardless of grid bias or signal during the conduction period. Cut-off is accomplished by utilizing the inductive back EMF of the collapsing magnetic field within the actuator coil; this back EMF follows total discharge of capacitor C107.

6-13. Figure 6-2 shows the voltage waveform at the anode of V404 under the above conditions. At the beginning of the trace, V404 is fired ON by a positive pulse to its grid; the anode voltage drops abruptly from 600 volts to approximately 10 volts and remains at this level during the time that C107 is discharging. This 10-volt level represents the more or less constant drop through V404 during conduction. At approximately 800 microseconds after T_0, the current through V404 attempts to go negative, effectively cutting off V404. At approximately 1200 microseconds the anode voltage suddenly returns to the original 600-volt level, indicating that C107 has been recharged (to be discussed later).

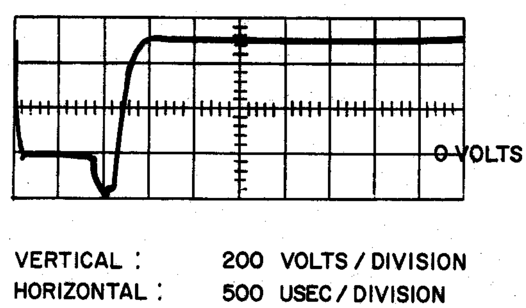
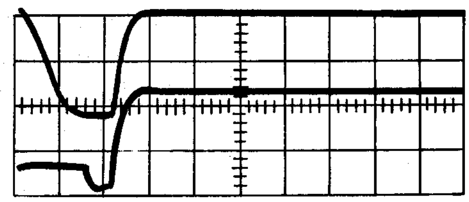


Figure 6-2
Waveshape, Anode of V404

6-14. The top waveform of Figure 6-3 indicates the voltage waveforms at C107 superimposed on the waveshape of Figure 6-2 during the firing of thyratron V404. The discharge path is the series circuit consisting of C107, the actuator coil, and the effective resistance of the conducting thyratron.

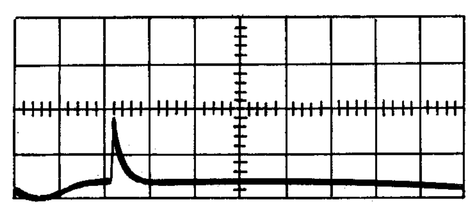
6-15. Figure 6-4 shows the waveshape of the current involved in the discharge and recharge cycle of C107. This pattern is derived by measuring across a temporarily installed 0.1 ohm resistor in the ground leads. Beginning with zero current at T_o, the current increase along the exponential discharge curve to a maximum of approximately 2 amperes at 250 microseconds, then decreases to zero at approximately 800 microseconds, indicating complete discharge of C107. (The slight discontinuity in the curve at 200-250 microseconds is caused by the saturation point of the reed and the point at which the reed begins to move from one position to the other.) At 1200 microseconds, the capacitor is recharged.

6-16. During actuator operation any external shunt loading across the actuator coil must be avoided, or the resultant lowering of thd Q of the circuit will prevent the induction of back EMF sufficient to cut off the associated thyratron.



UPPER TRACE: VOLTAGE, C107
VERTICAL: 300 VOLTS/DIVISION
HORIZONTAL: 500 USEC/DIVISION
LOWER TRACE: ANODE, V404
VERTICAL: 300 VOLTS/DIVISION
HORIZONTAL: 500 USEC/DIVISION

Figure 6-3
Waveshapes, C107/Anode of V404



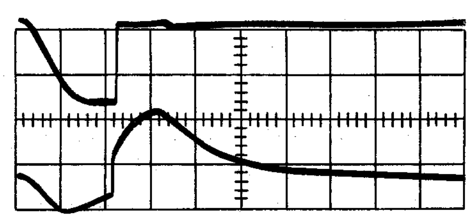
VERTICAL: 5 AMPERES/DIVISION
HORIZONTAL: 500 USEC/DIVISION

Figure 6-4
Waveshape, Discharge Current C107

6-17. The thyratron circuit of V104 is a time-delayed electronic switch, isolating the basic power supply from C106 and C107 until the actuator cycle has been completed.

6-18. When power is first applied to the tape transport, approximately 450 vac from the secondary of T102 is supplied to the bridge rectifier composed of silicon rectifiers CR111 through CR118. The rectified output from this bridge is connected through the coil of overload relay K101, its resistor R110, and two series-connected contact sets of K101 to capacitors C103 and C104. R110 is adjustable in order to vary the overload current cut-out point. The capacitance input filter causes the no-load dc voltage to be approximately 600 volts at C103 and C104. The 600 volt supply charges C106 and C107 through resistor R105, the current limiting resistors R107 and R108, and the series-connected isolation rectifiers CR109-CR110 and CR107-CR108. The time constant of this initial charging circuit is relatively long, but C106 and C107 are charged to full potential long before the filament of V104 has heated sufficiently to allow electron emission. When V104 does warm up, it will not conduct, because the anode and cathode are at the same potential and because the grid is held at ground potential through the grid resistor R106. R105 maintains C106 and C107 charged during periods of relatively long idle.

6-19. Figure 6-5 illustrates the cathode and grid potentials of V104 operation. At T_O, V404 has fired to shift the actuator ON. The cathode voltage of V104 follows the exponential discharge curve of C107. Capacitive coupling between the cathode of V104 and its grid is furnished by capacitor C105. As the cathode potential is driven in a negative direction, the grid is likewise driven negative because of the capacitive coupling. However, as soon as the rate of charge of cathode potential is reduced, the negative potential on the grid starts to leak off through R106, and the grid voltage tends to return to zero (ground). At approximately 1200 microseconds, the grid bias is so low that it no longer can prevent conduction within V104 and that tube fires. As V104 conducts, its cathode rapidly reaches supply voltage potential, and at the same time allows C103 and C104 to recharge C107 via the small inductance L101, the recharge limiting resistor R108,



UPPER TRACE: CATHODE, V104
VERTICAL: 300 VOLTS / DIVISION
HORIZONTAL: 500 USEC / DIVISION
LOWER TRACE: GRID, V104
VERTICAL: 300 VOLTS / DIVISION
HORIZONTAL: 500 USEC / DIVISION

Figure 6-5
Waveshapes, Cathode/Grid V104

and series diodes CR109-CR110. Because the grid assumes a potential somewhere between the potential of the cathode and the anode during conduction, the grid voltage is elevated along with that of the cathode. Approximately 200 microseconds is required for recharging C107, but it is necessary to cut-off V104 before the next actuator cycle can begin. The collapsing field in L101 provides an inductive back EMF at the end of the recharging of C106 or C107, with the result that the cathode is momentarily driven more positive than the anode, cutting off the tube, and allowing the grid to regain control. Since the grid was at essentially cathode potential at the time of cut-off, this positive grid potential must leak off to ground via R106. Figure 6-5 shows that the grid is at nearly ground potential after a total elapsed time of 2.8 milliseconds from T_o.

6-20. Capacitors C106 and C107 are actually connected in parallel, the connection being made through resistors R107 and R108 and isolating rectifiers CR107-CR108 and CR109-CR110. The capacitors are isolated to provide independent power sources for the forward and reverse actuators. Since the system has no "memory" of which actuator is ON at a given instant, demand is made by safety interlocks to position both actuators OFF, (as when vacuum or power fails, etc.). The pair of safety contacts may not close at exactly the same instant, and split capacitors are required. The series rectifier circuits prevent discharge of one capacitor simply because the other one discharged. This also limits the charging current to that necessary to charge only one capacitor and minimizes the heat dissipation and power supply loading.

6-21. Because of the time required for an actuator to complete one cycle, it is mandatory that the spacing of commands to the actuator control be no closer than 2.5 milliseconds, regardless of the command. If for any reason a command signal to the system is programmed closer than 2.5 milliseconds to a previous command, two things may occur:

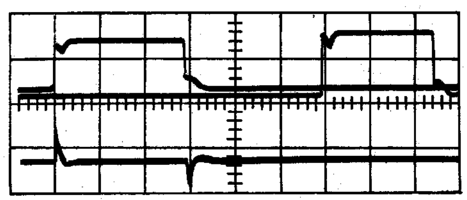
(1) The control thyratron associated with the previous command will not be permitted to cut off (by virtue of the second command). As a consequence, V104 will connect the power supply to ground via the thyratron and actuator coil.

(2) The grid of V104 will have insufficient time for return to ground potential after the previous command, and V104 will fire prematurely; this, in turn, will shunt the power supply across the actuator coil involved with the result that the associated control thyratron will not cut off.

In either instance, the power supply will be overloaded, and the overload relay K101 will energize. As the contacts of K101 break the power connection, C103-C104 and either C106 or C107 will discharge rapidly through whichever control thyratron is still conducting, and by the time the relay contacts again close the power circuit, the control thyratron will be back to normal status. Thus, accidental programming of commands too close together will not damage the equipment (because of the overload safety feature), but will cause the sequential nature of the programming to be interrupted by one or more missed functions.

