SECTION IV THEORY OF OPERATION

4-1. RECEIVER-TRANSMITTER BLOCK DIAGRAM DISCUSSION.

4-2. The operation of the Receiver-Transmitter is shown in the system block diagram (see figure 4-1). All operational controls for the Receiver-Transmitter are in the Control Box. Primary power circuits for the Receiver-Transmitter are completed through the function selector switch.

4-3. The Receiver-Transmitter contains the following three major subsystems: the receive-transmit subsystem, which performs the functions of reception and transmission of the Tacan signal; the ranging subsystem which decodes the received signal, detects the beacon identity information, and computes the range indication; and the bearing subsystem, which operates on the decoded received signal to provide a bearing indication.

4-4. RECEIVE-TRANSMIT SUBSYSTEM. The circuits used in the receive-transmit subsystem are contained in the RF module. The receive-transmit subsystem is automatically tuned, by a signal from the Control Box, to any of the 126 channels. The transmitter, operating in the frequency band of 1025 to 1150 me, has assigned frequencies that are spaced l mc apart, starting with channel l at 1025 mc and ending with channel 126 at 1150 mc. Each channel has its own particular crystal.

4-5. There are 126 crystals mounted in two wafer banks. Associated with each transmitting channel is a receiving channel whose frequency is exactly 63 mc above or below the transmitting frequency. The receiver operates in the following two frequency bands: 962 to 1024 mc (channels l to 63) for transmitter frequencies of 1025 to 1087 mc; and 1151 to 1213 mc (channels 64 to 126) for transmitter frequencies of 1088 to 1150 mc.

4-6. Channel selection is accomplished with the channel selector switch on the Control Box. The channel selector switch causes a signal to be applied to the channel servo motor which operates the motor and tunes the four RF amplifier cavities, the four preselector cavities, and the six stages in the frequency multiplier. It also causes the proper crystal to be selected. When the channel servo motor stops, the proper crystal is selected for the transmitter frequency of the desired channel, the frequency multiplier and RF amplifier stages are properly tuned to transmit at the desired frequency, and the preselector is tuned to receive at the receiver frequency associated with the selected channel.

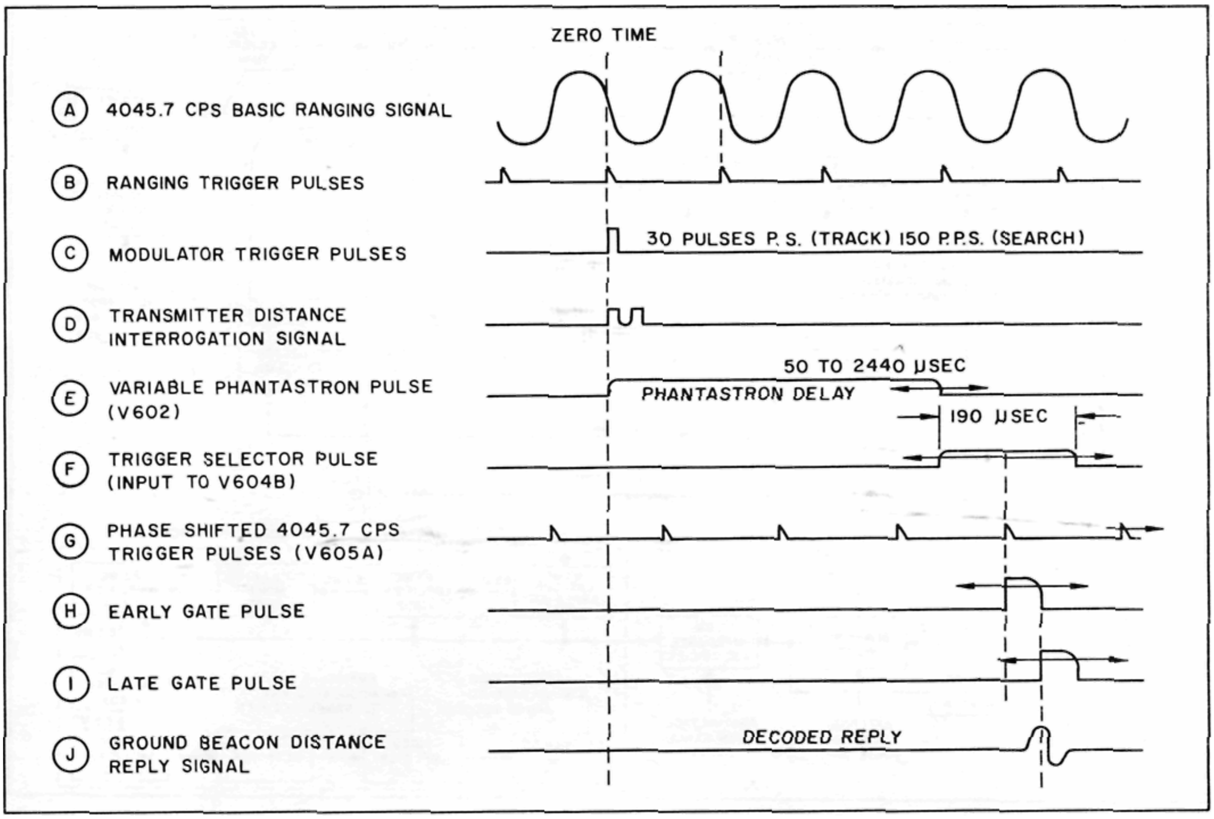
4-7. The frequency multiplier supplies two signals at the transmitter frequency: One signal is used in the RF amplifier as the carrier, and the second signal is used in a crystal mixer as the first local oscillator. Since for any channel the receiver frequency is 63 me above or below the transmitter frequency, the crystal mixer produces a 63 mc signal for the IF amplifier. The signal received at the antenna is passed directly to the preselector. This consists of four tunable resonant cavities, a cascaded pair for the low band of channels l to 63 and a cascaded pair for the high band of channels 64 to 126. When the channel selection is made, the proper pair of tuned preselector cavities is connected. The output of the preselector is fed to the crystal mixer along with a signal at the transmitter frequency. The resulting 63-mc signal is passed to the IF amplifier.

4-**8. The 63-mc signal** is amplified by two stages and converted to the second IF of 8.5 rnc. Following this, the signal is further amplified, detected and passed to the range circuits. The gain of the IF amplifier is varied by an agc voltage to maintain a constant signal to the range circuits. A deblocking circuit is also operated by the IF amplifier output to prevent blocking the receiver.

4-9. The 4-stage RF amplifier is maintained at cut-off by a large positive bias on the cathodes. When the Receiver-Transmitter is operating in the transmit-receive mode (that is, when ranging information is desired) a series of single trigger pulses is applied to the modulator. For each input trigger pulse, the modulator produces a negative 12-μsec spaced pulse pair in the positive RF amplifier cathode bias. There-fore, a series of properly spaced Tacan pulse pairs is transmitted. The trigger pulse to the modulator also triggers a blanking circuit to supply a large negative pulse in the agc voltage to blank the receiver IF amplifier during transmission.

4-10. RANGING SUBSYSTEM. The detected IF signal is fed to a decoder stage which passes pulse pairs spaced 12 μsec apart and rejects pulses of other spacing. The decoded signal is amplified and passed to the bearing circuits and a limiter. The limiter produces a signal used in both the range and bearing circuits.

4-11. Range measurement starts with the generation of the basic 4045.7-cps sine wave as a reference signal for time measurement (see figure 4-2, waveform A). This frequency is used because one cycle represents 20 nautical miles in radar range which is a convenient division of the total range of the equipment. The 4045. 7-cps signal is formed into a pulse signal of 4045.7 pps (see figure 4-2, waveform B) and then fed to a countdown blocking oscillator. The countdown blocking oscillator generates pulses which are exactly synchronized with the 4045.7-pps signal but have a jittered prf of approximately 30 pps in range tracking or lock-on and 150 pps in range search (see figure 4-2, waveform C). The countdown blocking oscillator pulses are fed to the modulator to provide the twin trigger pulses for the RF amplifier (see figure 4-2, waveform D) and to the phantastron to initiate the ranging function.



4-12. The pulse applied to the phantastron causes the stage to generate a rectangular pulse (see figure 4-2, waveform E) whose duration is determined by the de clamping voltage at the plate of the phantastron. This voltage is derived from the movable arm on the distance measuring potentiometer. The trailing edge of the phantastron pulse determines the Start of a selector pulse of approximately 190 µsec in width (see figure 4-2, waveform F). Since the distance measuring potentiometer arm makes one revolution for each search cycle, the duration of the phantastron pulse, and in turn the position in time of the selector pulse, will vary from 0 to 292 nautical miles.

4-13. The output of the 4045.7-cps oscillator is also fed to the phase-shifting resolver where the signal is phase-shifted (see figure 4-2, waveform G) with respect to the signal triggering the modulator. The shaft of the phase-shifting resolver is geared in a ratio of 15:1 to the shaft of the distance measuring potentiometer. Therefore, one complete revolution of the resolver causes a phase shift representing one-fifteenth of the total range, or 20 nautical miles. The phase-shifted 4045.7-cps signal is then formed into pulses and fed to the trigger selector stage. The position of the pulses generated by the phase-shifted signal with respect to that of the trigger pulses to the countdown blocking oscillator represents a distance of from 0 to 20 nautical miles, depending on the angular position of the phase-shifting resolver.

4-14. Coincidence of the selector pulse with a phase-shifted 4045.7-pps pulse causes the early gate to be formed (see figure 4-2, waveform H). The trailing edge of the early gate triggers the late gate (see figure 4-2, waveform I). It should be noted that the time at which the early gate is initiated is determined primarily by the phantastron delay and the phase shift of the 4045.7-pps signal. Since both the phantastron delay and 4045.7-pps signal phase shift are continuously varying, the positions of the early and late gates are continuously varying in time in relation to transmitted pulse pairs.

4-15. The received signal and the early and late gates are fed to the diode coincidence circuit. A reply pulse coincident with either the early or late gate causes a coincidence pulse to be applied to either the early or late gate coincidence amplifier. Coincidence of reply pulses with either the early or late gate initiates the transition which establishes the tracking mode of operation. The output of the coincidence amplifiers is fed through an interrogator to the reply pulse amplifier stage. Six reply pulses coincident with the late gate cause the reply pulse amplifier to conduct and switch relays: this places the range circuits in lock-on. In lock-on, the amplified early and late gate coincidence pulses are fed to their respective halves of the duo-triode range motor-generator control tube. The output of this stage controls the range magnetic amplifier output and therefore determines the speed and direction of rotation of the range motor-generator, Coincidence in one gate will unbalance the conduction of the control tube and cause the range motor-generator to rotate in one direction; coincidence in the other gate will reverse the direction of rotation.

4-16. A memory period of approximately 10 seconds is provided in case the received signal is lost. During this period, the range indication remains unchanged with the range flag in view. Should a reply return during this period, the flag disappears and tracking resumes. If no signal is received, search operation is resumed.

4-17. The unstable nature of the jittered countdown blocking oscillator prevents the range circuits of one aircraft from tracking replies initiated by interrogations of other aircraft since the prf of each equipment is unstable and the timing between successively transmitted pulses and replies will vary from set to set and from cycle to cycle. Therefore, it will be impossible for one aircraft to be more than momentarily synchronized with another aircraft and replies other than those synchronized with interrogations will fail to yield a stable range indication.

4-18. BEARING SUBSYSTEM. The ranging circuits provide a decoded amplitude modulated signal. This signal is fed to the peak rider detector which detects the variable phase 15- and 135-cps modulations. The variable phase modulation signals are then amplified and separated. The ranging circuits also provide a limited received signal, which is passed to a 15-cps reference detector and a 135-cps reference detector. The 15-cps reference signal is formed from the main reference burst in the received signal, white the 135-cps reference signal is derived from both the main and auxiliary reference signals.

4-19. When the beacon signal is first received, the bidirectional bearing circuits operate on the coarse 15-cps signals. The 15-cps variable phase modulation signal is passed through a sine-cosine potentiometer which is driven by the bearing motor-generator. The phase of the output signal is continuously changing while the bearing motor-generator is moving. The phase-shifted 15-cps variable phase modulation and the unshifted 15-cps fixed phase reference signals are fed to a 15-cps phase comparator. The output of the comparator provides an error signal to the bearing motor control tube which, through the bearing magnetic amplifier, controls the operation of the bearing motor-generator. The phase-shifted 15-cps variable phase modulation is used to form the 40° gate which is continuously shifted while the bearing motor-generator is in operation. When the main reference burst is coincident with the 40° gate, a relay control tube activates relays to provide for fine 135-cps bearing operation. The phase-shift necessary to make the 40° coincident with the main reference burst is an approximate measure ± 20°), in degrees, of the bearing of the aircraft to the beacon.

4-20. When both the 135-cps reference and modulation components are present, the bearing circuits switch to fine 135-cps operation. In fine 135-cps operation, the 135-cps fixed phase reference signal is phase shifted by the 135-cps resolver. The 135-cps resolver is also driven by the bearing motor-generator, and continuously changes the phase of the output signal. The phase-shifted 135-cps fixed phase reference and the unshifted 135-cps variable phase modulation signals are fed to the 135-cps phase comparator. The 135-cps phase comparator provides an error signal to the bearing motor control tube which through the bearing magnetic amplifier controls the bearing motor-generator,

4-21. When a balanced output from the 135-cps phase comparator is obtained, the bearing motor-generator stops. The phase shift necessary to maintain this balanced condition represents the actual bearing of the aircraft to the beacon.

4-22. Should the received Tacan signal sharply deteriorate, a total memory period of 3 to 8 seconds is provided. The bearing circuits will remain in 135-cps operation for approximately l second, alter which, switching occurs to 15-cps operation. The final memory period is from 2 to 7 seconds in 15-cps operation, after which the bearing circuits switch to search. If a complete usable Tacan signal appears before the end of the total memory period, the equipment switches back to the 135-cps operating condition.

4-23. CONTROL BOX BLOCK DIAGRAM DISCUSSION.

4-24. The operation of the Control Box is shown in the system block diagram (see figure 4-1). Channel selection is accomplished by use of the CHAN switch. Error voltages, supplied by resistance bridges associated with this switch, are led to the channel servo circuit in the RF module. The mode of operation is selected by the function selector switch. When set to OFF, all power is removed from the Receiver-Transmitter. When set to STBY, the Power Supply module is energized. When set to T/R NOR or T/R SHORT, all modules are energized. However, in T/R SHORT position the short range search circuit is also energized. The VOL control is used to adjust the identity signal level.

4-25. RECEIVER-TRANSMITTER DETAILED THEORY OF OPERATION.

4-26. The detailed theory of operation for the Receiver-Transmitter is given in the following manner:

a. RF module.

b. Range circuitry which includes the Range Decoder, Range A, Range B, and Range Mechanical modules and the search limit assembly of the Main Chassis.

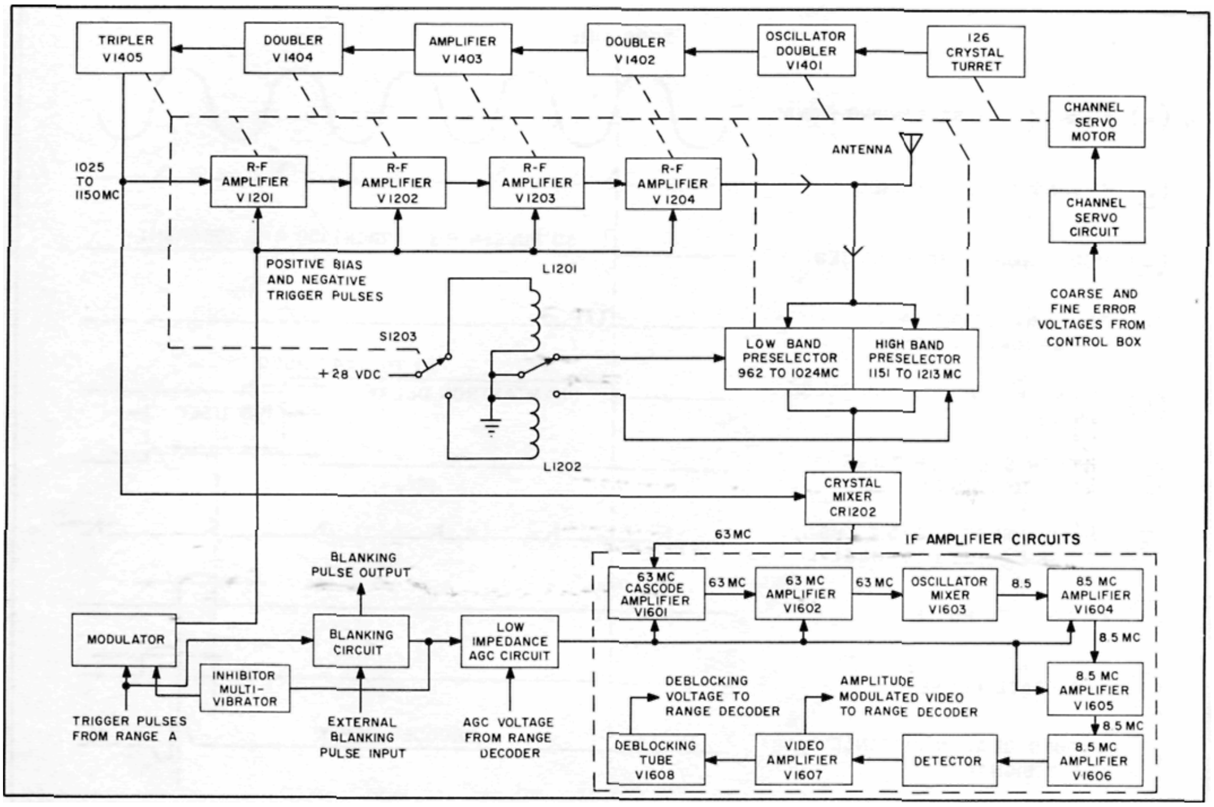
c. Bearing circuitry which includes the Bearing Decoder, Bearing A,
Bearing B and Bearing Mechanical modules.

d. Magnetic Amplifier module.

e. Power Supply module, f. Self Test module.

4-27. RF MODULE. (See figure 4-3.)

Figure 4-3. RF Module, Block Diagram



4-28. The RF module contains the IF amplifier, frequency multiplier, modulator, RF amplifier, preselector-mixer, channel servo, motor control circuit, blanking pulse circuit, and low impedance agc circuit. Each of these assemblies and circuits will be described. separately in the following paragraphs.

4-29. IF AMPLIFIER (See figure 4-4.)
4-30. CASCODE AMPLIFIER VI601. The input Stage of the IF amplifier is a twin triode connected in a modified cascode circuit to form a low noise high gain amplifier. The 63-mc signal from the crystal mixer is fed through J1601 to the IF amplifier and is applied to the grid of VI60IA through an impedance matching network. This network, consisting of CI602, L1601, and C1603, is tuned to 63 me by adjusting L1601; this has the effect of increasing the source impedance of the IF amplifier input signal. The source impedance is increased to approx. 2500 ohms which is optimum for a high gain at a low noise figure.
4-31. Stage V1601A is a triode grounded cathode amplifier which provides a low noise figure at a high available power gain. Any tendency toward instability is overcome by coupling the output of V1601A through a one-to-one transformer to the cathode of grounded grid stage V1601B which is extremely stable because of its cathode feedback and low plate-cathode capacitance. Maximum gain is obtained because the output impedance of V1601A is equal to the optimum input impedance of V1601B. The plate signal of V1601B is coupled to the next stage through a double-tuned interstage circuit. Tuning at 63 mc is accomplished by adjusting L1602 and LI603.

4-32. 63-MC IF AMPLIFIER V1602. The output of the 63-mc double-tuned. interstage circuit is passed to the grid of 63-rnc amplifier V1602, The output of high gain pentode amplifier V1602 is fed to a double-tuned circuit, the tuned frequency of which is adjusted by L1604 and L1605. The output of this 63-mc IF transformer is fed to the mixer tube.

4-33. OSCILLATOR-MIXER V1603. Stage V1603B is a <u>54.5-mc crystal</u> controlled, tuned-plate, grounded-grid oscillator. The plate signal is coupled regeneratively by T1602 to a resonant circuit composed of crystal Y1601 and L16II. The 54.5-mc signal across L1611 is fed to the cathode of V1603B, amplified, and passed to the tuned plate circuit consisting of the 1-2 winding of T1602 and stray circuit capacitance. This tuned circuit is adjusted to provide maximum feedback voltage for the crystal at 54.5 me. The 54.5-mc signal is tapped off at the cathode of V1603B and fed to the cathode of V1603A. The 63-mc grid signal to the mixer tube beats with the 54.5-mc cathode signal, thus producing sum and difference frequency signals at the plate. The tank circuit, composed of L1606 and C1619, is tuned by L1606 to the difference frequency of 8.5 mc, The 8.5-mc signal is then fed to the first 8.5-mc IF amplifier.

4-34. FIRST, SECOND, AND THIRD 8.5-MC AMPLIFIERS. The 8.5-mc signal is fed from the mixer to the first 8.5-mc IF amplifier V1604. The output of V1604 is fed to an 8.5-mc double-tuned interstage circuit. The frequency to which this coupling network is tuned is adjusted by L1613 and L1614. The first 8.5-mc IF amplifier is followed by two identical 8.5-mc IF amplifiers in cascade. The output of the third 8.5-mc IF amplifier stage is fed to the detector video amplifier.
4-35. DETECTOR AND VIDEO AMPLIFIER V1607. The 8.5-mc IF signal from V1606, the third 8,5-mc amplifier, is fed to diode detector CR1601 in the input of the fourth 8.5-mc interstage circuit. The resultant negative pulses are applied to video amplifier V1607A, The pulses are amplified and inverted by V1607A and appear as positive pulses at the grid of V1607B. Stage V1607B is a cathode follower providing a low source impedance for the video signal. The positive video output signal developed across R1628 is fed to the Range Decoder module through P1601, pin C and P1201, pm 15, and to the deblocking circuit through C1662.

4-36. DEBLOCKING CIRCUIT. The deblocking circuit provides a large negative pulse of agc voltage when the received signal strength suddenly becomes very great. The negative deblocking voltage prevents the IF strip from being blocked by the received signal before the agc voltage can change. Stage V1608A is normally cut off by the -19 v bias developed across R1631. The IF amplifier output rides on this negative bias. If the received signal changes faster than the agc voltage, the video pulses exceed the bias and V1608A conducts. This results in negative pulses at the plate of V1608A, These pulses are passed to ground by CR1602, charging C1663 positively, This positive rise in voltage at the junction of CI663, R1633, and CR1602 is integrated by the circuit composed of R1633 and C1664. The output is then applied to the grid of cathode follower V1608B. The positive pulse developed across R1635 is passed through diode CR1603 to the Range Decoder module. The cathode follower serves to lower the deblocking circuit output impedance, while diode CR1603 removes any negative undershoot in the deblocking pulse. The positive deblocking pulse is superimposed on the positive video input to the agc amplifier where it increases the agc voltage rapidly.

4-37. FREQUENCY MULTIPLIER. (See figure 4-5.}

4-38. OSCILLATOR-DOUBLÉR V1401. Tube VI401, a dual triode, is connected as a modified Butler crystal oscillator-doubler. The crystal selected from the crystal turret is applied between the cathodes of the two sections of the tube. The crystal acts as a series-tuned circuit which provides energy at its fundamental and overtone frequencies to V1401, pin 2. Variable inductor L1401 in the plate circuit of V1401A is tuned to resonate with C1401 at the third harmonic mode of the crystal. Assuming that a 15-mc fundamental crystal is in use (channel 56), the plate circuit of V1401A is tuned to 45 me. The 45-mc signal developed across L1401 is fed through CI403 to the grid of V1401B. As V1401B is made to operate as class C at this frequency, the RF signal developed across cathode resistor R1403 is coupled back to the cathode of V1401A through the crystal. Since cathode-coupling through the crystal provides a signal in phase with the signal in V1401A, the circuit will be regenerative and the frequency of oscillation will be controlled by the crystal, A pulse of plate current occurring in V1401B during the positive half-cycle, is passed to the tuned-plate circuit of V1401B. Variable inductor L1402 in the plate circuit of V1401B is tuned to resonate with C1404 at the second harmonic of the 45-mc input signal. The cathode of V1401B is normally grounded through R1403, L1425, and the contacts of channel Information relay K1010 in the main chassis. When changing channels, relay K1010 is energized by the negative memory disable voltage. The energizing voltage for K1010 is developed in the diode bridge connected across the channel servo motor terminals. This cuts off section V1401B and eliminates the possibility of spurious oscillations during channeling.

4-39. DOUBLER V1402 AND AMPLIFIER V1403. Assuming that the channel selector is set to channel 56, the 90-mc signal is coupled from the tuned plate circuit of V1404B through C1405 to the control grid of doubler V1402, Stage V1402 operates as a class C frequency doubler, the plate being tuned by the series resonant circuit composed of L1407, C1414, and C1410. The plate is tuned to resonate at 180 me by L1407. The 180-mc signal is tapped off from across C1414 and fed to the cathode of grounded grid amplifier V1403, Grounded grid amplifiers are used in the remaining stages of the frequency multiplier because this isolates the input and output circuits, preventing self-initiated oscillations. Amplifier V1403 provides a high amplitude driving signal to the series-tuned circuit of L1412, C1416, and C1418 in the plate.

4-40. DOUBLER V1404 AND TRIPLER V1405. Assuming that conditions are the same as those in paragraph 4-55, the 180-mc signal is tapped off across C1418 and fed to the cathode of grounded grid class C frequency doubler V1404. The plate is tuned to 360 me by the parallel resonant circuit of Z1401. The 360-mc output signal is loop-coupled by L1414 to the cathode of grounded grid class C frequency tripler V1405. The plate circuit is tuned to 1080 me by the series resonant circuit of L1416 and C1421 {adjustable). The output signal is picked up by L1417 and L1418. L1417 is positioned to provide optimum signal output which is fed through J1402 and cable W1201 to the grid-to-cathode line of the first RF amplifier stage. L1418 is positioned to provide a sufficient signal at the transmitter frequency for use as a local oscillator signal in the mixer crystal. The local oscillator signal passes through J1403, P1212 and cable W1203 to the mixer crystal.

4-41. MODULATOR. (See figure 4-6.)

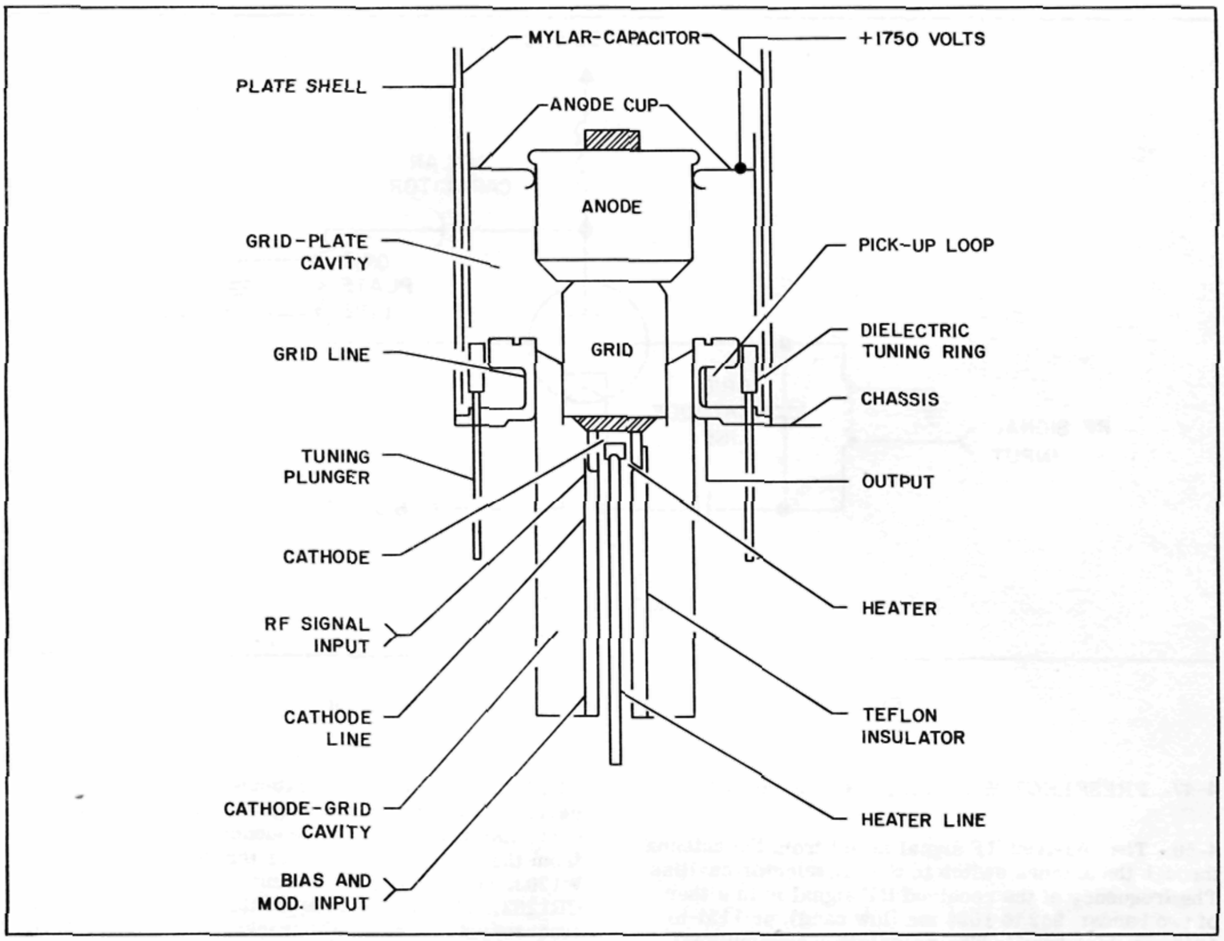
4-42. The modulator contains the switching and pulse shaping circuits which generate pulse pairs spaced 12 µsec apart and which are of sufficient amplitude to trigger the RF amplifier tubes. The RF tubes are cut off by the large positive bias (approx. +70v) applied to the cathodes. The large negative pulses supplied by the modulator are superimposed on the positive bias and neutralize the positive bias, allowing the RF amplifier tubes to conduct during the pulse pair, The modulator is triggered by either of two signals: one consists of the 30- or 150-pps trigger pulses supplied in the T/R modes by the Range A module countdown blocking oscillator; the second consists of a series of trigger pulses supplied by the coincidence tube when the Self Test module is in operation. The operation of the modulator is the same for either trigger source and is described below.

4-43. In the T/R mode, positive trigger pulses are supplied to the modulator through CR1512; during self test operation, they are supplied through CRI 511. These positive trigger pulses are fed through emitter follower Q1509 to delay line DL1501. Two output trigger pulses are supplied by DL1501 for each input trigger pulse. The output trigger pulses are displaced one from the other by 12 μsec and are used to generate the Tacan pulse pairs. The first output trigger pulse (of a pulse pair) is taken from DL1501, terminal 2, and is applied to silicone controlled rectifier (**SCR**) CR1515 via RI528 andR1529. The leading edge of the trigger pulse has a relatively long rise time and therefore the firing time of CR 1515 can be varied by adjustable resistor R1529. The firing of CR1515 relative to the firing of CRI519 determines pulse pair spacing. Diode CR1514 removes any negative under-shoot of the trigger pulse. The positive trigger pulse at the gate of CR1515 causes the SCR to fire. Initially, capacitor C1507 is charged to 120v. When the SCR fires, the capacitor discharges via paralleled L1501 and R1518 and the 3-4 winding of T1501. This pulse forming L-C circuit is a series resonant circuit with a characteristic period of approximately 7 μsec. At this time, the capacitors of a second series resonant circuit (the SCR turn-off circuit) also discharge through the SCR. This circuit, consisting of L1503, C1511 and C1512, has a longer characteristic period than the pulse forming resonant circuit. The current through the SCR is the vector sum of the currents of the two resonant circuits and the +120-vdc supply. When the current in the pulse forming resonant circuit reverses (due to the ringing of the circuit), current is drawn from the turn-off resonant circuit and the +120-vdc supply, reducing the current through the SCR. When the vector sum of the three currents falls below the hold value of the SCR, it is turned off. The capacitors now recharge to 120 volts. Further ringing of the pulse forming resonant circuit is blocked by the non-conducting SCR and the back-biased CR1516. This action results in a sinusoidal output voltage induced in winding 7-8 of T1501. The negative portion of the output of T1501 is developed across R1523 and R 1524 and is the first pulse of the video Tacan pulse pair. The positive portion is shorted by CR1539.