6-22. Two external input connections are provided at the terminals 7 and 9 of the actuator control etched board assembly AC-400; these terminals are connected to terminals 34 and 35 of J303. The input common lead is connected to terminal 8 of the etched board assembly; this common lead may be grounded if desired, but it must serve as the return for the automatic input signals. Start and stop commands must be generated by a dc voltage level change. The actuator will function on a 8 volt (+12, -0) level change, such as -10 to 0 vdc or 0 to +10 vdc for the start command, maintained at the particular voltage for the duration of the run time. Returning the command level to the original level constitutes a stop command. The rise time of this step function dc signal should be no greater than 10 microseconds. The top pattern of Figure 6-6 indicates such an input signal.

6-23. The dc signal is applied to current limiting resistor R413, through the parallel network of C408-R414, and thence to the primary of pulse transformer T408. (The R-C network raises the dc input impedance of the system to prevent undue loading of the external source.) The combination of the input network and the pulse transformer is such that at terminal 1 of T408 only a sharp spike remains of the original input signal. This is illustrated by the bottom pattern of Figure 6-6. The peaked



UPPER TRACE:	TYPICAL INPUT SIGNAL
VERTICAL:	10 VOLTS/DIVISION
HORIZONTAL:	5 MSEC/DIVISION
LOWER TRACE:	TERMINAL 1, T408
VERTICAL:	10 VOLTS/DIVISION
HORIZONTAL	5 MSEC/DIVISION

Figure 6-6
Waveshapes, Typical AC-400
Input/Resulting Pulse

signal in the primary of T408 is stepped up and applied to the grids of V403 and V404. An ON signal causes a positive spike to appear at the primary of T408; a positive spike will then appear at the grid of V404, causing V404 to conduct and shift the actuator ON. At the same time, a negative spike is applied to the grid of V403, adding to the already present fixed dc bias so that V403 does not conduct. If the input command is OFF (signal shifting from zero volts to -10 volts), a positive signal will be applied to the grid of V403 and a negative signal applied to the grid of V404.

6-24. Four external manual control connections are provided at terminals 12, 4, 6 and 10 of the etched board AC-400, corresponding to terminals 44, 41, 40 and 42 of J303. Application of a ground to these terminals will cause the indicated actuator operation to occur. For example, suppose it is desired to shift the forward actuator to ON. Applying a ground to terminal 6 of the etched board by means of an external relay or switch will cause a positive spike to appear at the grid of V404. The spike is created by the charging of .002 mfd capacitor C409 through the grid circuit of V404. When the ground is subsequently removed from terminal 6, C409 discharges via shunt resistor R417; the circuit thus is ready for the next similar command. As the ground is applied to terminal 4, a positive spike appears at the grid of V403 and the forward actuator shifts to OFF. Shunt capacitor C406B bypasses any transient impulses picked up via the external wiring. If the manual control is returned to +14 vdc instead of ground, essentially the same results are obtained, but a positive-going spike of greater amplitude is provided to the associated thyratron grid. (See Figures 6-7 and 6-8.)

6-25. The external manual control system must be interlocked by switches and/or relays to prevent application of opposed or contrary commands. For example, it should not be possible to apply a forward ON and a reverse ON command simultaneously, (or in sequence without going through an OFF command). The limitation on spacing of commands is the same as during automatic operation: 2.5 milliseconds minimum between subsequent commands. It is also recommended that the automatic and manual inputs be interlocked so that it is impossible to apply simultaneous manual and automatic signals. Such interlocks are included in the Ampex Manual Control Panel, and are also indicated in Figure 2-7.

6-26. An actuator interlock circuit prevents both forward and reverse actuators from being ON simultaneously and thus prevents damaged tape. Simultaneous ON commands can arise in three ways:

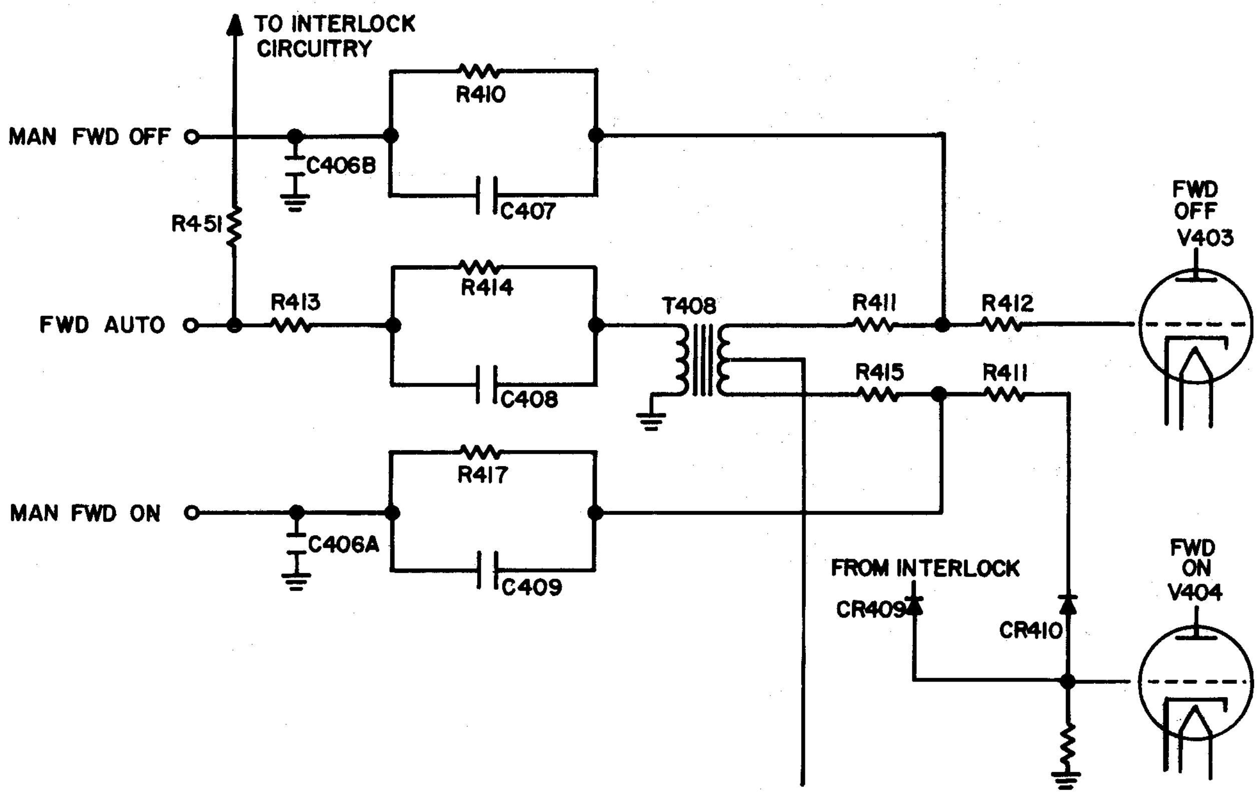


Figure 6-7
Partial Schematic, AC-400 (Forward Control)

(1) Simultaneous commands in error from the computer.

(2) Inadvertent firing of one actuator ON due to external noise when the other actuator is on the ON position.

(3) Failure of an actuator when commanded to move from the ON position to the OFF position due to a defective thyratron or actuator.

The interlock circuit will prevent simultaneous actuation caused by the first two conditions, but not the third.