4-44. Twelve μsec after the trigger pulse appears at terminal 2 of DL1501, a second trigger pulse appears at terminal 4 of the delay line. This pulse is used to form the second pulse of the Tacan pulse pair. It is fed to SCR CR1519 via Q1510, R1533 and R1534. The theory of operation for CR1519 and its associated pulse forming circuit is the same as that described for CRI 515 and its associated pulse forming circuit. The pulse is formed by the series resonant circuit consisting of C1509, L1502, and R1519. The circuit that turns off CR1515 also turns off CR1519. The pulse appearing at the 7-8 winding of T1501, resulting from current in winding 5-6, forms the second pulse of the video Tacan pulse pair, The amplitude of the pulse pairs is adjusted by R1523. The pulse pairs are fed to the cathodes of the RF amplifiers.

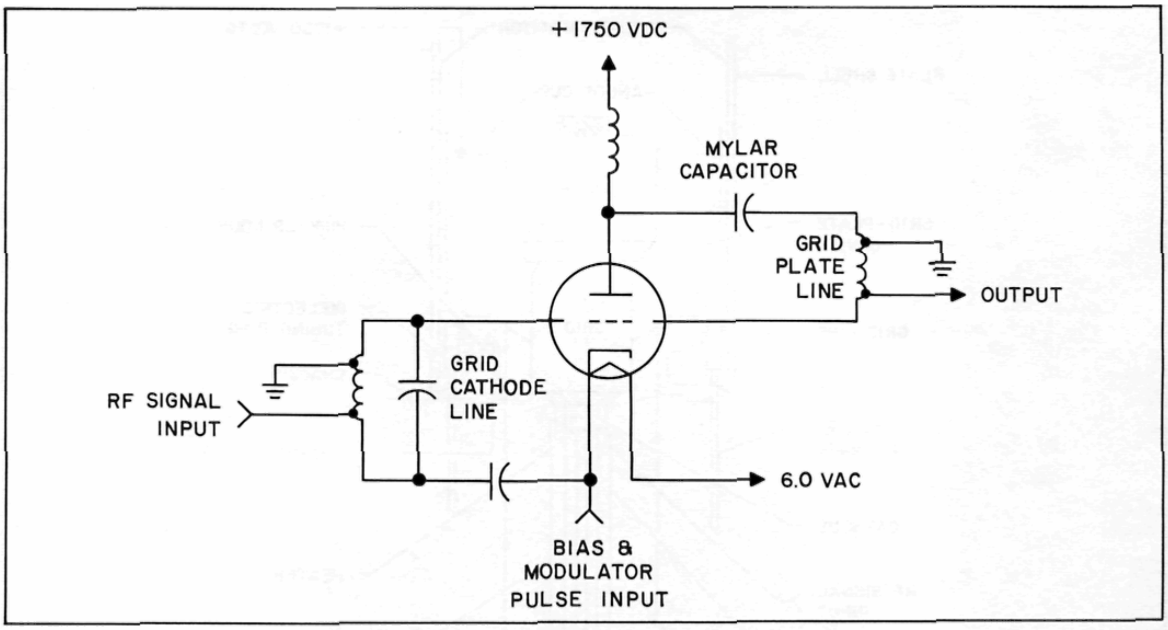
4-45. In the quiescent condition, a positive bias voltage is developed across zener diode CR1517 and fed to the cathodes of the RF amplifiers from the center arm of R1523. This accurately maintained bias holds the RF amplifiers below cut-off. during the quiescent period. The negative pulse pairs developed in the modulator are superimposed on the positive bias, causing the RF amplifiers to conduct. The output of the RF amplifiers are RF pulses whose characteristics are determined by the modulating pulses from the modulator.

Figure 4-8. RF Cavity Simplified Mechanical Diagram



4-46. RF AMPLIFIER. (See figure 4-7.)

4-47. The RF amplifier consists of four cascaded coaxial, cavity-type amplifiers operating in the 1000-mc region. These stages accept the RF output of the frequency multiplier, amplify the signal, and pulse-modulate the signal with the coded interrogation pulses from the modulator. The coaxial line type cavity has a high Q and low radiation, and it permits easy isolation of stages. The geometry of the RF amplifier tube and the circuit structure of the associated resonant cavities greatly reduce inter electrode feedback. Each stage employs two coaxial line cavities, each electrically equal to approximately one-quarter wavelength at the desired operating frequency. One section forms the cathode-grid tank circuit and the other forms the grid-plate tank circuit. Thus each stage constitutes a grid separation amplifier with grounded grid. RF excitation is applied to the cathode-grid input circuit and the output is taken from the grid-plate line. Exact tuning is accomplished for the particular operating frequency by means of an adjustable tuning ring in the grid-plate line (see figure 4-8). This ring is constructed of dielectric material and acts as a variable capacitor which effectively lengthens or shortens the capacity according to the frequency. Figure 4-8 shows the physical construction of the RF amplifier stage used in this equipment, and figure 4-9 shows the electrical equivalent of this circuit. As seen in these figures, the input RF power is fed to the circuit via a coaxial line, is amplified by the tube and then appears in the plate-grid line. Note that there is no direct coupling between the grid-cathode and plate-grid lines although a common grid line is used. This is true because at microwave frequencies cur-rent flows only at the surface of the conductor; consequently, the cathode-grid current flows only on the inner surface of the grid line. Plate-grid current flows only on the outer surface of this line. There is essentially no coupling, at microwave frequencies, between the inner and outer surfaces oï the line. The RF power developed in the grid-plate line is picked up by a probe inserted into the grid-plate cavity and passed to the cathode of the following stage or to the antenna jack.



4-48. The operation of the RF amplifier is determined by the position of the control unit selector switch. The +1750-V plate voltage for the RF amplifier stages is only supplied by high voltage supply Z1501 when the selector switch is set to T/R-NOR or T/R-SHORT; thus, the RF amplifier will only operate for these switch positions. With no trigger applied and the selector switch set to T/R-NOR or T/R-SHORT, +1750V is applied to the plates of the four RF amplifier tubes; the frequency multiplier RF signal Is applied to the cathode-grid of the first RF amplifier stage. Amplification does not occur, however because of the large positive bias (supplied by the modulator) on the cathodes. Amplification will only occur when the negative modulator pulses are added to the cathode bias. The amplified RF pulses are passed through P1202 to the antenna for radiation. These pulses have a minimum peak power of 1.5 kW on all channels. In both the T/R-NOR and the T/R-SHORT positions, the transmitted signal consists of 30 or 150 pulse pairs per second. The first three stages of the RF amplifier are identical, and the last stage (V1204) uses the same type cavity with a higher power tube.

Figure 4-9. RF Amplifier Stage Electrical Equivalent

4-49. PRESELECTOR MIXER. (See figure 4-7.)

4-50. The received RF signal is fed from the antenna through the antenna switch to the preselector cavities. The frequency of the received RF signal is in either of two bands: 962 to 1024 mc (low band), or 1151 to 1213 mc (high band). The preselector assembly is divided into two pairs of tuned cavities: namely, one pair for the high band and a second pair for the low band. Electrically, the cavities function as extremely high Q tuned circuits (quarter-wave lines), thus passing only a very narrow band of frequencies about the desired frequency. Series connection of the two cavities of each band further increases the selectivity of the preselector. RF energy is coupled into the first cavity by a coupling loop, and from the first cavity of the pair to the second by window-like apertures. The tuned frequency of the cavities is varied by the tuning rods driven through a gear train by the channel servo motor. The two cavities not in use are shorted to ground by leaves which project through slots in the cavity walls. Leaf actuation is controlled by solenoids LI 201 and 1,1202 which, in turn, are controlled by switch S1203. Solenoid L1202 shorts the low band cavities, and solenoid L1201 shorts the high band cavities. Switch S1203 is printed on the crystal turret and is tripped when the channel selector switch is set from a channel in one band to a channel in the other band. Switch S1203 supplies + 28V to either L1201 or L1202 to short the proper cavities. Diodes CR1205 and CR1206 reduce transients in the windings of solenoids L1201 and L1202, respectively. The output signal of the preselector is coupled by mixer loop CPI201 to crystal mixer
CR1202. The mixer loop extends into the output cavity of both the low and high band sections. The cw transmitting channel frequency signal is coupled from the frequency multiplier through J1403, cable W1203, J1207, and the coupling post to crystal mixer CR1202, The mixer

produces the sum and difference frequencies, Because the transmitting and receiving frequencies on a channel are 63 me apart, the IF frequency is the 63-mc difference. L1203 and C1209 match the 50-ohm IF line to the 400-ohm crystal circuit impedance. Capacitor C1209 and inductive loop L1204 match the 50-ohni output line from the frequency multiplier to the crystal mixer circuit. Capacitor C1210 acts as a decoupling element which presents a high impedance to the 63-mc IF signal, thereby preventing the frequency multiplier output circuit from absorbing any of the IF signal. The 63-mc IF signal is passed through J1208 and cable W1202 to the IF strip input.

4-51. CHANNEL SERVO. (See figure 4-6.)

4-52. CHANNEL SERVO ERROR BRIDGES. The tuning and channel selection circuits are energized by error voltages supplied by the coarse and fine channel servo error bridges. The coarse channel servo error bridge, located in the Control Box, is connected at both ends to a continuous-rotation potentiometer (R1201) located in the RF module. The fine channel servo error bridge, also located in the Control Box, is connected at both ends to a continuous rotation potentiometer (R1202) in the RF module. Connected across each continuous rotation potentiometer is 26V supplied from the floating transformer windings of T801. This circuit constitutes two separate ac bridges yielding ;m error voltage at each potentiometer arm whose phase and amplitude are a function of the arm position. The potentiometer arms are directly geared to the channel servo motor. The error signal is fed to the phase sensitive channel servo amplifier which energizes the channel servo motor to reduce the error signals to zero.

4-53. CHANNEL SERVO AMPLIFIER. The coarse and fine error voltages are fed into the amplifier input circuit. This circuit provides for proper mixing of the error voltages and ensures that the coarse error takes precedence. Since coarse error potentiometer R1201 is driven in discrete steps by a geneva wheel, the coarse error voltage is varied in fixed equal intervals of approximately 2 v. When the coarse error potentiometer is set to the proper position, the coarse error voltage goes to zero and the fine error signal from R1202 is in control. Diodes CR1526 and CR1528 completely cut-off any residual coarse error signal due to poor null positioning of the coarse error potentiometer. This is necessary since the fine error signal is a low level and the same order of magnitude as the residual coarse error voltage. In this manner, the coarse error signal is switched off and the fine error signal is switched on. The magnitude of the fine error voltage appearing at the junction of R1565 and R1566 (in the absence of a coarse error voltage) depends on voltage divider R1565 and diodes CR1530 and CR1531. The impedance presented by CR1530 and CR1531 to a high level fine error signal is very low; therefore, the error signal into the channel servo amplifier is of low amplitude. For a low level fine error signal, the diodes present a higher impedance. In this manner, the available error signal increases as the null is approached. The error signal appearing at the junction of R1565 and R1566 is amplified by a standard two-stage transistor amplifier consisting of Q1518 and Q1519. Both stages are temperature stabilized by bridge-biasing provided by R1567, R1569, R1572, R1571, and CR1532. The amplified error signal varies the voltage across C1526 about its steady state de value. The steady state de voltage level across C1526 is set by adjusting RI571. A negative feedback voltage, supplied to the emitter of Q1519, is proportional to the channel servo motor speed and is developed only when the channel servo motor is operating (see paragraph4-56).

4-54. PULSE FORMER Q1520. Pulse former Q1520 is a uni-junction transistor used in a pulse forming circuit. A uni-junction transistor is a semiconductor device with one emitter and two bases. If one base is connected to a voltage supply and the other base is grounded, the emitter will not conduct until its voltage is at a particular fraction of the voltage supply. When conduction occurs, it increases regeneratively until limited by the emitter supply. Potentiometer R1571 (see figure 4-6) is used to set the de voltage appearing across C1526 (the voltage at the emitter of Q1520) just below the conduction threshold of Q1520. When an error signal appears at C1526, its positive voltage swing raises the emitter voltage above the threshold, regenerative conduction takes place, C1526 is discharged, and emitter conduction is quenched. Capacitor C1526 is then quickly recharged through R1573 until the conduction potential is again reached. When an error signal voltage is present, a train of conduction pulses are developed in the emitter. The interval between pulses is determined by the time constant of R1573 and C1526; while the duration of each train of pulses is determined by the portion of the positive half-cycle of error signal exceeding the threshold bias of Q1520. The emitter pulses in QI520 are passed through the 3-4 winding of TI502 and cause positive-going pulses to appear at terminals 6 and 2 of T1502„ These pulses trigger silicon controlled rectifiers used in the motor control circuit. Zener diodes CR1527 and CR1533 are temperature compensated and maintain Q1520 emitter threshold voltage constant over the operating temperature range,

4-55. MOTOR CONTROL CIRCUIT.

4-56. Power from the same 400-cps ac source that provides the error signal is connected through P1501, pins 4 and 5. In normal operation, diodes CR1544 and CR1538 are shorted by their respective limit switches (Z1502 and Z1503 are line filters). Therefore, the 26-v supply is effectively across silicon controlled rectifiers CR1536 and CR1537. Silicon controlled rectifiers CR1536 and CR1537 are connected so that each can conduct for only one-half cycle of the 400-cps supply voltage. Thus, if CR1536 is made to conduct, current will flow through channel servo motor B15D1 in a direction which causes B1501 to run in the up channel direction. If CR1537 is made to conduct, the current flow will reverse and B1501 will run in the down channel direction. In this manner, the direction of rotation is controlled by the conduction of CR1536 and CR1537. The conduction of CR1536 or CR1537 depends on the presence of triggers from Q1520 on the control element and a positive forward voltage across the silicon controlled rectifier terminals. Since the generation of triggers during any particular half-cycle of the 400-cps supply depends on the phase of the error signal, and since conduction of a particular silicon controlled rectifier depends on the time coincidence of triggers and the operating half-cycle of the 400-cps supply voltage, the direction of channel servo motor rotation is dependent only on the phase of the error signal. Proper phasing then causes B1501 to turn in the direction which will reduce the magnitude of the error signal to zero. Resistor R1522 provides a fixed holding current for CR1536 and CR1537 independent of the motor inductance.

4-57. The portion of the conduction half-cycle applied to the motor depends on the position of the first pulse in $Q1520_B$ Thus, for a large error signal, the conduction half-cycle of the 400-cps error signal produces pulses in QI520 near the beginning of the half-cycle. When the error signal is small, conduction in Q1520 may occur only at the peak of the error signal. Since the 400-cps source which supplies the voltage for the error signal also supplies the voltage to the channel servo motor, the phase of the triggers is directly related to the voltage across the silicon controlled rectifiers. Conduction in the corresponding silicon controlled rectifier takes place during virtually the full half-cycle for high error signals and reduces to nearly a quarter-cycle when the error is s mail. This provides proportional speed control as the channel servo motor approaches the required position and allows for high motor speed for long distance channeling and low motor speed for accurate positioning without hunting. CR1538 and S1201 operate together to prevent excursion of the tuning mechanism beyond channel 126, and CR1544 and S1202 operate together to prevent excursion of the tuning mechanism below channel 1. Lower limit switch S1202 and upper limit switch S1201 are micro-switches which are mechanically operated by a pin on the crystal turret gear. When engaged, the pin activates a rocker mechanism which depresses the button of either microswitch. However, both switches are normally closed, shorting diodes CR1538 and CR1544 and providing a current path in either direction through BI 501. When B1501 is driven to either extreme of the tuning range (channel O or 127), either S1201 or SI202 opens and removes the short across CRI 538 or CR1544. This opens the current path in one direction and prevents tuning mechanism damage by stopping BI501. The current path through the motor in the reverse direction is complete so that the motor may b e reversed.