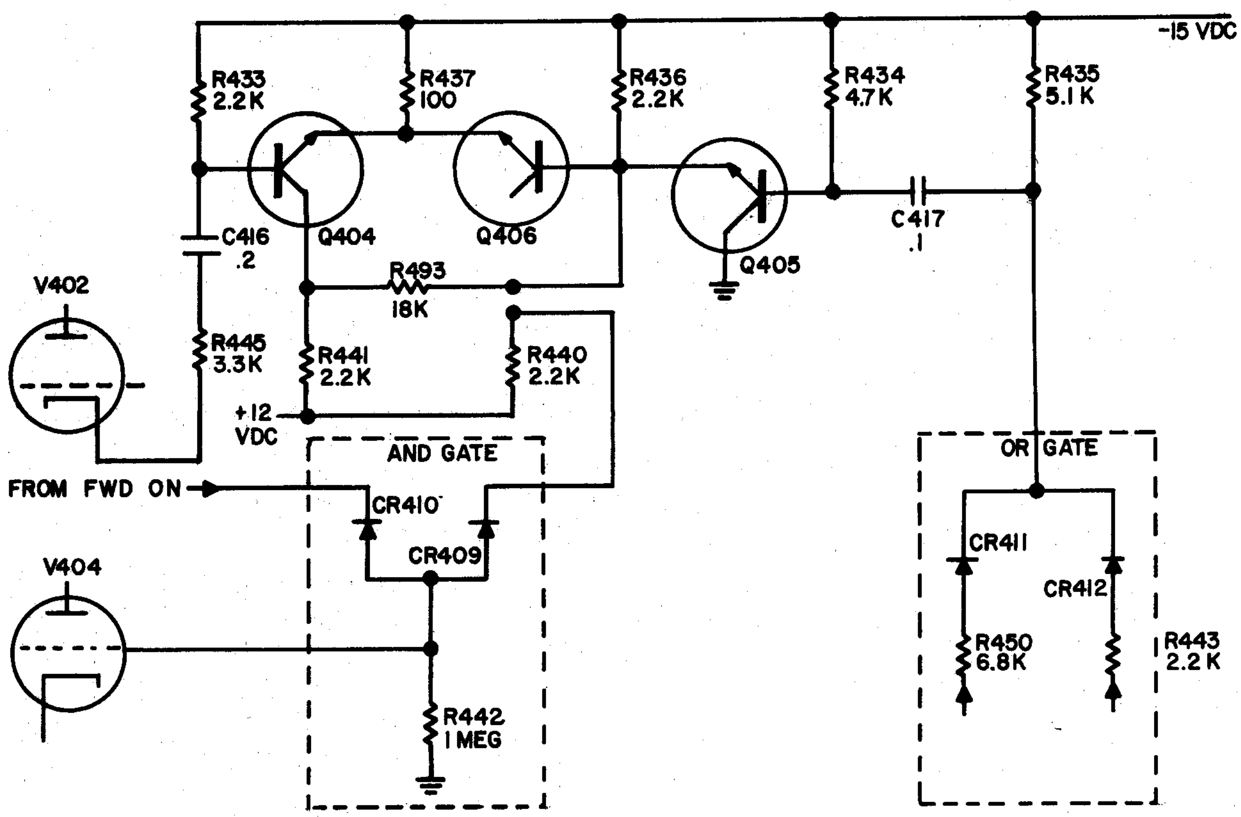


Figure 6-8
Partial Schematic, AC-400 (Forward Interlock)

6-27. Basically, the circuit consists of a flip-flop and an associated AND gate for each of the forward and reverse ON actuator circuits. The flip-flop controls the AND gate, which in turn is connected in series with the ON thyratron grid circuit. For example, if the reverse actuator is commanded from OFF to ON positions, the command signal via the flip-flop associated with the forward circuit inhibits the AND gate for the forward ON thyratron, thus preventing operation, even if a forward ON command signal is received. Conversely, should the reverse ON thyratron fire because of a transient, the discharge of the OFF thyratron triggers the flip-flop to inhibit the AND gate to the forward ON thyratron.

6-28. In the following discussion, operation of the forward interlock will be described; operation of the reverse is similar.

6-29. A positive-going pulse is applied to pin 9 of P102, and via isolation resistor R450 through one leg of the OR gate consisting of CR412, CR411, and R435. The signal is then coupled to emitter-follower Q405, via C417. The emitter-follower arrangement is used for impedance matching, since the input impedance of the flip-flop is very low. Output from emitter-follower Q405 is fed to flip-flop consisting of NPN transistors Q404-Q406. The flip-flop is a set-reset Eccles-Jordan saturating type, designed so that when power is turned ON, the flip-flop will be in one particular state, i.e., Q404 conducting.

6-30. The operation of the flip-flop is as follows: Assume that Q406 is OFF and Q404 is ON, ON being defined as the condition in which the transistor is conducting.

6-31. Since Q404 is conducting, its collector potential is highly negative; thus the potential at the base of Q406 is near the value of the negative supply, the value being determined by the ratio of R439 to R436. The emitter is approximately 1.5 vdc positive with respect to the negative supply because of the drop in R437.

6-32. The resulting negative bias of 1.2 vdc exists across Q406 base-emitter. Q404 base-emitter is positively biased. Since Q406 is not conducting the collector of Q406 is positive being clamped to +7.5 vdc by CR413, R444, R432, C419 combination. The positive bias for Q404 is provided by R438.

6-33. If a positive pulse is applied to Q406 (assume Q406 is OFF) then this transistor is triggered ON; Q406 conducts thus dropping Q406 collector to -12 vdc and R438 couples a signal to base of Q404, thus cutting Q404 off. When Q406 is conducting, the positive AND gate consisting of CR410, CR409 and R442 is inhibited; thus, a command signal applied to the gate input through CR410 would not reach the grid of V404. Conversely, if Q406 is not conducting, then a positive command signal applied to AND gate input (CR410) would not be inhibited and thus the grid of V404 would drop to near ground potential via R442, causing this thyratron to fire.

6-34. The flip-flop is reset, allowing the forward actuator to be turned to its ON position by a signal from the reverse OFF thyratron V401. The actual resetting of the flip-flop is accomplished by the positive voltage across R449 resulting from the firing of V401, coupled through R445 and C416 to trigger reset transistor Q404.

6-35. The operation is similar in the MANUAL mode, save that the flip-flop is triggered from the firing of the reverse ON thyratron V402, rathen than by the automatic reverse input signal.

6-36. Two supplies power the interlock circuit; the supplies have a common return through pin 11 to chassis ground. The -15 vdc supply consists of rectifier/filter network CR404-C412-R419-C413. The regulation of the supply is achieved by Zener diode CR415. The +12 vdc supply consists of rectifier/filter network CR403-C410-R418-C441. The supply is regulated by Zener diode CR410.

6-37. SERVO SYSTEM.

6-38. Two servo systems, identical in design and operation, constitute the tape tensioning and storage arrangement. (See Figure 6-9.) Although the transport is basically a reel-to-reel device, a quantity of tape is stored on either side of the capstans in vacuum chambers. The servos are used to maintain the lengths of these loops at a nominally constant length.

6-39. In these servos, any variation in tape position initiates a series of actions to maintain the tape loop length at its ideal, or null position. This "ideal" position is the position of the loop at which the transducer core is in its null position, delivering minimum error signal to the servo motors through the system of amplifiers and thyratrons. This null position is the steady state of the servo.

6-40. Sensing slots, running virtually the entire length of the vacuum chamber, are pneumatically connected to the diaphragm of the transducer. When the loop expands or contracts in the chamber, the transducer core (connected to the diaphragm) moves. Any movement from the null position induces an error signal from the transducer; this error signal, demodulated and dc amplified, controls the firing of the power thyratrons. These thyratrons fire as a reflection of the transducer core movement. The firing of these thyratrons controls the servo reel motors, which deliver tape according to the demand of the tape loop position, thus completing the servo loop.

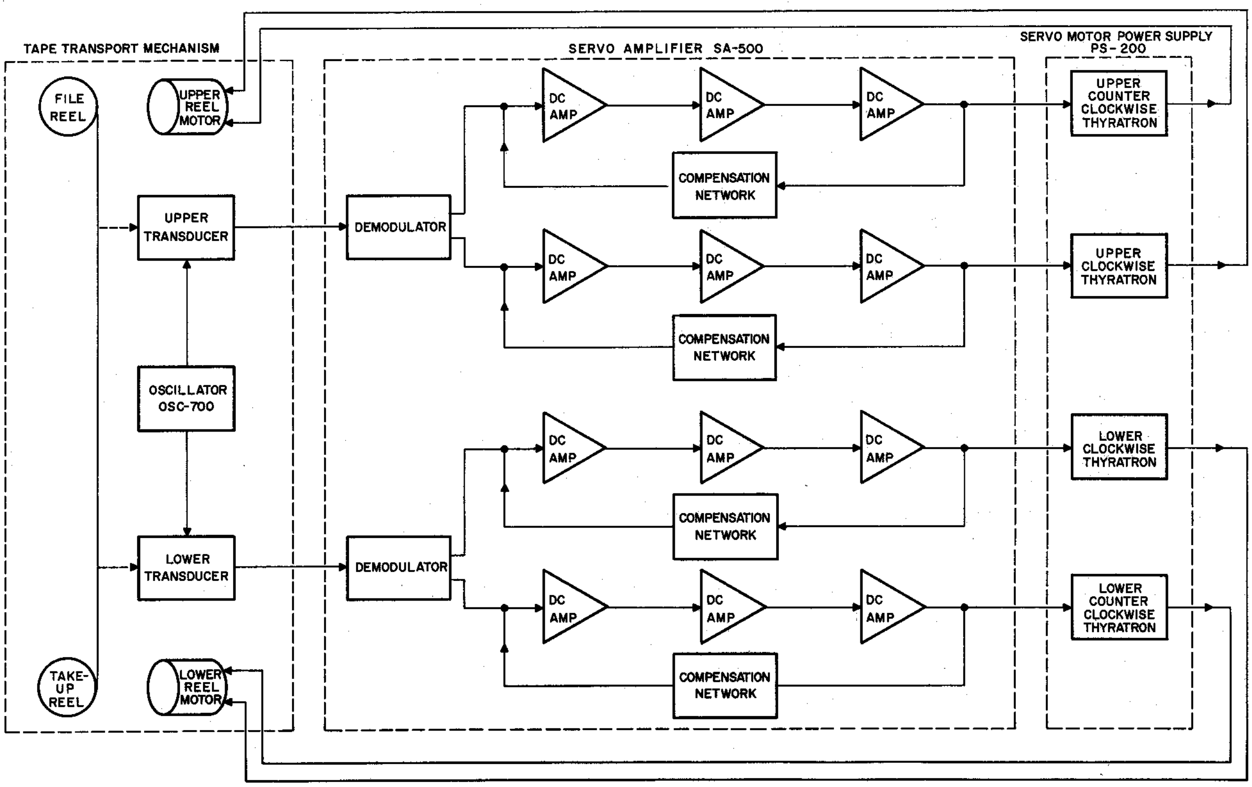


Figure 6-9
Block Diagram, Reel Servo System

6-41. The servo amplifier (SA-500) and the servo power supply (PS-200) form the intermediate link between the tape position error signals and the rotation of the servo motors. It should be noted that the only moving mechanical parts of the servo system are the transducer bellows and core, the servo motors, and the tape itself.

6-42. The following discussion will be limited to the upper servo system (associated with file reel and left vacuum chamber). Details of the lower servo system (take-up reel and right vacuum chamber) are identical. Note that the two servos are independent and that servo action in one vacuum chamber has no effect on the other. It is possible, under certain programming sequences, to have either servo rotating clockwise and the other counter-clockwise for short periods.

6-43. The transducer is a pneumatic, diaphragm-operated linear differential transformer. Vacuum from the sensing slots in the vacuum column is connected to one side of a sensing diaphragm, which expands and contracts linearly with changes in vacuum within the plenum behind the slot. The core of the transducer is rigidly attached to the diaphragm, so that movement of the diaphragm displaces the core with respect to the cylindrically wound primary and secondary windings of the transformer.

6-44. The primary of the transformer is excited at nominally 2000 cps by the oscillator (OSC-700), the output amplitude of the oscillator being varied to adjust servo gain. When the core is positioned equidistant between the primary and the two secondaries, the output from the phase-opposed secondaries is at null. When the diaphragm moves the core away from null, a voltage differential appears between the two secondaries.

6-45. When properly adjusted, the transducer produces a null with the ends of the tape loop approximately 14 inches apart in the vacuum chamber. Displacement of the tape loops in either the long or short loop directions will cause a corresponding output voltage change as measured across the transformer secondary.

6-46. These slight changes in secondary output ultimately serve as the direction sense for servo motor control. Overall sensing is such that the servo motor always tries to rotate the tape reel in such a direction as to return the tape loop to the null position.

6-47. The pneumatic/mechanical speed of response of the transducer to tape loop position change is quite rapid. Low mass, small penumatic capacitance, and high sensitivity assure that minute variations in plenum pressure result in a rapid change in induced secondary voltage.

6-48. The oscillator assembly, mounted on the rear of the tape transport, is a three stage unit, composed of oscillator, buffer stage, and push-pull power output stage. A block diagram is shown in Figure 6-10.

6-49. The B+ and filament power for operation of the oscillator is obtained from the PS-100 power supply.

6-50. Signals developed across the plate load of the oscillator are attenuated and shifted in phase by the RC networks composed of C2-R4, C3-R5, and C4-R6. At the 2000 cps frequency of the oscillator, each of the frequency selective networks shifts the signal in phase by 60°, so that the signal appearing at the grid of oscillator tube V701A is 180° out of phase with the signal at the plate, thus supporting and sustaining oscillation.

6-51. The oscillator signal is fed to V1B, which functions principally as a buffer to prevent any load changes at the output from interacting with the oscillator.

6-52. The push-pull power output stage consists of the two halves of V702 in a conventional circuit, driving output transformer T701, which in turn feeds the primaries of the transducers. Potentiometers between the secondaries of this transformer and the primaries of the transducers are used to set servo system gain. Typical oscillator output is shown in Figure 6-11.

6-53. The servo amplifier board consists of two demodulators and two dc amplifiers. Only the demodulator and dc amplifier relating to the upper servo will be discussed here.

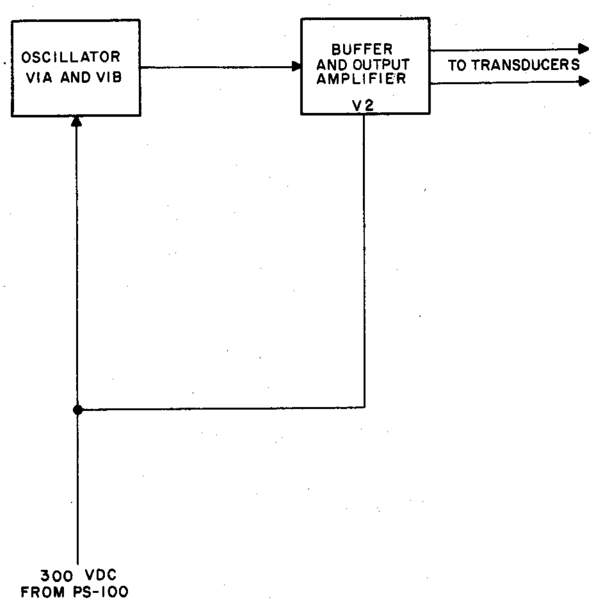


Figure 6-10
Block Diagram, Servo Oscillator
OSC-700

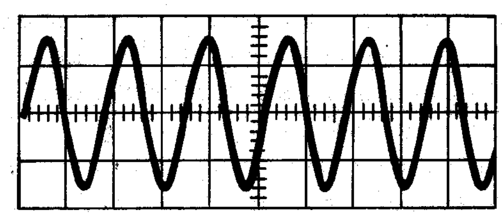


Figure 6-11
Waveshape, Typical Oscillator
Output

6-54. The input to the servo amplifier board is the signal developed in the secondary of the differential transformers above. The output of the servo amplifier board is a variable dc level determined by the position and rate of position changes within the vacuum plenum.

6-55. The signal developed in the secondary of differential transformer TR701 is the input to a diode demodulator circuit. Diodes CR510 through CR513 are so polarized that filter capacitors C510 through C513, associated with the amplifier input grids, are charged either positively or negatively according to the respective diodes. The magnitude of the charge is proportional to the transformer secondary output. The charges on these capacitors are also summed by resistors R510 through R513, common to each input grid. Since in steady state conditions, the secondary outputs are equal, the impressed voltage across the summing resistors is equal and of opposite polarity, therefore a zero error voltage appears at the input grid. Any deviation from this steady state condition results in an error voltage being impressed upon the input grid, the polarity of which depends on the direction of deviation. (See Figure 6-12.)

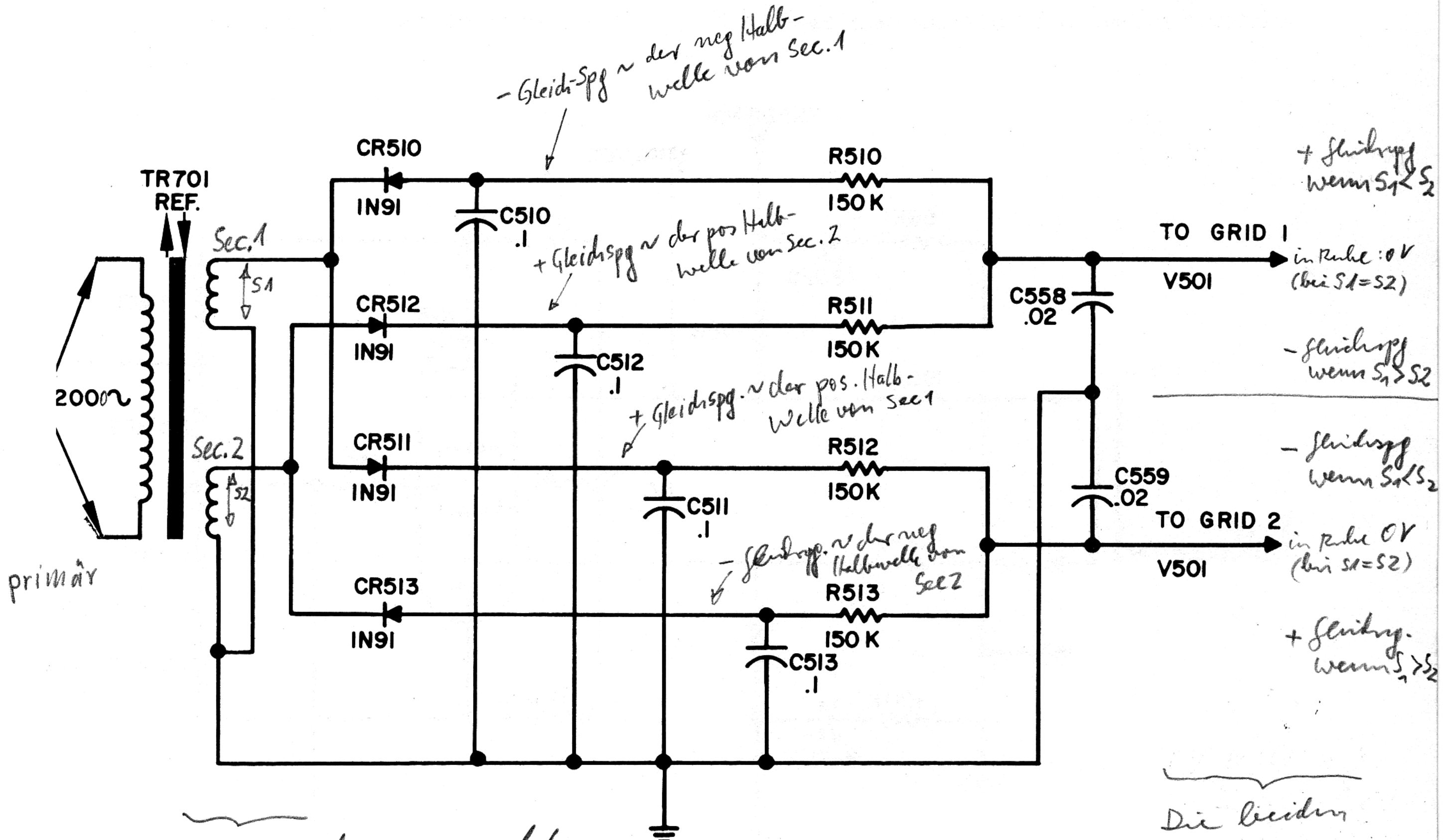
6-56. Since the foregoing is true of both input grids, with opposite polarity, double gain of the demodulator is achieved.