4-58. MEMORY DISABLE. The voltage applied to the channel servo motor during channeling is formed by bridge rectifier CR1540 through CR1543 into a negative de voltage. This voltage is used to energize channel information relay K1010 in the main chassis and to provide negative feedback to the channel servo amplifier for increased stability. When energized, relay K1010 removes ground from the frequency multiplier oscillator by opening contacts G and 8, and connects ground to the Range B module memory circuit by closing contacts l and 6.

Relay K1010 also connects -108 vdc to the transmitter muting circuit at contacts 2 and 5 (refer to paragraph 4-158).

4-59. BLANKING PULSE CIRCUIT. (See figure 4-6.)

4-60. During normal and search limit operation, the blanking pulse circuitry provides for the following:

a. A positive 24-µsec pulse to desensitize external equipment operating in the same, adjacent or harmonic frequency bands.

b. A negative 24-µsec pulse which is applied to the AGC circuit of the IF amplifiers to prevent lock-on to its own interrogation pulses. During self test, however, this negative pulse is disabled so that the equipment can lock-on to its own interrogation pulses. {External equipments may also blank the IF amplifiers by injecting a blanking pulse at J1023.)

c. An inhibitor pulse, 700 µsec wide, produced from the trailing edge of the positive blanking pulse to prevent interrogations from occurring less than 700 µsec apart. Monostable rnultivibrator, Q1511 and Q1512, is triggered by an interrogation from either the Range A module or the Self Test module. The output of this multivibrator, a positive 24-µsec wide pulse, forms the blanking pulse. This pulse is amplified by Q1513 and Q1515 and fed to the AGC circuits and to the inhibitor multivibrator. In the AGC circuit, the positive pulse is inverted by Q1514 and fed to the AGC of the IF amplifiers via emitter followers Q1516 and Q1517. In the inhibitor circuit, the positive blanking pulse is applied to the monostable rnultivibrator Q1521 and Q1522 after first being differentiated by C1528 and RI540. The negative trigger derived from the differentiated trailing edge of the blanking pulse is fed through CRI 554. This trigger back-biases CR1555. Transistor Q1522, which is conducting in the stable state, is suddenly cut off initiating multivibrator action. The positive output pulse of the multivibrator is inverted by Q1523 and fed to Q1509 as a 700-µsec wide pulse, inhibiting thus transistor. During self test, pin 15 of P1501 is grounded through CR2305 and K2301 of the Self Test module (refer to paragraph 4-150). This prevents the blanking pulse from being applied to the AGC.

4-61. LOW IMPEDANCE AGC CIRCUIT. (See figure 4-6.)

4-62. The low impedance AGC circuit performs two necessary functions for the receiver. It provides a means to desensitize the receiver when a blanking pulse is applied from the blanking pulse circuitry. It also provides for a very low source impedance AGC for the IF amplifier. In the quiescent state with no applied blanking pulse, Q1514 is cut off and its collector is at +35 v Zener diodes CRI 522 and CRI 524 operate as switches closing at a back voltage of +35 and +20 v, respectively. An external blanking pulse is fed through R1549 to the base of Q1514, and the internally developed blanking pulse is fed to the base through R1550 and R1551. When a positive blanking pulse appears at the base of Q1514, the transistor conducts and the collector drops to a low positive voltage. When this occurs, zener diode CR1522 opens. The common point of R1525, CR1523, and CR1522 is slightly positive in the absence of a blanking pulse and, since the input agc voltage is normally -l to -5 v, diode CR1523 is open. However, when a blanking pulse turns off zener diode CR1522, CR1523 conducts since it is forward biased by the -20 v across zener diode CR1524. This conduction causes the voltage at the bases of Q1516 and Q1517 to drop by approximately 10 v. The emitter s of these transistors follow the voltage change and thereby provide a negative pulse on the AGC line of approximately 15 v. Without an input blanking pulse, the low impedance AGC circuit operates in much the same manner as discussed above. Diode CR1523 is back biased by the small positive voltage at the junction of R1555, CR1523, and CR1522. The AGC output voltage of the AGC cathode follower in the Range Decoder module is fed through R1560 to the bases of paralleled transistors Q1516 and Q1517. The emitters of these transistors follow the variation in the agc voltage and pass this variation to the AGC line. The source impedance of the AGC line to the IF amplifier is related to R1560 and the bèta factor of Q1517. This impedance is of the order of 50 ohms.

4-63. RANGE CIRCUITRY.

4-64. RANGE DECODER MODULE. (See figures 4-10 and 4-11.)

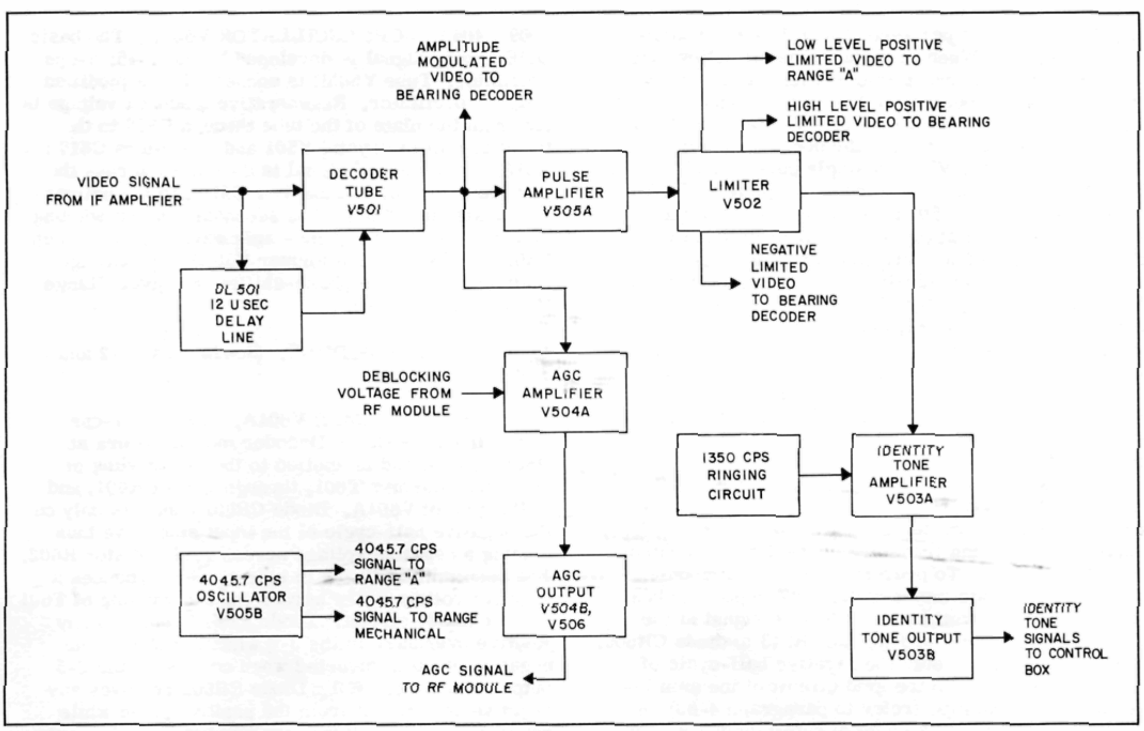
4-65. DECODER TUBE V501. The composite video signal from the IF amplifier enters at J501, pin 15. This signal is applied through C501 and R501 to the suppressor grid and through CS01 and 12-µsec delay line DL501 to the control grid. Tube V501 is normally cut off by the positive bias applied to the cathode across R503. The tube remains cut off until positive signals of proper amplitude are applied simultaneously to the suppressor and control grids. Therefore, conduction will occur only when the pulses in the pulse pairs are 12-µsec apart. This prevents the passing of improperly spaced pulses. The first pulse of the pulse pair is delayed 12µsec by delay line DL501 and applied to the control grid of V501. When the pulse spacing is 12-µsec, the second pulse of the undelayed pulse pair arrives at the suppressor grid simultaneously with the arrival of the delayed first pulse at the control grid. This causes V501 to conduct, producing a single negative pulse across the 5-4 winding of T503 for each properly spaced received pulse pair. The 2-3 secondary winding of T503 supplies the decoded, amplitude-modulated pulses to the Bearing Decoder module and to pulse amplifier V505A

4-66. PULSE AMPLIFIER AND LIMITER. The negative portion of the pulse from the 3-2 winding of T503 is passed through CR501 and C504 to the grid of pulse amplifier V505A. Diode CR501 serves to eliminate the positive portion of the pulse. The grid is returned to the cathode through R508, This fixes the no signal bias at approximately O v and permits the maximum grid swing to produce high-level, positive-going pulses.

Figure 4-11. Range Decoder Module, Block Diagram

These pulses are passed through C505 and R513 to limiter V502. Pulse distortion is also reduced by the degenerative feedback obtained across un-bypassed cathode resistor R510. The limiter (V502) bias is developed by the positive input pulses which cause grid current to flow, charging C506 negatively. The input pulses have sufficient amplitude to cause the grid of V502 to clamp to the cathode so that all the pulses applied to T501 will have the same constant amplitude. Diode CH502 in the grid circuit of V502 will short any excessive negative voltage at the junction of R513 and R511. R546 is the limiter threshold adjustment, The limited positive video signal developed at the plate appears at the secondary of T501 as both a negative and positive limited video signal. The limited output at pin 3 of T501 is fed through P501, pin 10, to the Bearing Decoder module, and through C512 and R522 to the grid of identity tone amplifier (V503A)„ This output consists of a high level, positive limited video signal, The output at pin 2 of T501 is fed through P501, pin 12, to the Range A module; it consists of a low level, positive limited video signal. The negative limited video signal at pin l of T501 is fed through P501, pin 11, to the Bearing Decoder module.

4-67. IDENTITY TONE CIRCUIT. The surface beacon generates an assigned identifying letter-number group in international Morse code approximately every 37.5 seconds



by automatic keying. Each dot and dash is transmitted by bursts of pulse pairs at a rate of 1350 pulse pairs per second with 100-usec spacing between twin pulses. When the beacon identification tone is transmitted, the range information pulses are cancelled. However, because of the memory function, the range indicator does not search. The beacon identification tone pulse pairs pass the decoder and appear at the plate of limiter V502 as single pulses of 1350 pps. The 1350-pps signal developed at the plate of V502 appears at pin 3 of T501 as a limited positive video signal. The output at pin 3 is fed through C512 and R522 to the grid of identity tone amplifier V503A which has the 1350 cycle-tuned ringing circuit in its plate. The 1350-pps signal excites the tuned ringing circuit of L501 and C51IB causing the circuit to ring and to generate a 1350-cps sine wave signal. V503A amplifies the beacon identification tone and passes the signal to the grid of identity tone output V503B. The identity tone threshold is adjusted by potentiometer R517, while diode CR503 prevents the grid self-bias of V503B from altering the fixed bias level. The amplified signal is sufficient to overcome the -27V bias at V503B, and brings V503B out of cutoff. The identity output is coupled from the 3-4 winding of impedance matching transformer T502 to the control unit VOL control. To prevent the Range B module from switching into memory during reception of beacon identity information, the 1350-cps signal at the plate of V503B is fed by C522 and R543 to diode CR506. Diode CR506 passes only the negative half-cycle of the 1350-cps signal to the grid circuit of the sum information control tube (refer to paragraph 4-88) and aids in maintaining this stage in cutoff during identity tone reception.

4-68. AGC GENERATION. The positive portion of the pulse from the decoder is applied through C508 and CR505 to the grid of AGC amplifier tube V504A. Diode CR505 serves to eliminate the negative portion of the pulse. This stage is normally cut off by a negative voltage difference between the grid and the cathode. The bias of V504A is determined by the setting of high level AGC adjustment R529 which varies the level of the de voltage applied to the cathode. The bias must be adjusted to prevent the AGC voltage from distorting the Signal output at the IF amplifier. The biasing of V504A is such that a signal very low in amplitude (noise, etc) will not be large enough to cause conduction in the tube and generate AGC voltage. V504A conducts on the positive portion of the pulses and produces a negative change in voltage at the plate. This voltage change is proportional to the amplitude of the pulses applied to the grid. RC integrating networks R526 and C513, R527 and C515, and R531 and C516 filter the voltage and apply it to the grid of AGC cathode follower V504B. The negative de voltage level applied to the grid of V504B is proportional to the average amplitude of the modulated pulses. The no signal voltage is clamped by V506 to a value set by AGC threshold potentiometer R533. The variations of the de voltage applied to the grid of V504B are reflected as changes in the negative voltage across cathode resistor R535. This negative voltage is fed to the low impedance AGC circuit in the RF module (see paragraph 4-59}. The AGC cathode follower serves to lower the output impedance of the AGC amplifier.

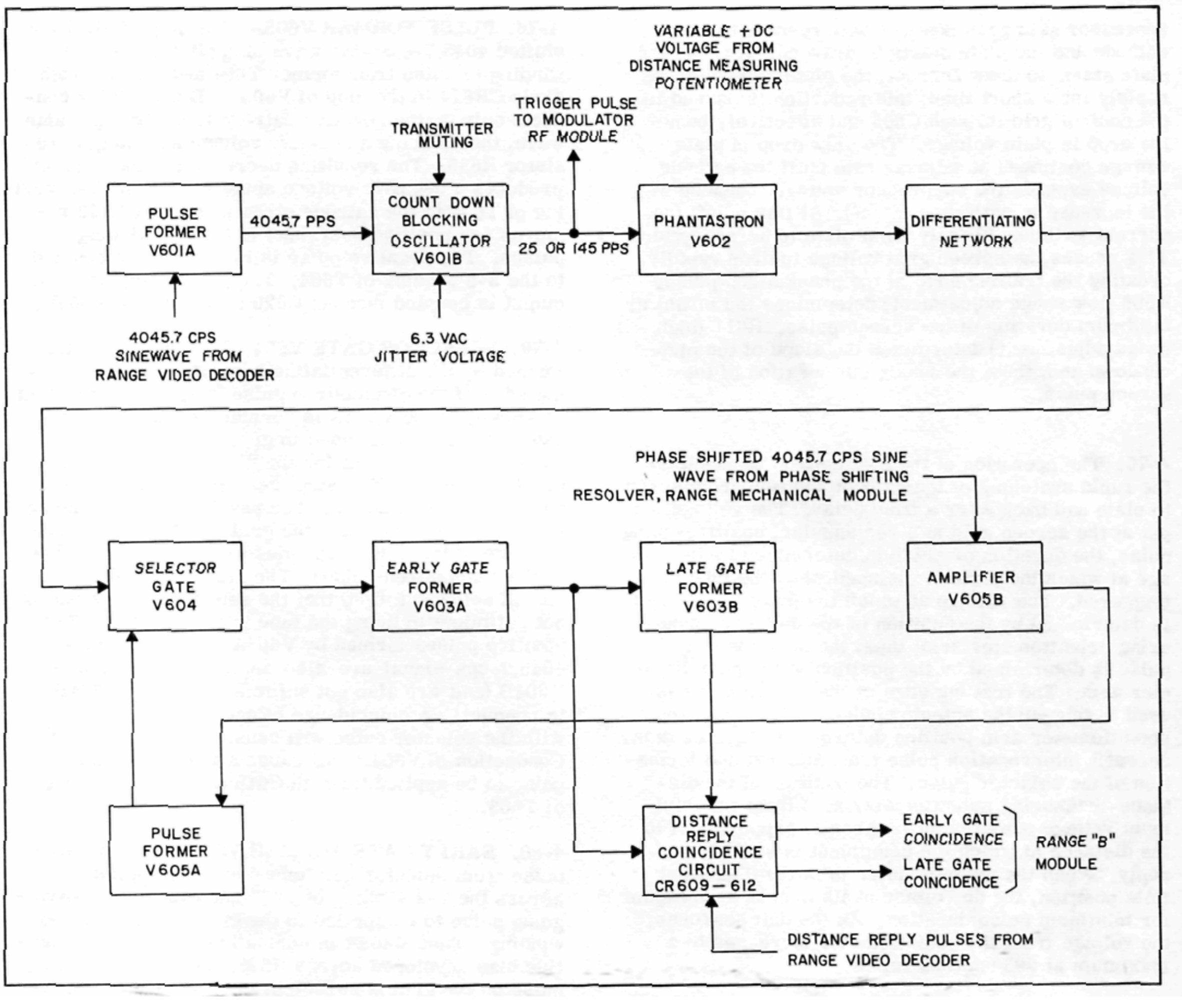
4-69. 4045. 7-CPS OSCILLATOR V505B. The basic DME timing signal is developed by the 4045.7-cps oscillator. Tube V505B is connected as a modified Colpitts oscillator. Regenerative feedback voltage is fed from the plate of the tube through R538 to the tuned circuit of crystal Y501 and capacitors C517 and C518. An amplified signal is developed across the plate tank circuit of capacitor C519 and the primary of transformer T504. The secondary output winding of T504 feeds a $4045_0$7cps- sine wave output through P501, pin 13, to pulse former V60IA, and through P501, pin 19, to the phase-shifting resolver {Range Mechanical module).