6-57. Three stages of amplification follow the demodulator. To minimize drift, each stage is a cathode-coupled differential amplifier. The low-frequency gain of the three stages is such that the characteristics of the amplifier are essentially the ratio of the input and feedback impedance. This ratio is so determined that at the higher frequencies, gain is much greater than at lower frequencies or at dc. The components which determine amplifier response are the simple resistor/capacitor networks composed of R537-C516-R533, R514-R585-C514-R589, R540-C517-R534, and R517-R586-C515-R570. The characteristic resulting from these networks is that slow variations in tape position result in one output, whereas fast changes of tape position cause much larger outputs. These networks also provide the compensation required for servo loop stability. (See Figures 6-13 through 6-15.)

6-58. When system power is turned ON, 2.5 vac at 6.3 amperes is supplied from the four secondaries of filament transformer T205 to thyratrons V201 through V208. Thyratrons V201 through V204 are associated with the upper servo. The center taps of the secondaries of T205 are connected to ground; the common returns from the servo motors are grounded at the same point. This filament center-tap ground permits the servo motor power supply to operate as a dc power supply with the positive side grounded.

6-59. The primaries of anode transformers T206 and T207 are supplied with 117 vac after a delay of 45 seconds from the initial application of power to the system. The secondary of the anode transformer T206 (in the case of the upper servo) provides 300 vac, with the center tap of the winding connected to the external motor load. The thyratrons are connected in a dual full-wave configuration; V201-V202 deliver negative dc (essentially rectified ac) to the clockwise winding of split-series upper servo motor B704. V203 and V204 function in an identical manner to furnish dc to the counterclockwise winding of upper servo motor B704.

6-60. The thyratrons function in a conventional manner in that they will not conduct (rectify) until three conditions are fulfilled:



hier wird vorausgesetzt, daß die pos. und die neg. Halbwelle jeder Schwingung tatsächlich gleich groß sind!!

Figure 6-12
Partial Schematic, SA-500 (Demodulator)

Die beiden Ausgangsspannungen verändern sich also gegensinnig wenn der Kern des Transducer aus der Nullstellg. gebracht wird!

1) The anode is more positive than the cathode (filament) by greater than 15 volts.

2) The grid voltage is less negative than the point at which the thyratron is prevented from firing.

3) An external load is connected.

Once a thyratron fires, it continues to fire until the anode potential drops to approximately that of the cathode.

6-61. An alternating current applied to the primaries of grid transformers T201 and T202 is attenuated and phase shifted by R-C networks in the primary circuit of each transformer and in the grid circuit of each thyratron. This

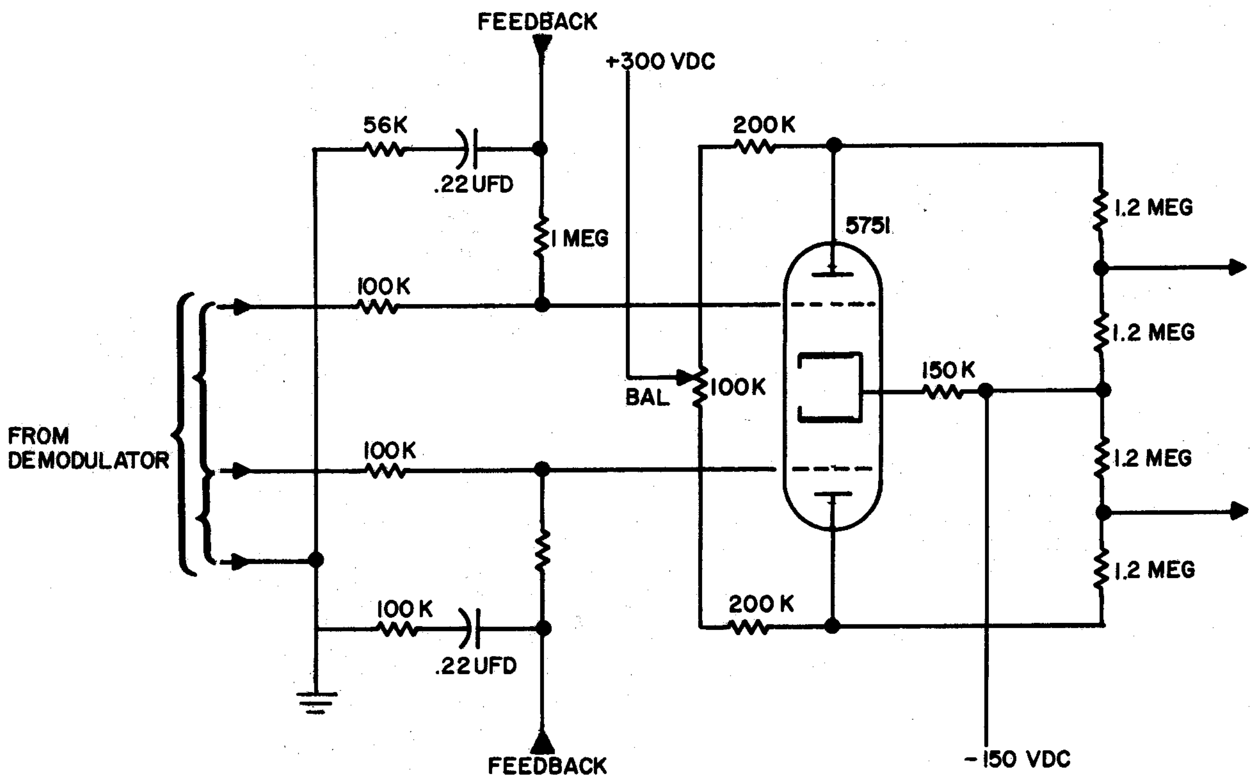


Figure 6-13
Partial Schematic, SA-500 (First Stage)

phase shift, in conjunction with the normal phase reversal from primary to secondary of the transformer, produces approximately 12 volts peak-to-peak at the grid of each thyratron. This grid voltage lags the plate in phase by 270°. To control thyratron conduction, a dc level is combined with the ac bias at the center tap of each grid transformer. By this device, thyratron conduction becomes a linear function of the dc level.

6-62. Inasmuch as the dc level is the output of the servo amplifier, thyratron conduction becomes a direct function of tape loop excursion. The nominal value of the dc control level is -6 vdc. The phase relationship between the grid and anode voltages is shown in Figure 6-16. Recalling the manner in which thyratron conduction occurs (see above) it can be readily seen from Figure 6-16 that, with a less negative value of dc, the thyratron will begin to conduct as the dc control level becomes more positive. The thyratron will conduct over the larger portion of the anode positive cycle. This process is continued until such time as the dc level reaches a positive value equivalent to the peak amplitudes of the ac bias. At this value, full 180° conduction occurs.

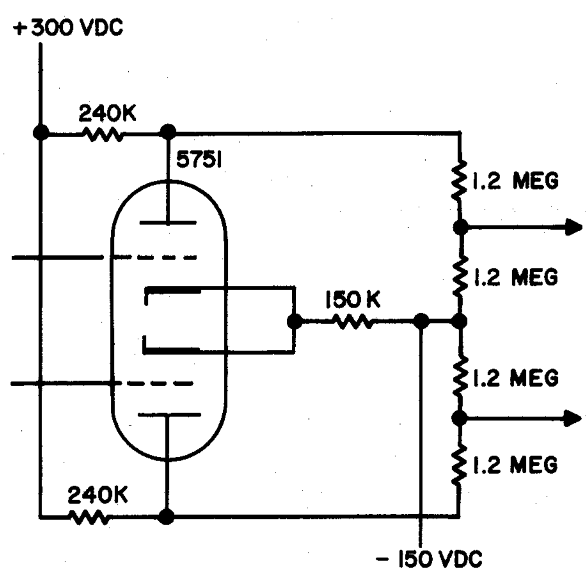


Figure 6-14
Partial Schematic, SA-500
(Second Stage)

6-63. Under steady state conditions, all four thyratrons are conducting over part of each anode positive half cycle, the combination applying power to the servo motor. Since half this total power is applied to the clockwise winding and half to the counter-clockwise winding, the net torque is zero. The power loss is negligible, and does not contribute appreciably to motor heating.

6-64. MANUAL CONTROL PANEL.

6-65. The manual control panel offers facilities for power control, selection of command source (manual or automatic), selection of tape motion under manual control, and a manual write/leader drive control. The control functions are so arranged that in the MANUAL mode it is impossible to present simultaneous ON signals to the two actuators.

6-66. The panel consists of four switches for control of the above functions, two time delay/relays, four conventional relays, four rectifiers, and two control indicators (POWER ON and READY).

6-67. The power source is connected to pins 47 and 48 of P303 through the circuit breakers CB301 and CB302 on the connecting chassis (CC-300) of the control power supply assembly. When S806 on the manual control panel is placed in the ON position, power is connected across thermal delay relay K805 through normally-closed contact set K805C of time delay interlock relay K805. Power is also routed to pin 50 of P303, from whence it is connected to the servo motor power supply (PS-200) and through circuit breaker CB303 to electronics power supply PS-100. If the circuit breakers are all in the ON position, the capstan drive motor will start capstan rotation, the

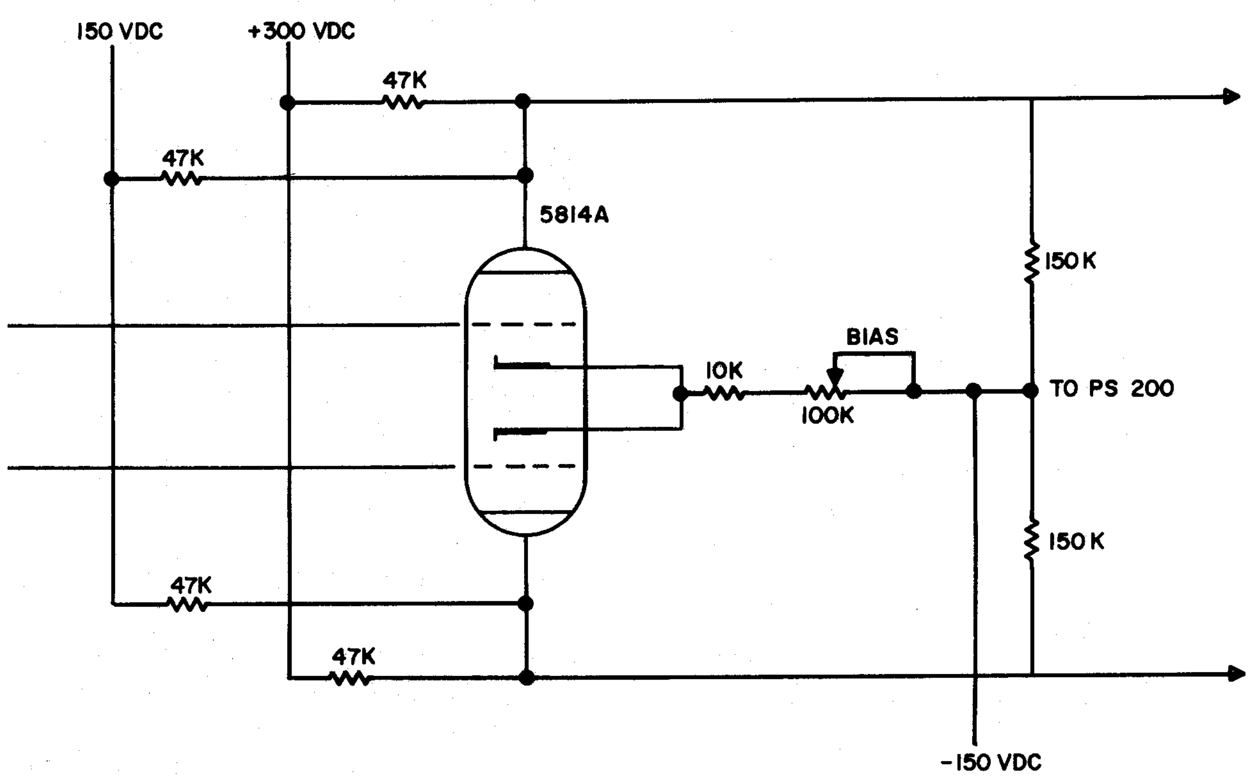
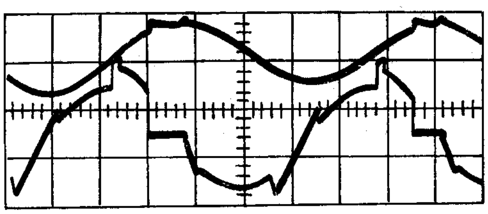


Figure 6-15
Partial Schematic, SA-500 (Final Stage)

vacuum blower motor and the cabinet cooling fan motors will start as switch S806 is closed. After a 45-second time delay, relay K805 operates. Its contact set couples 24 vdc (rectified by CR805 and CR806 from 52 vac supplied from electronics power supply PS-100) across the coil of time delay interlock relay K806. Contact set K806A from a holding circuit for the relay, paralleling the contact set of K805. Contact set K806B connects -24 vdc to the external series circuit consisting of the leader clamp switch, interlock switch, door interlock switch, and loop warning switches. This circuit re-enters the manual control panel at pin 13 of P303. Contact set K806C breaks the power connection to time delay relay K805 which eventually cools and re-opens its contacts. The -24 vdc is also used to illuminate POWER indicator DS802.

6-68. The MODE SELECTOR switch has four decks, each deck a three-pole, three-position switch. When the MODE SELECTOR switch is placed in the AUTOMATIC position, -24 vdc from the interlock circuit is connected through contacts 1 and 2 of deck III to the coil of relay K804, energizing the relay. Contact sets K804A and K804B are paralleled to connect 117 vac to terminal 39 of P303, from whence the power is routed to anode transformers T206 and T207 in the servo motor power supply (PS-200). An additional -24 vdc output, rectified by diodes CR803 and CR804 from a 52 vac source in the electronics power supply PS-100, supplies power to the brake solenoids through contact sets K804C and K804D to release the brakes on the servo motors.



UPPER TRACE: THYRATRON GRID
VERTICAL: 10 VOLTS/DIVISION
HORIZONTAL: 2 MSEC/DIVISION
LOWER TRACE: THYRATRON ANODE
VERTICAL: 200 VOLTS/DIVISION
HORIZONTAL: 2 MSEC/DIVISION

Figure 6-16
Waveshape, Relationship
Grid/Anode Voltages

6-69. If the LOOP WARNING switches are in their normally closed position, -24 vdc is also connected across the coil of interlock relay K802 through contacts 5 and 6 of deck IV; the relay is then energized. Contact sets K802E and K802F are concerned solely with AUTOMATIC mode operation; in their energized position they complete the circuit from the automatic forward and reverse signal inputs to the applicable circuits in the actuator control unit (AC-400).

6-70. Contacts 1 and 2 of deck IV and contacts 9 and 10 on deck III connect the tape sensing circuits to terminals 6 and 10 on P303 for remote tape sensing. Contacts 5 and 6 on deck III connect the -24 vdc to terminal 9 of P303, where it may be used as a remote AUTOMATIC READY indicator. Contacts 5 and 6 and 1 and 2 of deck I are in series with relay contacts sets K802E and K802F in the automatic input circuit.

6-71. Should the programming sequence cause a long loop or short loop to be formed in either vacuum chamber while the transport is in the AUTOMATIC mode, the -24 vdc will be removed from pin 13 of P303 (by virtue of the long loop/short loop switch opening). This, in turn, will cause K802 to de-energize until such time as the servo system recovers. There is a time delay of 20 milliseconds (supplied by R805-C801) to permit recovery of loop position. In de-energizing, K802E and K802F open the automatic input circuits; K802C and K802D apply +14 vdc to both actuator OFF circuits, supplying OFF current pulses to both actuators and causing whichever actuator is ON at that moment to switch to the OFF position. K802 will be re-energized as soon as the long loop or short loop condition is removed by servo action, permitting programming to continue.

6-72. If the basic interlock circuit is broken while the transport is in the AUTOMATIC mode (as by power failure, door opening, vacuum failure, etc.), K802 and K804 will de-energize. These relays cannot be re-energized until the basic interlock is again completed.

6-73. When the MODE SELECTOR switch is placed in the MANUAL position, power relay K804 is energized through isolation diode CR807 and contacts 1 and 4 on deck III. (The interlock circuit must be completed in order that the power relay may be energized.) The contact sets of relay K804 perform the same functions as described above under AUTOMATIC operation.