4-70. RANGE A MODULE. (See figures 4-12 and 4-13.)

4-71. PULSE FORMER V601A. The 4045.7-cps signal from the Range Decoder module enters at P601, pin 13, and is applied to the 1-4 winding of pulse transformer T601, through diode CR601, and to the grid of V601A. Diode CR601 conducts only on the negative half-cycle of the input sine wave thus placing a negative voltage across grid resistor R602. The resultant decrease in tube current produces a negative voltage spike across the 3-6 winding of T601 in the cathode circuit. Diode CR617 removes any positive overshoot in the 3-6 winding pulse. The negative pulse is inverted when coupled to the 2-5 output winding of T60I. Diode CR602 removes any negative undershoot from the positive pulse while zener diode CR618 limits the amplitude of the positive pulse. The positive pulse is coupled through R645 and C60I to the 1-2 primary winding of blocking oscillator transformer T602. Potentiometer R645 is provided to adjust the trigger level to V601B, thus compensating for variations in V601B.

4-72. COUNTDOWN BLOCKING OSCILLATOR V601B. Tube V601B is connected as a conventional free-running blocking oscillator with the frequency determined by the grid RC network and T602. The grid resistance is adjustable under control of potentiometer R652 and the Range B module. During search, ground potential is applied through J601, pin 20, to grid resistors R60T and R652. This shunts grid resistor R606 with a variable resistance. Potentiometer R652 is adjusted to set the free-running frequency at approximately 145 pps. When tracking, the ground is removed from J601, pin 20, thus eliminating R607 and R652 from the grid circuit RC time-constant. The blocking oscillator free-running frequency is now determined by R606 and is approximately 25 pps. The grid of V601B is returned to ground through C622 and the 6.3-v filament supply, thus causing the 4045.7-pps triggers to ride or jitter on the 400-cps signal. These jittered trigger pulses are coupled through T602 to the grid of V601B. They serve to synchronize the blocking oscillator to the basic 4045.7-cps timing signal. In a random selection, a trigger pulse will raise the grid out of cutoff just before the normal grid rise would make the tube conduct. This triggers V601B at a different point of time for each cycle and aids in establishing the coding or unique timing of the interrogation triggers of the particular unit. The positive pulses developed across cathode resistor R604 are coupled from the cathode through J601, pin 11, to the modulator in the RF module; negative pulses from the plate are

Figure 4-12. Range A Module, Block Diagram



fed through C604 to phantastron V60. During search, the prf is approximately 145 pps; during track, the prf is approximately 25 pps. A negative voltage applied to the grid through R609 and CR620 gates off the blocking oscillator during transmitter muting (refer to paragraph 4-158),

4-73. PHANTASTRON V602. The phantastron determines the time delay between the interrogation trigger and the beginning of the selector pulse. Tube V602 is a pentode in which both the suppressor and screen grids control the flow of current to the plate. In its quiescent state, the tube is conducting. However, all the cathode current flows to the screen grid because the suppressor grid is effectively negative with respect to the cathode, The control grid is clamped to a positive voltage with respect to ground through CR604, R655, and R617. The voltage drop across cathode resistor R614 is sufficient to place the cathode potential above that of the suppressor grid. The plate is clamped by diode CR605 to the positive variable de voltage from the center arm of the distance measuring potentiometer. This voltage is determined by the position of the distance measuring potentiometer arm.

4-74. The negative trigger pulses from countdown blocking oscillator V601B are passed by diode CR605 to the plate of V602 and through C605 to the control grid since the voltage across C605 cannot change instantaneously. The control grid is driven rapidly negative, but not far enough to cut off the tube. This reduces the cathode-to-screen current, thus causing a fast drop in the cathode voltage and an equally fast rise in the screen voltage. This continues until the suppressor grid goes positive with respect to the cathode and the plate starts to draw current. As the plate starts to draw current, the plate voltage drops rapidly for a short time; this reduction is passed to the control grid through C605 and effectively bucks the drop in plate voltage. The slow drop in plate voltage continues at a linear rate until the cathode voltage exceeds the suppressor voltage (because of the increase in cathode current). At this point, the current switches sharply from plate to screen grid. This causes the screen grid voltage to drop rapidly, creating the trailing edge of the phantastron pulse. R608 (low range adjustment) determines the initial or minimum duration of the screen pulse. R611 (high range adjustment} determines the slope of the plate rundown and, thus, the maximum duration of the screen pulse.

4-75. The operation of the phantastron is based on the rapid switching of the cathode current from screen to plate and back after a time delay. The voltage output at the screen grid is a rectangular, positive-going pulse, the duration of which is determined by the voltage at which the plate is clamped when the tube is triggered. The voltage at which the plate is clamped is determined by the position of the distance-measuring potentiometer arm; thus, the duration of the pulse is determined by the position of the potentiometer arm. The trailing edge of the screen pulse is used to trigger the selector pulse. Therefore, the potentiometer arm position determines the time delay between interrogation pulse transmission and formation of the selector pulse. The position of the distance-measuring potentiometer arm from the minimum voltage output point is directly proportional to the distance at which the equipment is seeking a reply, When the potentiometer is in the 0 nautical mile position, the de voltage at ifs arm is a minimum for minimum pulse duration. As the unit searches, the voltage from the potentiometer increases to a maximum at 295 nautical miles.

4-76. DIFFERENTIATING NETWORK. The positive-going phantastron screen grid pulse is applied to a differentiating network composed of C609 and R619. The result is a large narrow negative pulse whose leading edge corresponds to the trailing edge of the phantastron pulse. This pulse is applied to the grid of V604A.

4-77. PHASE-SHIFTED 4045.7 CPS AMPLIFIER V605B. The phase-shifted 4045.7 cps sine wave out-puts from the phase shifting resolver enter at P601, pins 22 and 23, and are added in the RC network of R637andR612. (At 4045.7 cps, the impedance of C612 is equal to that of R637.) The phase-shifted signal is tapped off at the junction of C612 and R637 and sup-plied to the grid of V605B. The signal is amplified and supplied from the 4-3 winding of T606 through C611 to the 4-1 winding of T604. The resolver shifts the 4045.7-cps sine wave over fifteen 20-mile segments for the 295 nautical miles range (one period of the sine wave is equal to 20 nautical miles). The RC network of C611 and R644 serves as an adjustable phase-shifting network, the phase being varied slightly by adjusting R644 (zero mile adjustment).

4-78. PULSE FORMER V605A. The amplified, phase-shifted 4045.7-cps sine wave is applied to the 4-1 winding of pulse transformer T604 and then through diode CR614 to the grid of V605A. Diode CR614 con-ducts only on the negative half-cycle of the input sine wave, thus placing a negative voltage across grid resistor R635. The resulting decrease in tube current produces a negative voltage spike across the 3-6 winding of T604 in the cathode circuit. Diode CR613 re-moves any positive overshoot in the 3-6 winding pulses. The negative pulse is inverted when coupled to the 2-5 winding of T604. The positive-go in g pulse output is coupled through C620 to the grid of V604B

4-79. SELECTOR GATE V604. The negative pulse formed by the differentiating network from the trailing edge of the phantastron pulse is applied to the grid of V604A. Tube V604A is normally conducting because its grid is clamped to ground. The negative pulse cuts the tube off for the duration of the charge of C609. When C609 discharges, the tube emerges from cutoff and clamps. The resulting positive pulse in the plate is coupled to the grid of V604B (the leading edge of the pulse coincides with the trailing edge of the phantastron pulse). The grid of V604B is biased below cutoff so that the selector pulse alone is not sufficient to bring the tube into conduction. The positive pulses formed by V605A from the phase-4045.7-cps signal are also applied LO the grid of V604B (and are also not sufficient to cause V604B to conduct). A coincidence of one of these pulses with the selector pulse will cause V604B to conduct. Conduction of V604B will cause a negative-going pulse to be applied through C619 to the 1-2 winding of T603.

4-80. EARLYGATE FORMER V603A. The negative pulse from selector gate tube V604B is applied across the 1-2 winding of T603 and causes a positive-going pulse to be applied to the grid through the 5-6 winding. Tube V603A is normally cut off by the negative bias developed across R623. The positive-going pulse on the grid is sufficient to overcome the negative bias, and V603A conducts. Conduction causes a positive-going pulse to form across cathode resistor R620. This pulse is passed to the diode coincidence circuit and through C614 to the late gate former. Diode CR608 serves to remove any positive overshoot in the negative plate pulse.

4-81. LATE GATE FORMER V603B. The positive-going, early gate pulse is applied to the RC differentiating circuit composed of C614 and R639. The negative voltage spike formed from the trailing edge is passed by diode CR615 to the 1-2 winding of T605. The operation of late gate former V603B is similar to that of early gate former V603A and is explained in paragraph 4-97. Since the late gate is formed from the trailing edge of the early gate pulse, the late gate is related in time to the early gate and to the phantastron pulse. The positive-going pulse (late gate) formed across R638 is passed to the diode coincidence circuit.

4-82. DIODE COINCIDENCE CIRCUIT, Two Coincident circuits detect the presence of a reply in either the early or late gates. The +150 v applied at the junction of CR609 and CR6U and at the junction of CR610 and CR612 causes all four diodes to conduct in the quiescent condition. The positive-going early and late gates are applied at the negative sides of diodes CR609 and CR610, respectively. These pulses cause diodes CR609 and CR6ÏO to cease conduction. The limited reply pulse from the Range Decoder module is applied to the junction of diodes CR611 and CR612, This pulse causes diodes CR611 and CR612 to cease conducting. Coincidence of a reply pulse with the early gate, causes a pulse to form and pass via C603 and P601, pin 16, to the early gate coincidence amplifier. Coincidence of a reply pulse with a late gate causes a pulse to form and pass via C610 and P601, pin 17, to the late gate coincidence amplifier. The actual circuit operation is as follows: A late gate pulse occurring at the negative side of diode CR610, with no coincident reply pulse, will remove the clamping effect of CR610. However, the voltage at the junction of CR610 and CR612 does not rise because it is still clamped to ground by diode CR612, In a similar manner, a reply pulse occurring at the negative side of CR612 with no coincident late gate will remove the clamping effect of CR612 although the voltage at the junction of CR6IO and CR612 does not rise because it is still clamped to ground through CR610. However, a late gate pulse and a reply pulse applied simultaneously will remove the clamping effect of both diodes. This wilt cause the voltage at the junction of CR610 and CR612 to rise sharply as the current through R625 falls. Capacitor C6ÏO couples the positive-going pulse via P601 through pin 17 to the late gate coincidence amplifier. The operation of the early gate reply circuit is identical.

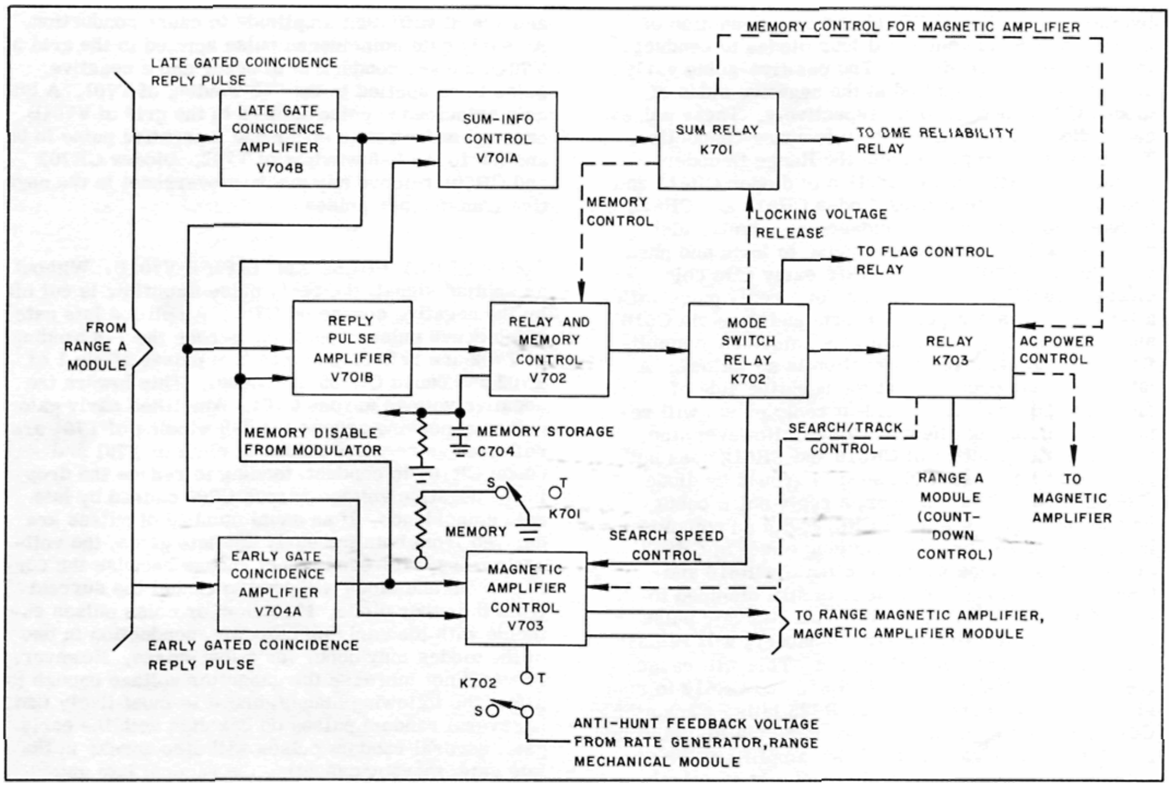
4-83. Since the range circuits search in the direction of increasing range, the reply pulse in search will always become coincident with the late gate pulse first. The searching speed, the repetition rate, and the early and late gate pulse widths are such that a sufficient number of coincidences between the late gate pulses and the reply pulses can be attained be-fore the late gate is driven past the position of the reply pulse. This will allow the equipment to lock on and track at the proper distance. In track, coincidences occur between the reply pulses and both the early and late gates. However, depending on the direction of travel of the aircraft, the reply will move more into one gate than the other. This will cause the Range B module to reposition the distance measuring potentiometer center arm, and cause the phantastron and the early and late gates formed from it, to track the reply.

4-84. RANGE B MODULE

4-85. EARLY AND LATE GATE COINCIDENCE AMPLIFIER V704. The early and late gate coincidence amplifier is a duo-triode stage. V704A amplifies the early gate coincidence pulse, and V704B amplifies the late gate coincidence pulse, Both sections of V704 are normally cut off since the grids are maintained at a more negative voltage than the cathodes. Early and late gate coincidence pulses from the Range A module are applied to the grids of V704 and are of sufficient amplitude to cause conduction. Au early gate coincidence pulse applied to the grid of V704A causes conduction to occur and a negative pulse to be applied to the 7-8 winding of T701. A late gate coincidence pulse applied to the grid of V704B causes conduction to occur and a negative pulse to be applied to the 7-8 winding of T702. Diodes CR702 and CR701 remove any positive overshoot in the negative transformer pulses.

4-86. REPLY PULSE AMPLIFIER V7Q1B. Without an applied signal, the reply pulse amplifier is cut off by the negative charge on C701. Amplified late gate coincidence pulses appearing across the 7-8 winding of T702 are reflected as positive pulses at pin I of T702 and cause CR705 to conduct, This lowers the negative voltage across C701, Amplified early gate pulses appearing across the 7-8 winding of T701 are rejected as negative pulses at pin 2 of T701 and cause CR704 to conduct, tending to reduce the drop in the negative voltage across C701 caused by late gate coincidence.

Figure 4-14. Range B Module, Block Diagram



If an equal number of pulses are derived from both the early and late gates, the voltage across C701 sees no net change because the current from one diode will tend to cancel the current from the other diode. If random or noise pulses coincide with the early or late gate, conduction in one of the diodes may occur for a few pulses, However, this will not increase the capacitor voltage enough to affect the following stages, and it is most likely that 'f several random pulses do coincide with the early gate, several random pulses will also appear in the late gate, thereby canceling the random late gate pulses. When more than six or seven successive late gate coincidence pulses are obtained, C701 charges in the positive direction sufficiently to bring V701B into conduction. The conduction of V701B causes the voltage at the plate to drop, thereby changing the condition of the succeeding stages from search to lock-on and track. For lock-on and track operation to be maintained, continued coincidence must occur. Coincidence can only be continued when the reply pulse repetition rate is synchronized with the interrogation pulses. Furthermore, since the pulse repetition rate of the interrogation pulses is random, only replies to the interrogation of the individual equipment can cause proper coincidence to occur for an extended period of time.

4-87. RELAY AND MEMORY CONTROL TUBE V702. Relay and memory control tube V702 conducts when the range circuits are in search operation. The conduction of V702 holds relay K702 in its energized search condition. When energized, relay K702 connects +28 v through contacts 6 and l of K702 and R720 to energize and hold K701 in its energized search condition. When energized, relay K702 also connects the plate of V703A and one side of L2201 to ground through contacts 2 and 5 of K702„ When V702 conducts, relay K702 holds relay K701 energized and thus prevents the operation of V701A from affecting the condition of relay K701 when the range circuits are in search. When a sufficient number of late gate coincidences occur for the reply pulse amplifier to conduct, the drop in its plate voltage is sufficient to cut off V702. The cutting off of V702 releases relay K702, energizes relay K703 by connecting its coil to + 28 v via relay K702 contacts 6 and 8, and allows V701A to control K701. In search operation, the junction of R722 and C705 is at a high positive potential when V702 is cut off by V701B during late gate coincidence, This energizing of K703 by K702 grounds the junction through contacts l and 6 of K703, Since the voltage across C705 cannot change instantaneously, a large negative pulse is fed to the suppressor grid of V702 to maintain V702 at cutoff in the event that the late gate is driven slightly beyond the reply before V701B conducts. In this way, C705 aids in establishing lock-on, When a lock-on is obtained, V701A is cut off and relay K701 is released. In summary, relays K702 and K701 are released in lock-on and relay K703 is energized; in search, the relay states are changed. In its track (energized) condition, relay K703 removes the ground from contact 8 (lowering the prf of countdown blocking oscillator V601B from approximately 150 pps to approximately 30 pps), balances the connection of magnetic amplifier control tube V703, and connects 115 v, 400 cps to range magnetic amplifier L2201 via contacts 6 and 8 of K701. Relay K702 in its track (de-energized) condition, energizes relay K703 by connecting -f28 v through contacts 6 and 8, removes the ground from L2201 and V703 (pin 1), and completes the ground return for T703,causing a large feedback voltage to be applied to the grids of V703, Relay K701, in its track (de-energized) condition, connects ground through contacts 2 and 4 to distance measuring equipment reliability relay K2501 and supplies 115 v, 400 cps through contacts 6 and 8 to range magnetic amplifier L2201 via contacts 2 and 5 of relay K703.

4-88. SUM INFORMATION CONTROL TUBE V701A. Once lock-on has occurred, the sum Information control tube determines the con d j tl on of relays K701, K702, and K703, Amplified early and late gate coincidence pulses are reflected as negative pulses in the 5-6 windings of T701 and T702„ These negative pulses are passed by diodes CR706 and CR703 to the grid of V701A. V701A is in damp when no signal is supplied to its grid since its grid is connected through a resistive network to -120 v, The negative pulses passed by diodes CR703 and CR704 when coincidence occurs, develop a negative voltage across C702 and C712. The negative bias developed is sufficient to cut off V701A provided continued coincidence occurs. Therefore, as long as coincidence is maintained, V701A is cut off and relay K701 is de-energized. In its de-energized track condition, relay K701 ungrounds the junction of R721 and R7I3.. thus allowing memory capacitor C704 to charge to a large negative voltage. The negative voltage across C704 when K701 is in track is sufficient to cut off the plate current of V702 independent of the signal applied to the control grid oï V702. Thus, once lock-on has been established, the signal at the grid of V701A determines whether or not subsequent tracking is continued. As long as either early or late gate coincidence is maintained, V701A is cut off and lock-on is continued.

4-89. RANGE MEMORY CIRCUIT. The de-energizing of relay K701 when range lock-on occurs causes C704 to charge to a large negative potential which is sufficient to cut off V702 independent of the signal at the grid of V702. If for any reason coincidence pulses should cease, V701A conducts, energizing relay K701 and grounding the junction of R713 and R721. Relay K701 also opens the path of the 115 v, 400-cps signal to the range motor control tube, causing the range indicator to stand stationary at its last reading with the range flag in view. The grounding of the junction of R713 and R712 causes C704 to discharge to ground through R718, R742, R713, and contacts 2 and 5 of relay K701. The discharge time constant and the initial voltage of C704 are sufficient to maintain V702 at cut off for approximately 10 seconds. During this period the range motor-generator remains stationary. Should coincidence pulses (either early or late gate) return during the memory period, V701A is cut off, relay K701 is released, and tracking résumés. If at the end of the memory period the coincidence pulses fail to return, V702 conducts to its plate, thus energizing relay K702 and releasing relay K703; this in turn, returns the Range B module to search operation. Operation of the memory circuit is disabled when the channel servo mechanism is in motion. This is achieved by applying a ground via relay K1501 (relay K1501 is energized while channeling) and R719 to C704. The negative capacitor voltage is rapidly discharged to ground. When the desired channel is reached, the ground is removed and normal operation is restored.

4-90. MAGNETIC AMPLIFIER CONTROL TUBE V703. The detailed operation of magnetic amplifier control tube V703 is best described along with that of range magnetic amplifier L2201 and range motor generator MG1801. Motor-generator MG1801 consists of an induction motor and a rate generator. The phase and rms value of the range magnetic amplifier output is determined by the output of V703 and it controls, respectively, the direction and speed of rotation of MG 1801. The range magnetic amplifier consists of two cores, A and B, each wound with three windings; an output winding, a reference winding and a control winding. At this time a 115 vac, 400 cps voltage is applied to the reference windings and to the plates of V703 via the control windings.

4-91. In search operation (see figure 4-16) the plate of V703A and one side of the A core control winding are connected to ground, while the grid of V703B is connected to the large positive bias at the junction of R722 and C705. Therefore, in search, V703A is conducting slightly while V703B is conducting heavily. The conduction of V703B causes a de current to flow through the B core control winding. This saturates the B core and thus no voltage is developed in the B core output winding. However, the unsaturated A core produces an output voltage 90° out of phase with the fixed phase reference signal. The rms value of this signal depends upon the magnitude of the B core de current. This signal is fed to the control phase of phase induction motor. The phase of the range magnetic amplifier output voltage causes the motor to drive the indicator and rate generator in the direction of increasing range. During search, a large 400-cps voltage is developed by the rate generator. This voltage, which varies directly with the rate of the motor, is applied as feedback to the grids of V703 via T703. This feedback voltage is 180 degrees out of phase with the 115-v, 400-cps voltage applied to the plates of V703. When the reply pulses from the late gate cut off V702, K702 releases operative K703. This removes the ground from V703, pin l, and the positive bias from V703, pin 7. The ground return of T703 is completed, and the full feedback voltage is applied to the grids of V703, decreasing the control voltage. This slows the motor and the system is now in the track mode.

4-92. When a positive early gate coincidence pulse from the 3-4 winding of T70I passes through C710 to the grid of V703B, the tube draws grid current. The grid current drawn charges C710 negatively and causes V703B to be cut off after the pulse has passed. Capacitor C710 discharges exponentially through R729 and R730 with a time constant several times greater than the period of the 400-cps plate supply, Thus C7IO maintains V703B at cut off for several cycles of the 400-cps supply.

While V703B is cut off, V703A is conducting, passing a pulsating de current through the A core control winding. Thus, when an early gate coincidence pulse is applied to V703, the A core saturates and supplies no output voltage; the B core is unsaturated and supplies a control voltage. This control voltage is 90° out of phase with the reference signal and 180" out of phase with the signal provided by the A core in search. The B core control signal causes the range motor-generator to drive the range circuits in the direction of decreasing range to position the gates so that the reply pulses are between the early and late gates. Similarly, a positive late gate coincidence pulse causes V703A to go negative and then go into cutoff for several 400-cps supply voltage cycles. This causes the B core to be saturated and the A core to supply a voltage, the phase of which drives the range motor-generator in the direction of increasing range. Balanced signals are applied to V703 when the reply pulse appears between the early and late gates, thus producing no L220I output and causing

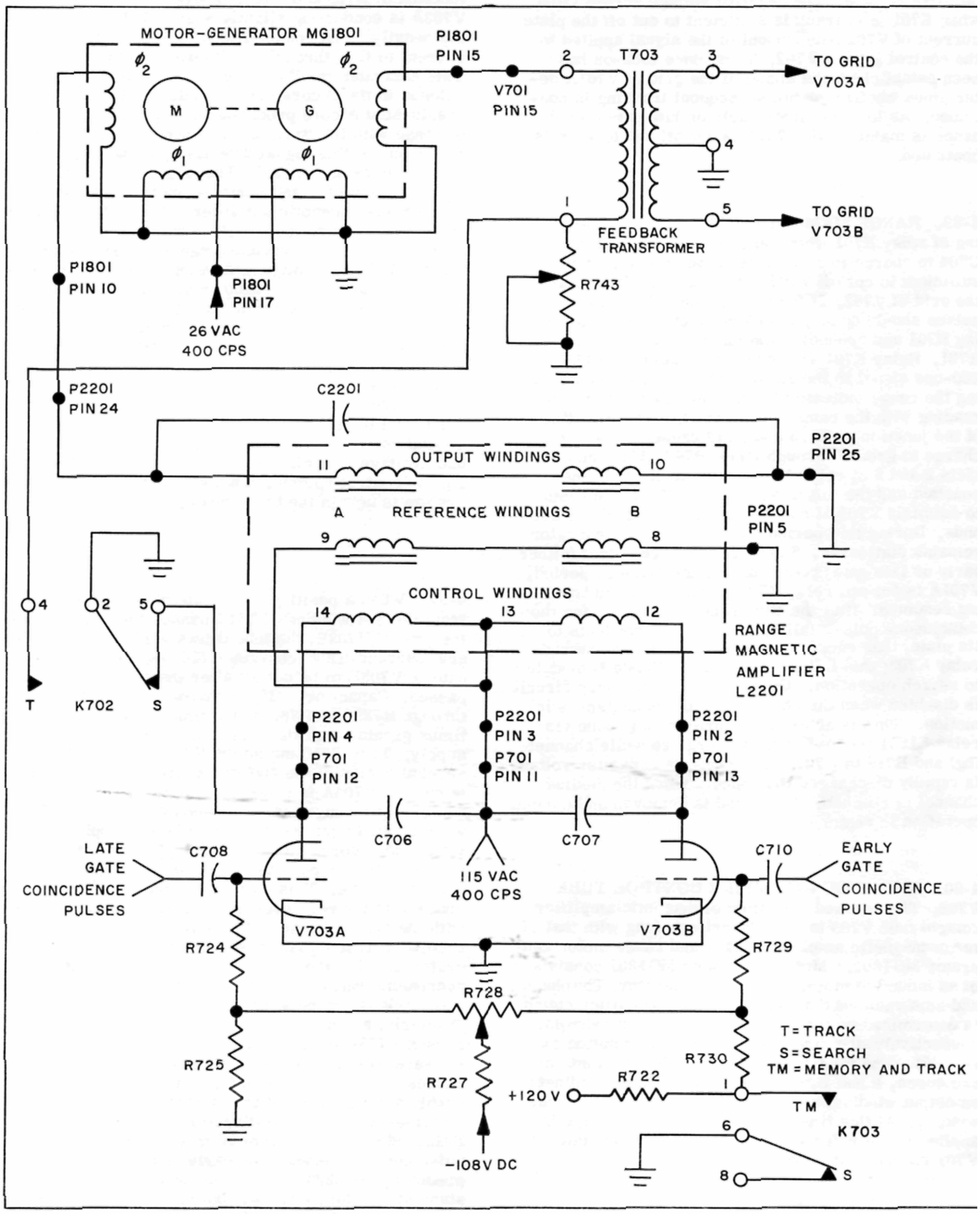


Figure 4-16. Range Motor-Generator Control Circuit, Simplified Schematic Diagram

MG1801 to stand still. During track, 400-cps feedback voltage, which is directly proportional to the velocity, is continuously applied to the grids of V703. This voltage appears superposed on the negative exponential waveform at the grids of V703.

4-93. SEARCH LIMIT CIRCUIT. (fig 4-17).
4-94. The range search limit circuit enables the Receiver-Transmitter to reduce its range search time on approaches by searching out to a preset distance less than total range, recycling the range circuit back to zero mile and beginning again until lock-on occurs. The circuit is set so that during operation it limits the unit range to approximately 75 nautical miles. At this point in range, a relay in the Main Chassis is energized which removes the range magnetic amplifier control signal and connects a 26-vac signal through a phase shifting network to the range motor-generator. This signal causes the range motor-generator to run in the direction of decreasing range. When zero range is reached, the relay is de-energized and the unit again searches the short range. Lock-on can only occur during search since while returning to zero mile a relay shorts the trigger path to the modulator.

4-95. The search limit circuit operates on the variable positive voltage at the center arm of the distance measuring potentiometer in the Range Mechanical module. As has previously been noted, this voltage is proportional to the range, and it is a ramp-type function increasing from a low voltage at zero mile to a high voltage at 292 nautical miles. The positive-going distance measuring potentiometer ramp voltage is applied to emitter followers Q1001 and Q1005, The ramp voltage will have no effect on QI005 since it is biased well below cut-off. The ramp voltage is fed to the base of Q1003 via emitter follower Q1002. Cascaded emitter followers are used to more effectively isolate the impedance sensitive distance measuring potentiometer circuit. In the stable state, QI003 is biased below cut-off by the voltage derived from voltage divider R1Q04, R1006 and R1014. The bias voltage to the base of Q1003 (adjustable by R1011) is set to a level such that Q1003 will be brought into conduction by the ramp voltage at a level representing the limit of the short search range.