6-74. Interlock relay K802 is energized if the short loop/long loop switches are in their normally closed positions. The energizing circuit extends from terminal 13 on P303 through contacts 5 and 8 on deck IV, the normally-closed contact set K803A, the MANUAL CONTROL switch (in its STOP position), to the relay coil. In its energized position, relay set K802A forms a holding circuit which bypasses the MANUAL CONTROL switch, permitting this switch to be turned from its STOP position.

6-75. Note that if the MODE SELECTOR switch is placed in the MANUAL position and the MANUAL CONTROL switch in any position other than STOP, relay K802 will not energize. Under these conditions, the MANUAL CONTROL switch must be placed in the STOP position once before any tape motion may be initiated.

6-76. Contact set K802B completes a circuit to +14 vdc through contacts 5 and 8 on deck II so that manual control signals for tape motion may be selected at the MANUAL CONTROL switch. (As previously explained, these signals for tape motion are created for overcoming the -15 vdc hold-off bias.) Contact sets K802C and K802D, in conjunction with contacts 9 and 12 on deck I and contacts 1 and 4 on deck II ensure that the forward actuator and reverse actuator cannot be shifted ON until the basic interlock is completed. (Contact sets K802E and K802F are applicable only to AUTOMATIC mode operation.)

6-77. Contacts 1 and 4 on deck IV and contacts 5 and 8 on deck III connect through the interlock circuit to the coil of end-of-tape relay K803. If the outer section of the upper tape sensing contact post is shorted to ground by conductive backing on the tape, the relay is energized. Contact set K803A de-energizes the holding circuit of interlock relay K802, the contacts of the relay return to their de-energized position, stopping tape motion. Note that end-of-tape relay K803 can be energized only in the MANUAL mode. Contacts 5 and 8 on deck III also supply -24 vdc (after the interlock has been completed) to the MANUAL WRITE section of the MANUAL WRITE/LEADER DRIVE switch, so that when that control is placed in the MANUAL WRITE position, associated remote relays for write application may be energized.

6-78. The MANUAL CONTROL switch S802 is a three deck control, each deck consisting of a two-pole, five-position switch. Deck I is a shorting (make-before-break) type switch; decks II and III are non-shorting. The control may be used to select any of the five tape drive conditions: FWD (Forward), FAST FWD (Fast Forward), STOP, REV (Reverse), and FAST REV (Fast Reverse or Rewind). It should be noted that the switch can select a drive condition only when the MODE SELECTOR switch S801 is in the MANUAL position, and that all actions previously described for that position are completed. The following discussion, therefore, assumes that the MODE SELECTOR switch is in the MANUAL position, and that relays K802, K804, and K805 have energized.

6-79. When the switch is placed in the FWD position, contacts 4 and 6 of deck III complete a +14 vdc circuit to the forward actuator ON circuit. The actuator will clamp the roller assembly against the rotating forward capstan, and tape motion will start. When the selector is returned to the STOP position, contacts 3 and 6 on deck I connect the +14 vdc signal to the forward OFF circuit; the roller assembly moves away from the capstan and the tape motion is stopped with the aid of the inertia brake on the roller assembly rocker arm.

6-80. When the MANUAL CONTROL switch is placed in the REV position, contacts 12 and 8 on deck III connect the +14 vdc to the reverse ON circuit. The reverse actuator clamps the tape against the rotating reverse capstan. When the selector is returned to the STOP position, contacts 9 and 12 on deck I connect the +14 vdc to the reverse OFF circuit. The roller moves away from the capstan, and tape motion is stopped with the aid of the inertia brake on the roller assembly arm.

6-81. When the MANUAL CONTROL switch is placed in the FAST FWD position, contacts 5 and 6 on deck III connect +14 vdc to the forward ON circuit. Contacts 12 and 11 on deck II connect -24 vdc to thermal time delay realy K801 and, via pin 8 of P303, to rewind relay K701 on the tape transport.

The latter relay selects the fast winding of the capstan drive motor so that the capstans will be driven at higher speed. After approximately two seconds, thermal time delay relay K801 will operate to open its contact set. The contact set will remain open as long as the MANUAL CONTROL switch is in the FAST FWD position; and for approximately five seconds after the control has been switched from this position. This feature prevents the sudden application of the opposite roller assembly when using the fast winding modes as, for example, if the MANUAL CONTROL switch were suddenly moved from FAST FWD to reverse while the tape was moving at high speed. If the roller assembly were permitted to clamp the tape almost immediately, the tape would be subjected to undue stress.

NOTE

> It should be remembered that once the actuator clamps the roller assembly against the capstan, it will remain in that position until the OFF signal is received. Thus, breaking the circuit by energizing K801 will not stop tape motion. The contacts of K801 are in series with both actuator ON circuits; hence, neither actuator can be shifted ON until thermal time-delay relay K801 has been allowed to cool.

Returning the selector to the STOP position results in connecting +14 vdc to the forward OFF actuator, through contacts 6 and 3 of deck I. The roller assembly is removed from contact with the forward capstan, rewind relay K701 on the transport is de-energized so that its contacts select the normal winding of the capstan drive motor, and the contacts of thermal time delay relay K801 close after approximately five seconds to close the circuit, allowing subsequent ON commands to operate the actuator circuits.

6-82. When the MANUAL control switch is placed in the FAST REV position, the action is similar to the FAST FWD discussed above. Contacts 12 and 7 on deck III connect the +14 vdc signal to the reverse capstan. Contacts 12 and 7 of deck II connect -24 vdc to K801 and K701, which perform identical functions as under FAST FWD operation.

6-83. The MANUAL WRITE/LEADER DRIVE switch S803 is a two-pole, three-position switch, with one position spring-loaded for return to the center (OFF) position. The switch appears in the circuit only when the MODE SELECTOR switch is in the MANUAL position.

6-84. The purpose of the MANUAL WRITE position is to make -24 vdc available to external controls for use in operating the write function under manual control. Contacts 5 and 6 route this control voltage to pin 25 of P303 when the switch is placed in the MANUAL WRITE position.

6-85. The purpose of the LEADER DRIVE position of the switch is to enable the operator to obtain tape motion when the end-of-tape relay K803 is energized, i.e., when the conductive backed tape is shorting the outer section of either sensing post to ground. To remove the metallized tape leader from the sensing post, contacts 1 and 4 complete the circuit for -24 vdc from terminal 13 of P303 (assuming that the short loop/long loop switches are closed) to the coil of interlock relay K802. It is thus possible to energize this relay and achieve tape motion from the MODE SELECTOR switch at times when K803 is energized. The LEADER DRIVE position of the switch is spring-loaded, so that the control returns to the center (OFF) position when released.

6-86. The function of interlock relay K802 in the MANUAL mode is basically the same as for AUTOMATIC operation. However, the long loop/short loop sensing operates while the system is in the MANUAL mode, K802 will not re-energize until the MANUAL CONTROL switch is repositioned to STOP (the holding circuit to K802 will have been interrupted, and must reset via contacts 3 and 6 on deck II of the MANUAL CONTROL switch).

6-87. Interruption of the basic interlock requires re-setting of the basic interlock and return of the MANUAL CONTROL switch to STOP for a moment before subsequent tape motion can be started.

6-88. PHOTOSENSE UNIT.

6-89. The photosense unit consists of a chassis on which printed circuit card connectors and the circuitry are mounted: two plug-in composite base cards, each providing the electronics required for one channel; and three plug-in power supply cards. Primary power for the photosense unit is obtained from the transport wiring harness; the outputs of the unit are connected through the transport harness to the Connector Chassis CC-300 on the control electronics assembly. A block diagram of the unit is shown in Figure 6-17.

6-90. The photosense electronics for a single channel consists of three assemblies: DC Amplifier, Schmitt Trigger, and Driver. A fourth element in the form of a Phantastron (hold circuit) may also be provided. These circuits are mounted on individual packets, which in turn are mounted on a composite base card. In the discussion which follows, operation of the electronics associated with Channel A will be discussed. The operation of electronics associated with Channel B is identical. The discussion will be facilitated by reference to the composite schematic diagram of the photosense electronics, which appears in another section of this manual. Note that in use of this composite schematic, component references are to individual packets, not to the composite electronics.

6-91. Assume first that the electronics are connected to the photosense head and a source of power; assume that all elements are operating properly and that at the moment no reflective tab is present under the photosense head. The base voltage of transistor Q1 in the dc Amplifier will be determined by the forward voltage drop of CR1. A current from the photocell, dependent on the amount of light impinging, will divide between the emitter of dc Amplifier transistor Q1 and potentiometer R4, which serves to adjust the amount of current allowed to flow to the emitter of the input transistor. Most of the emitter current flows through R5, causing a proportionate voltage drop across this resistor. Emitter-follower stage Q2 of the dc Amplifier provides low impedance output and prevents loading of the collector load resistor R5 by succeeding stages. Diode CR2 is included in the dc Amplifier circuit to limit the voltage across the photocell in the event that its output current should become so small as to turn Q1 off.