4-96. When short range search is not desired, the emitter of Q1004 is open-circuited at the Control Box and the incoming ramp voltage has no effect. When short range search is desired, the Control *Box* se-lector switch is set to T/R-SHORT and a ground is applied to the emitter of Q1004. Now, when the magnitude of the incoming ramp voltage exceeds the bias on Q1003, and Q1004 are brought into conduction, operating relay KI001, This action occurs at the limit of the short range search, approximately 75 miles. When K1011 operates, contacts l and 6 connect ground to the Range B module memory circuit, disabling the circuit. The closure of contacts 2 and 5 operate KI 006 and latch Q1003 in the conductive State via R1025. When K1006

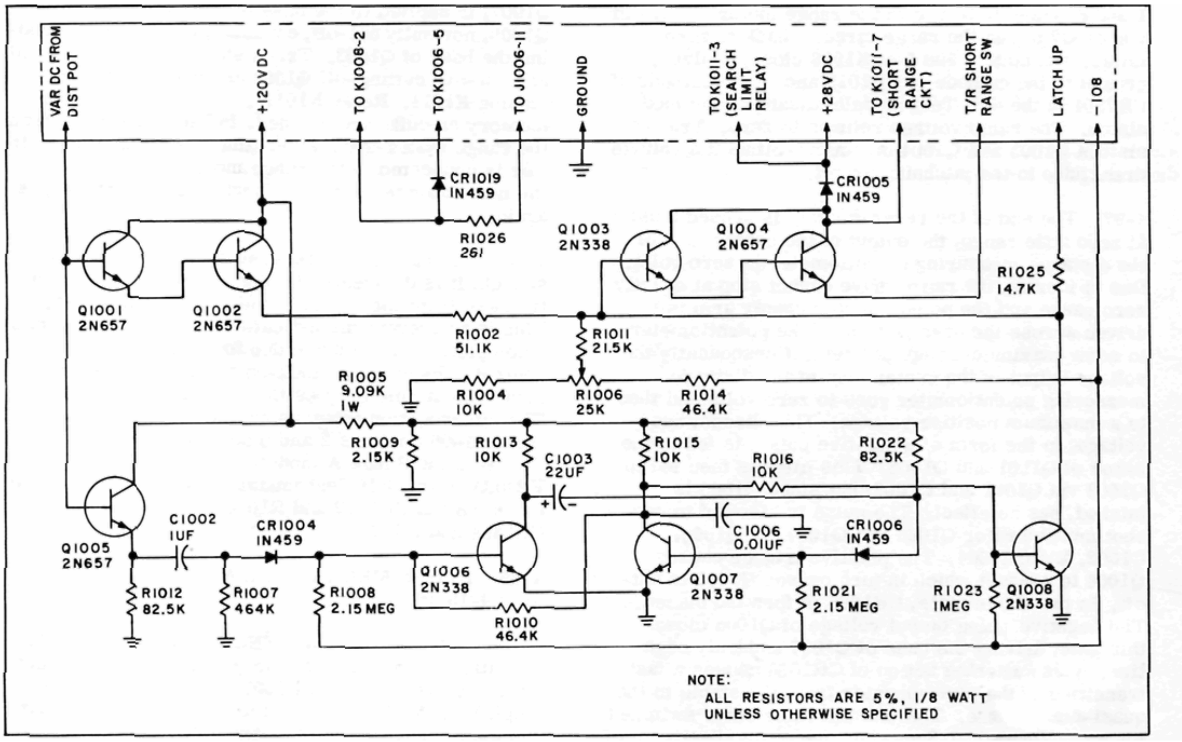


Figure 4-17. Search Limit, Schematic Diagram

operates, contacts 6 and 8 open and remove the range magnetic amplifier signal from the range motor-generator. The closure of contacts l and 6 connects 26 vac to the range motor-generator via Z1002 to run the range circuits back to zero miles. Contacts 2 and 5 of K1006 close, applying a ground to the cathode of CR10I9 and to the cathode of CR2304 in the Self Test module, disabling the modulator. The ramp voltage returns to zero„ Transistors Q1003 and Q1004 do not cut-off as the voltage drops, due to the latch-up circuit.

4-97. The end of the reverse cycle is sensed thusly: at zero mile range, the output of the center of the distance measuring potentiometer is zero volts. Due to inertia, the range drive cannot stop at exactly zero range and the potentiometer center arm is driven across the open portion of the potentiometer to some maximum range position. Consequently the voltage output of the center arm of the distance measuring potentiometer goes to zero volts and then to a maximum positive voltage. This discontinuous voltage, in the form of a positive pulse, is fed to the bases of QI001 and Q1005. This pulse is then fed to Q1003 via Q1001 and Q1002, but since Q1003 is latched, has no effect. The pulse is also fed to one-shot multivibrator Q1006 and Q1007 via Q1005, C1002, and CR1004. The positive trigger causes Q1006 to conduct which in turn causes Q1007 to cut-off. In the stable state, CR1006 is forward biased. The negative going output voltage of Q1006 closes this gate, driving the base of Q1007 suddenly negative. This switching action of CR1006 causes a fast transition of the multivibrator from the stable to the quasi-stable state. The multivibrator stays switched for approximately 1.5 seconds due to the discharge of C1003 via Q1006 and R1022. The output of the multivibrator, a positive pulse taken from the collector of Q1007, is applied to the base of Q1008. Transistor Q1008, normally cut-off, conducts, effectively grounding the base of Q1003. Transistor Q1003 is unlatched and cut-off) cutting-off Q1004 and consequently releasing K1011. Relay Kl011 releases K1006. The memory circuits are enabled, 26 vac is removed from the range motor-generator, the range magnetic amplifier is connected to the range motor-generator, and the modulator is enabled. Short range search begins again„

4-98. During a motor reverse cycle in short range search, it is desirable to disable the interrogation triggers from the Range A and Self Test modules. This is to prevent the indicator from running through a complete reverse cycle due to the loss of motor control voltage with a lock-on as the distance measuring potentiometer goes through its open position. The interrogation triggers are disabled by a ground from K1006 contacts 2 and 5 applied to the grid of V601B in the Range A module and to the grid of V2302A in the Self Test module. The ground is applied to V601B via CR1019 and R1026 and toV2302A via CR2304 and R2329.

Fig 4-19. Range Mechanical Module, Diagram

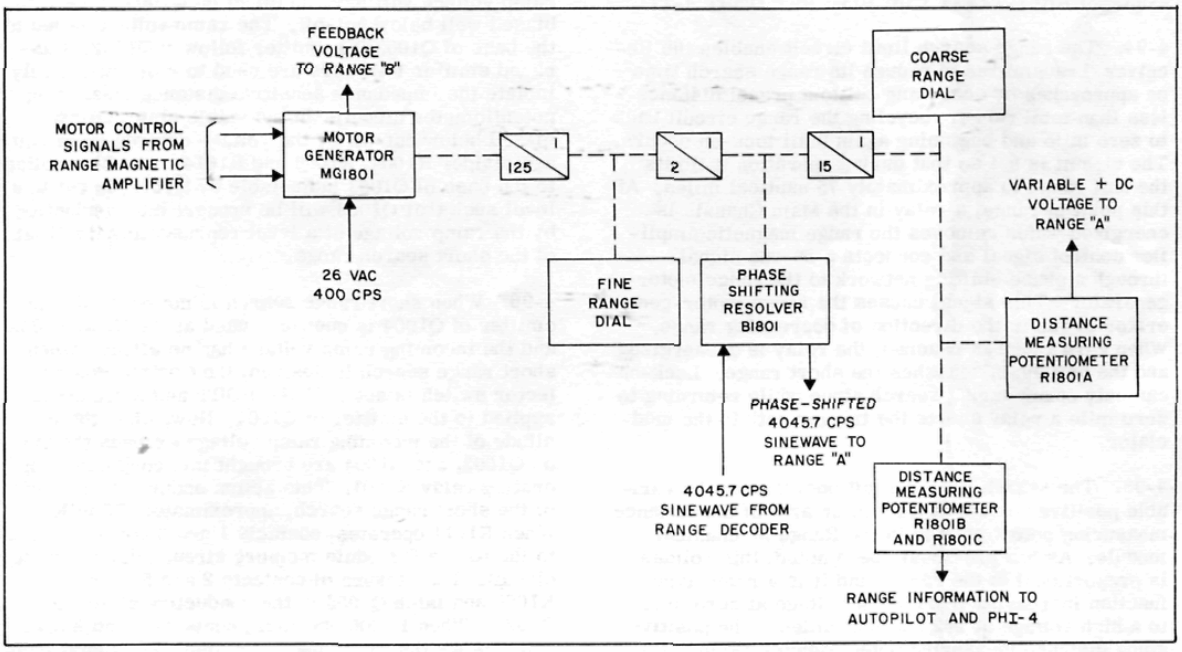
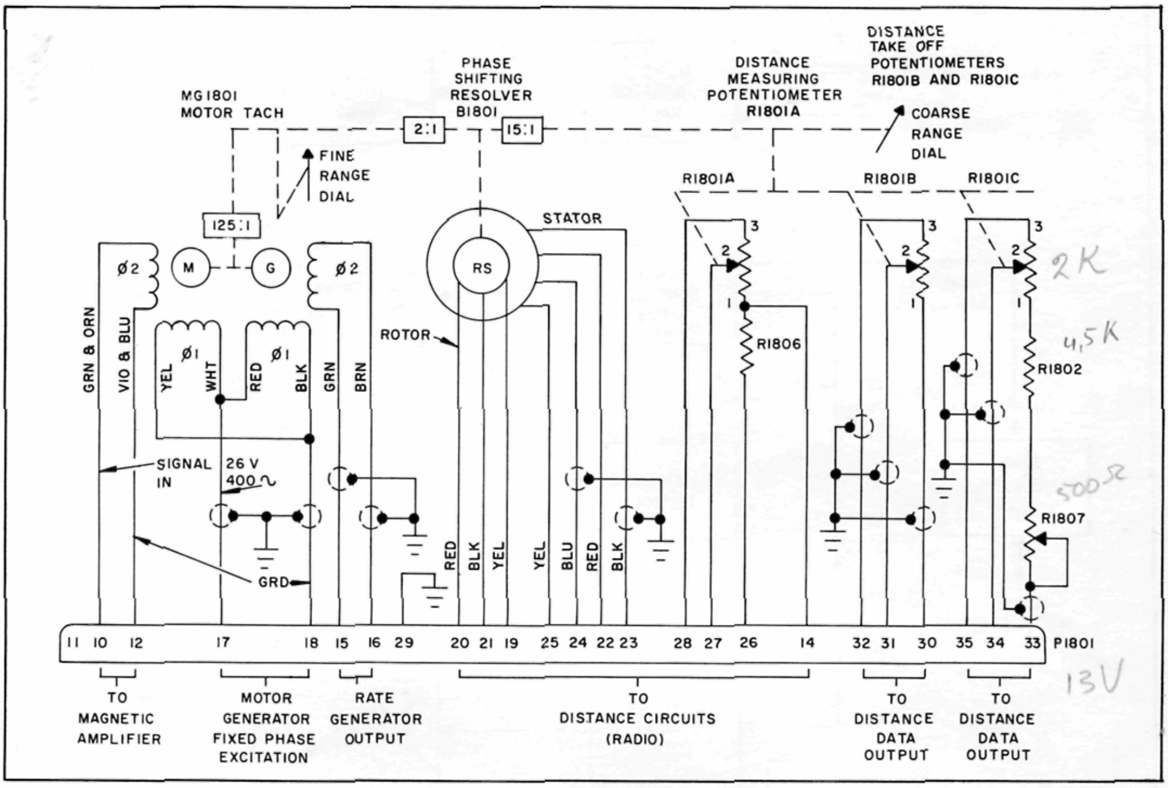


Figure 4-18. Range Mechanical Module, Block Diagram



4-99. RANGE MECHANICAL MODULE. (See figures 4-18 and 4-19.)

4-100. RANGE MOTOR-GENERATOR MG1801, The operation of the range motor-generator is controlled by the output voltage of L22Q1, the range magnetic amplifier. MG1801 drives the phase shifting resolver and the distance measuring and distance data potentiometers. In search operation, the range magnetic amplifier provides a signal which causes MG1801 to rotate in the direction which moves the range gates outward in range. For track operation, the range motor-generator is driven in the direction which will maintain the range gates in coincidence with the reply pulse.

4-101. PHASE-SHIFTING RESOLVER BI801. The 4045.7-cps basic range reference sine wave is ap-plied to the rotor of the phase-shift resolver, and the output sine wave across the stator windings is phase-shifted proportionally to the angular position of the rotor. The period of the sine wave is equal to 20 nautical miles, and the 4045.7-cps sine wave is shifted 360° for each complete revolution. This is equivalent to 20 nautical miles.

4-102. DISTANCE MEASURING POTENTIOMETER R1801A. The distance measuring potentiometer is electrically part of the phantastron in the Range A module. The voltage at the center arm of the potentiometer increases with range, and the arm is mechanically connected to MG1801. This voltage causes the trailing edge of the phantastron pulse to be moved continuously out in range in a 0 to 300 nautical mile-cycle in search; in track, the center arm voltage moves the trailing edge to maintain the receiver-transmitter in track.

4-103. DISTANCE DATA POTMETERS R1801B and R1801C. The distance data potentiometers are driven by the range motor-generator and provide a resistance which is proportional to range for use by the autopilot and Pffl-4 position and homing indicator. PHI-4 position and homing indicator derives its range information from R1801C, while the autopilot derives its range information from R1801B. The two range dials are for maintenance purposes.

4-104. BEARING CIRCUITRY,

4-105. BEARING DECODER MODULE. (See figures 4-20 and 4-21.)

4-106. BURST ELIMINATOR V201. Burst eliminator V201 and peak rider V202 work together to detect the 15-cps and 135-cps amplitude modulations of the received signal. The burst eliminator tube, without a signal, is cut off by the -5 v bias developed across R241. In this cut off condition, C201 charges highly positive. When a signal is received, the Ï-G winding of T501, Range Decoder module, supplies a negative limited video signal. This signal is passed

by diode CR201 and tends to discharge C201 through the 1-6 winding of T50I. Simultaneously, the amplitude modulated video signal from the 2-3 winding of T503, Range Decoder module, is applied to the grid of burst eliminator V201, This signal has sufficient peak positive voltage to bring V201 out of cut off and into conduction. The discharging of C201 by the negative limited video causes current to flow through R204 and R203, thus dropping the voltage at the suppressor grid. This drop in voltage tends to cut off the tube until C201 has recharged. If random noise, squitter, or reply pulses are being received, the time interval between them permits C201 to recharge sufficiently to permit amplification of the amplitude modulated signal at the control grid. However, if a north or auxiliary reference burst is applied, the time interval between pulses of the burst is much shorter than the spacing between reply, squitter, or noise pulses; thus, the capacitor does not have sufficient time between pulses to charge. Therefore, V201 will be cut off for all but the first pulse of the burst. Conduction of V201 causes a negative pulse with positive overshoot to appear at the plate. This is passed through C203 to the grid of V202A and to the 4-5 winding of T201. The pulse is inverted and passed by the 1-3 winding of T201 to the grid of V202B.