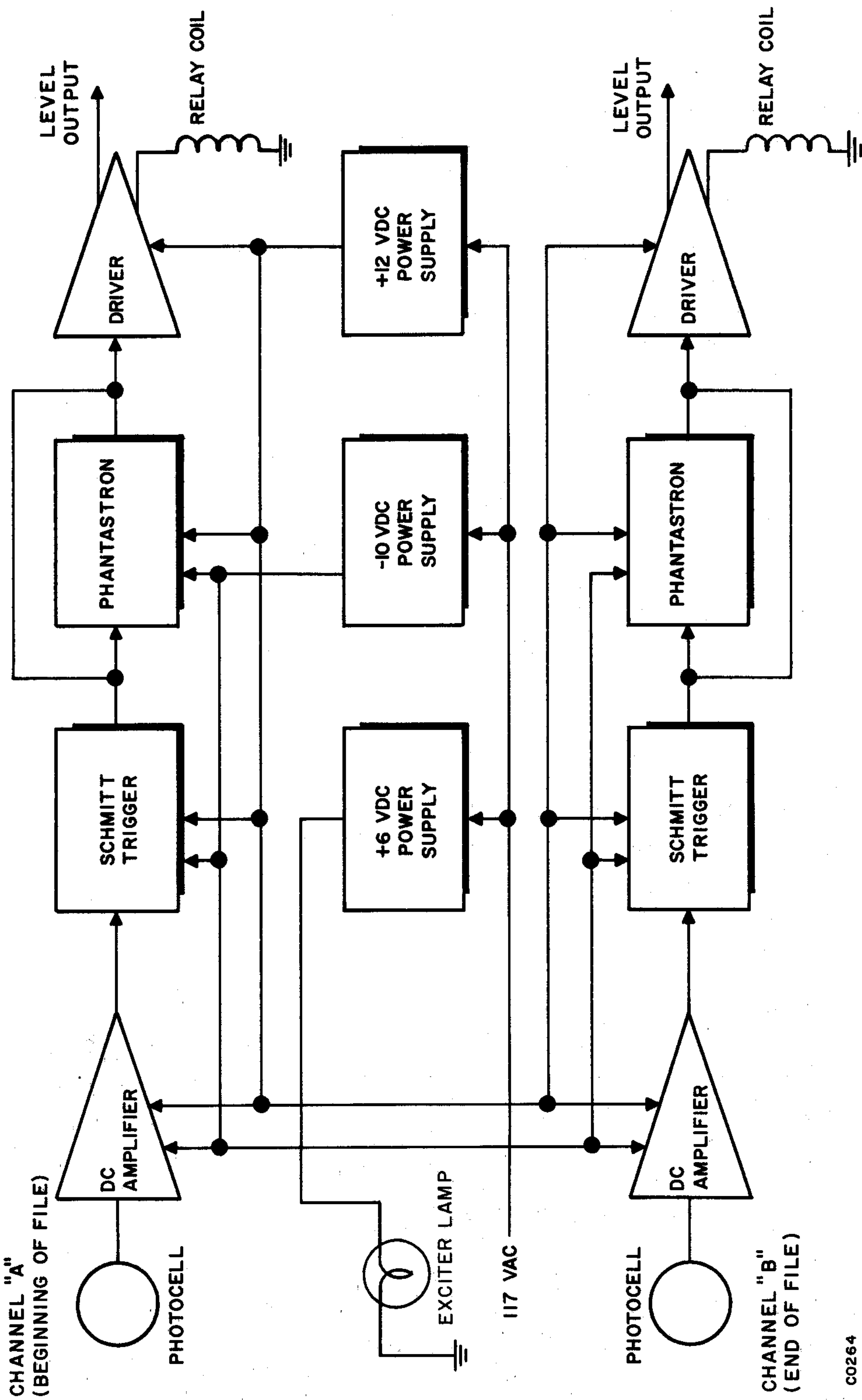


Figure 6-17
Block Diagram, Photosense Electronics

6-92. Since the voltage at the base of Schmitt Trigger transistor Q2 is determined by the divided network composed of R1-R3-R5, Schmitt Trigger transistor Q1 is off and Q2 is on when no reflective tab is present under the Photosense Head. This is one of the two stable conditions of the Schmitt Trigger. The collector voltage of Q2 is clamped to ground by diode CR1, thereby holding transistor Q1 in the Driver packet off. A voltage more negative than +12 vdc is determined by the divider composed of CR1 and R3 on the Driver packet. With Driver transistor Q1 off, Q2 is held off by R2, thereby preventing current flow to either the relay coil or the level change output load.

6-93. Assume now that a reflective tab appears under the photosense head. An increase in current from the photocell will result, the same current as before will be bled off by dc Amplifier potentiometer R4. The result is an increase in the current flowing into the emitter of dc Amplifier transistor Q1, causing a proportionate increase in the voltage drop across R5. Emitter-follower Q2 on the dc Amplifier packet will reflect this increased voltage; and the base of Schmitt Trigger transistor Q1 will accordingly swing more positive, turning this transistor on. As Schmitt Trigger transistor Q1 turns on, its collector voltage becomes more negative, causing the base of Schmitt Trigger transistor Q2 to become more negative. This tends to turn Schmitt Trigger transistor Q2 off and Q1 on. The circuit becomes regenerative and shifts to its second stable condition with Q2 off and Q1 on until such time as the output of the dc Amplifier again shifts the base of Schmitt Trigger transistor Q1 in a negative direction so as to turn this transistor off.

6-94. With Schmitt Trigger transistor Q2 off, resistor R4 in the Schmitt Trigger circuit holds Driver transistor Q1 on; Q1 supplies sufficient current through R1 to turn Q2 on. A level change occurs at the output and the relay coil (if relays are supplied) is energized.

NOTE

The following discussion is applicable only to units incorporating a Phantastron hold circuit.

6-95. Each time the dc Amplifier causes the Schmitt Trigger to change from the state in which Q1 is off and Q2 on to the state with Q2 off and Q1 on, a negative-going level change occurs at the collector of Schmitt Trigger transistor Q1. This level change is coupled into the Phantastron hold circuit to initiate Phantastron action.

6-96. In the quiescent state, Phantastron transistor Q3 is held on by R6, so that its collector is very nearly at +12 vdc. Since the voltage acorss CR1 in the Driver circuit is greater than the emitter-collector voltage of Phantastron transistor Q3, resistor R8 in the Phantastron circuit acts as an additional hold-off for Driver transistor Q2.

6-97. The emitter of Phantastron transistor Q2 is fixed by divider R3-CR4 at a voltage slightly more positive than ground. The transistor is therefore held on (in saturation) by resistor R2; the collector voltage (which is the emitter voltage of Phantastron transistor Q1) is thus very nearly at ground. Resistive divider R1-R5 is so designed that diodes CR2 and CR3 are forward biased, with the base of Q1 reverse biased so as to hold Q1 off. Diodes CR1 and CR5 are both reverse biased.

6-98. When the negative-going change occurs at the Phantastron input, it is coupled by C1 through CR2 which is conducting to the base of Q1, causing Q1 to turn on slightly. Thus, a changing positive-going voltage is established at the collector of Q1. Coupled through C3, this voltage causes Q3 to turn off, allowing R1 to hold Q1 on. Diode CR1 now becomes forward biased and clamps the base of Q1 to a voltage slightly more negative than ground, allowing Q1 to function as a common-base amplifier. The voltage at the collector of Q1 establishes itself so that the base current in Q2 is just sufficient to cause the correct current flow in Q1.

6-99. The Phantastron action thus begins. Resistors R2 and R4, capacitor C2, and transistors Q1 and Q2 form a Miller Capacitor which discharges at a nearly linear rate. The rate of voltage change at the collector of Q1 is large enough to cause sufficient current flow in C3 that Q3 begins to turn on. The circuit becomes regenerative and returns to its quiescent state, save for the collector voltage of Q1. Capacitors C2 and C3 must recharge through R4. When this is accomplished, the circuit can be triggered again.

6-100. Diode CR2 is included in the circuit so that should the Schmitt Trigger return to its normal off-tab state during the rundown period, the resulting positive-going input to the Phantastron cannot turn Q1 off to return the Phantastron to its quiescent state. Since the Phantastron transistor Q3 is off during the rundown period, Phantastron resistors R7 and R8 will hold Driver transistor Q2 on, regardless of the state of the Schmitt Trigger. This arrangement causes the level change and relay coil current to be held in the on-tab condition for 100 milliseconds (the rundown time of the Phantastron) regardless of how short a time the reflective tab is under the photosense head.

6-101. Three power supplies are used to provide the -10 vdc and +12 vdc for the base card composite assemblies and the +6 vdc for the exciter lamp in the photosense head. Each power supply is a conventional solid-state full-wave rectifier. The outputs of the supplies are set with Zener diodes. The rectifiers and filter capacitors are mounted on printed circuit boards which fit into receptacles on the electronic chassis. The power supply and Zener diodes are physically mounted to the electronic chassis.