4-107. PEAK RIDER V202, With no Signal received from the burst eliminator, both sections of peakrider V202 are cut off and C205 is charged highly positive. The grid of V202A, the charging section of the peak rider, receives a signal consisting of negative pulses 6-usec wide with positive overshoot. The grid of V202B, the discharging section of the peak rider, receives the

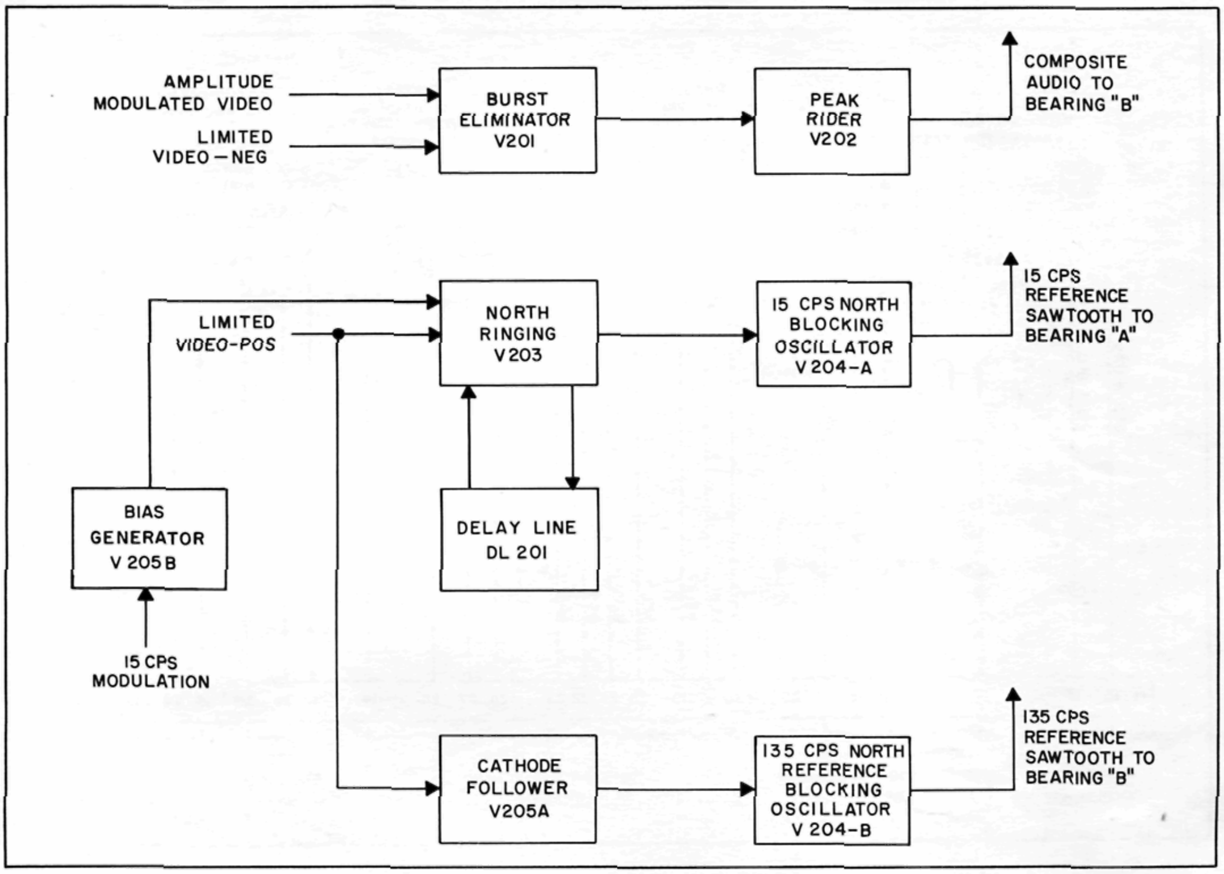


Figure 4-20. Bearing Decoder Module, Block Diagram

same signal, only inverted. With input signals the peak rider operates as follows: The negative pulse applied to the grid of V202A cuts off the section and stops the charging of C2Q5. The positive pulse appearing at the grid of V202B brings this section out of cutoff and discharges peak riding capacitor C105 through V202B and R208. When the pulse passes, V202B returns to its cutoff conduction and stops the discharge of C205. The *Q-/JSGC* delayed positive overshoot from the plate of V201 arrives and brings section V202A into conduction. This charges C205 to the peak of the positive overshoot. The capacitor retains this charge until the next pulse in the composite signal arrives. This is repeated for each pulse in the amplitude modulated video signal. Since the capacitor is discharged by the same number of volts for each input pulse and it charges to the peak amplitude of the positive overshoot of each pulse, the output of the peak rider follows the amplitude of the amplitude modulated video signal in the form of broad pulses with narrow spaces between them. The duration of each peak rider output pulse corresponds with the time space between received pulses. The time space between the peak rider output pulses corresponds with the duration of the received pulse. The peak rider output signal is passed to the coupling amplifier in the Bearing B module.

4-108. NORTH RINGING V203. The north ringing circuit is a gating stage designed to be triggered only by the north reference pulse groups in the positive limited video. The north reference pulse groups oc-cur 15 times per second and consist of pulse pairs spaced 30 usec apart. The north ringing tube, V203, is cut off between pulses by the negative bias applied to the control grid and in normal operation by the -10 v bias on the suppressor grid. AH pulses in the positive limited signal bring the tube into conduction, but all cathode current flows to the screen grid be-cause of the negative bias on the suppressor grid. The positive pulses at the control grid appear as amplified negative pulses at the screen grid and are passed to pin l of delay line DL201. The negative pulse travels down the line from pin l to 3 where it is reflected and inverted; it then travels back to pin 2. It is then passed through a clipper network consisting primarily of diode CR204, capacitor C228, and resistors R245 and R246, and fed to the suppres-sor grid of V203 as a positive pulse. The time elapsed going from pin l to pin 2 via pin 3 is **30 usec**. There will be no conduction to the plate unless the suppressor is driven positive at the same time the control grid is driven positive. This will occur when the pulses applied to the control grid are spaced 30 μsec apart: thus, it is unlikely that the stage can be triggered by any pulses other than those in the north reference burst. When conduction to the plate occurs because of the north reference burst, the ringing circuit of L201 and C210 is pulsed by negative pulses 30 usec apart, and rings at a frequency of 33. 3 kc (period 30 μsec). Each successive 30 microsecond pulse reinforces this ring, building up the ringing voltage and thereby detecting the north reference group. The output of the north ringing circuit is passed through C224 to amplifier V404 and through C211 to the 15-cps north blocking oscillator, The network of CR202, R240, and C226 is a clipping network used to keep high amplitude pulses (noise) in the positive limited signal off the control grid. Capacitor C226 charges to the signal strength with the first few pulses and back biases diode CR202. Thereafter, any large positive spike will be passed by CR202 through C226 to ground and will be attenuated. If adequate 15-cps modulation is present (normal operation), the suppressor is biased at -10 vdc. If the 15-cps modulation is below a certain reliable value, the suppressor is biased more negatively, cutting off V203.

4-109. BIAS GENERATOR V205B. The 15-cps modulation signal at P201, pin 22, is clamped before being applied to the control grid of V205B through capacitor C229 and resistor R248. The output of V205B is coupled through C230 and rectified by diodes CR206 and CR207. The resultant positive voltage is filtered by C232, C233, and R256. Most of the negative voltage biasing the suppressor grid of V203 is present at the anode of diode CR208 and is clamped to ground by the positive output of V205B. This causes V203 to conduct. Loss or decrease in amplitude of the 15-cps reference signal causes V203 to be cut off. In this condition, the 15-cps reference output of V204A is removed, causing relays in Bearing A and Bearing B modules to be deenergized. This shifts the bias to Bearing A module and causes positive counter-clock-wise bearing search.

4-110. 15-CPS NORTH BLOCKING OSCILLATOR V204A. The 15-cps north blocking oscillator is a single-swing blocking oscillator to which the north ringing circuit output is applied. The large output pulse is integrated by R220 and C214 and passed as the 15-cps reference sawtooth to the 15-cps reference filter in the Bearing A module. An output is also taken from the cathode and fed to the 135-cps reference blocking oscillator, R238 is the 15-cps north reference blocking oscillator threshold adjustment which sets the signal amplitude at which the tube fires. Loss or decrease in the 15-cps modulation component removes the output of V204A as described in the previous paragraph.

4-111. 135-CPS REFERENCE BLOCKING OSCILLATOR AND CATHODE FOLLOWER V204B AND V205A. The 135-cps reference blocking oscillator is a single-swing blocking oscillator which is triggered by the output pulse of the north reference blocking oscillator and by the auxiliary reference pulse groups. The positive limited video signal is passed to the ringing circuit of L202 and C221. Diode CR203 serves to prevent the ringing voltage on L202 from feeding back to the input. The circuit is tuned to 41.7 kc (period 24 µsec). The spacing of the pulses in an auxiliary reference pulse group is 24 usec; thus, the circuit of L202 and C221 rings only for auxiliary reference pulse group pulses and attenuates all other pulses. The output of the ringing circuit is coupled to the grid of cathode follower V205A. The output is fed to the 1-2 winding of T203. V204B is triggered by the north reference blocking oscillator pulse and then by eight auxiliary reference pulses. This triggering series is repeated 15 times per second producing a 135-pps signal. The output of V204B is shaped into the 135-cps reference sawtooth by R225 and C218. This is then fed to amplifier V402 in the Bearing B module. Potentiometer R231 is the 135-cps reference blocking oscillator threshold adjustment.

4-112. BEARING A MODULE. (See figures 4-22 and 4-23.)

4-113. 15-CPS FILTER V301A AND PHASE INVERT-ER V303A, The energized voltage for the sine-cosine potentiometer is developed by the 15-cps filter and the phase inverter from the composite audio. The composite audio signal from the coupling amplifier in the Bearing B module is applied to the grid of V301A. Stage V301A is a standard amplifier with a parallel "T" network connected from plate to grid. This network is tuned to 15 cps. A "T" filter network passes all frequencies except that to which it is tuned: thus, the 15-cps component of the composite audio is not fed back to the grid. Because of the 180° phase-shift in the amplifier, the output of the parallel "T" network acts as a negative feedback, and only the 15-cps component appears in the output. This is fed to stage V303A which is a conventional phase inverter. The two outputs, which are 180° apart, are passed to the card of the sine-cosine potentiometer in the Bearing Mechanical module.

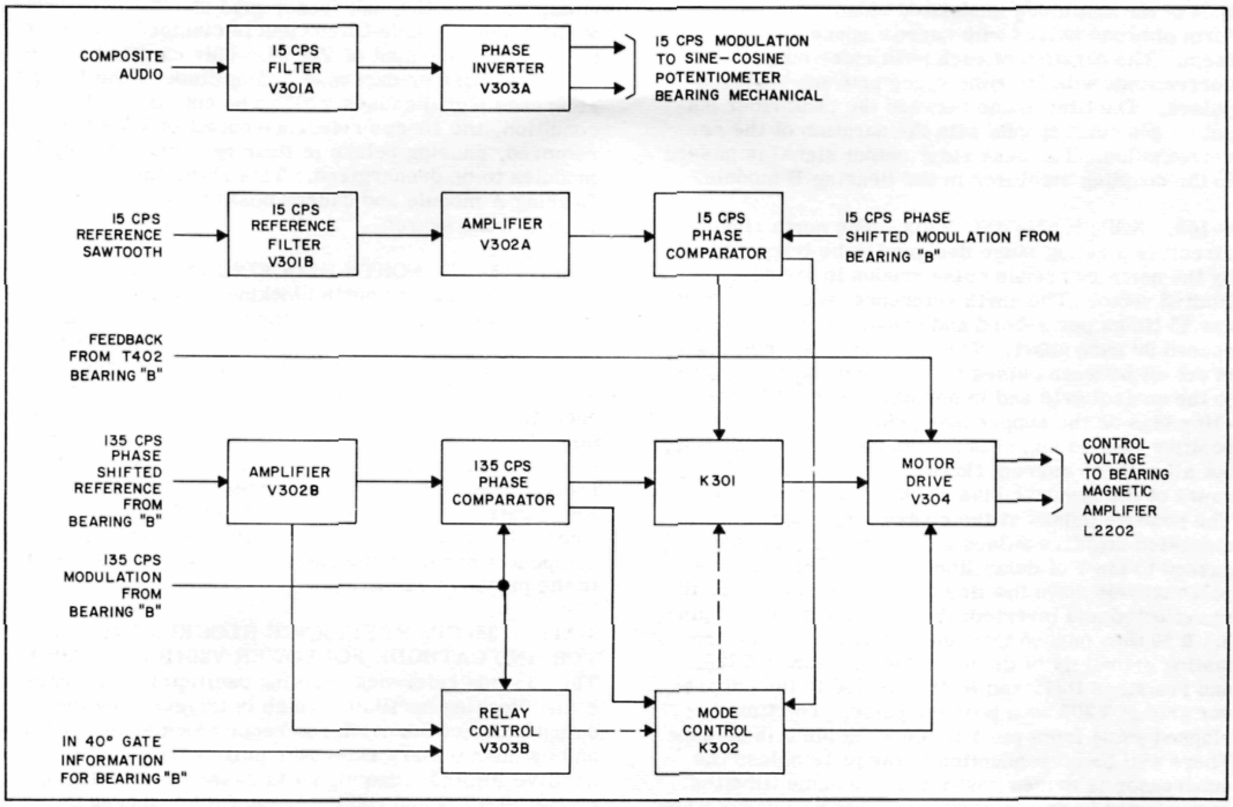


Figure 4-22. Bearing A Module, Block Diagram

4-114. 15-CPS REFERENCE FILTER V301A AND AMPUFIER V302A. The 15-cps reference sine wave for the 15-cps phase comparator is derived from the 15-cps reference sawtooth. The 15-cps reference sawtooth is applied to the grid of V301B, the 15-cps reference filter. This stage works in the same manner as 15-cps filter V301A which is described in paragraph 4-131. The 15-cps sine wave is amplified in V302A and fed to the 15-cps phase comparator through T301 as the 15-cps reference signal.

4-115. 15-CPS PHASE COMPARATOR AND MOTOR DRIVE V304. The 15-cps phase comparator adds the 15-cps reference and the 15-cps phase-shifted modulation voltages vectorially; The outputs being fed to the grids of motor drive tube V304 through relays K301 and K302. With no received signal, diodes CR301 and CR302 are back biased by approximately -20 vdc and relays K30I and K302 are deenergized. The -20 vdc at the junction of R332 and R331 is applied through R332 to contacts 6 and 8 of relay K302 and through resistors R361 and R378 (switched into the circuit by diode CR316 when no reference signal is present). The voltage divider formed by these resistors develops approximately -3. 3 vdc at the grid of V304A. When the junction of R378 and R379 is grounded through connector pin 19, diode CR316 be-comes forward biased. Resistor R378 is thereby switched into the circuit. H either a reference voltage is present or the 40° gate coincidence occurs, diode CR316 is back biased, switching out R378 and thereby permitting the full output of the phase comparator to appear at the grid of 304A. The other grid section of motor drive tube V304B is biased at approximately -20 v through contacts 4 and 2 of relay K301. Thus, with no received signal, section V304B of the motor .drive tube conducts, causing the servo motor to be driven in the direction for decreasing bearing. Positive feedback, derived from the bearing motor-generator in the Bearing Mechanical module, is fed through C326 and C325 to the grids of the motor drive tube to increase the search speed. When a signal is received, the 15-cps reference is applied to the 1-2 winding of T301 and appears in the output windings as two sine waves, 180° apart. The 15-cps phase-shifted modulation is fed to the center tap of T301 where it is added vectorially to the two reference sine waves. The positive portions of the two signals which exceed the biasing voltage across the diodes are passed to the grids of the motor drive tube. The conduction of the motor drive tube changes, and the servo motor is driven to position the wiper arms of the sine-cosine potentiometer for a balanced output voltage from the 15-cps phase comparator. (Unlike the range motor control tube, the hearing motor drive tube responds to input signals when un-balanced.) A balanced output occurs when the wiper arms of the sine-cosine potentiometer are positioned so as to shift the 15-cps modulation 90° with respect to the 15-cps reference. However, before the output is balanced, the operation of K401 in the Bearing B module removes a ground from the junction of R378 and R379 causing CR379 to become back biased. Relay K401, when operated, applies a ground to the cathode of relay control tube V303B via K308 pins 3 and 8. If the combined 135-cps reference signal and a reliable 135-cps modulation signal are present on the grid of V303B, the tube will conduct, operating relay K302. The feedback is reversed when K401 in the Bearing B module operates, to act as a negative anti-hunt voltage. A detailed description of the operation of V304 is given in paragraph 4-131.

4-116. AMPLIF1ER V302B AND RELAY CONTROL V303B. The phase-shifted 135-cps reference voltages from the 135-cps resolver are added by the net-work of R338 and C319 (at 135 cps, the impedances of C319 and R338 are equal) and applied to the grid of amplifier V302B. The amplified output appearing across windings 1-2 of T302 is also applied through C332 and R376 to a voltage doubler circuit consisting of diodes CR312 and CR313 to increase the reference voltage amplitude. The dc output of the doubler is limited to prevent saturating the voltage similarly _^ derived from the 135-cps modulation voltage, and both de voltages are applied to the grid of V303B. With no Signal, relay control V303B is cut off with approximately -18 vdc grid bias. The relay control tube will not conduct unless both the 135-cps phase-shifted reference and 135-cps modulation are present and the hearing circuits are operating in the 40° gate. When section V303B conducts, relay K302 is energized, in turn energizing relay K301 through pins 2 and 5. The relays, when energized, connect the output of the 135-cps phase comparator to the motor drive tube and simultaneously remove the 15-cps signal. Should the 135-cps signals cease, C331 provides approximately two seconds of memory before K302 releases and the bearing circuits then operate on 15-cps information. Diode CR3II and associated resistor network limits the magnitude of the modulation signal used for flag control, so that, in the presence of high modulation levels, the modulation signal does not take over control of the flag signal.

4-117. 135-CPS PHASE COMPARATOR. The 135-cps phase comparator operates essentially like the 15-cps phase comparator. The only major difference in the 135-cps phase comparator is that the reference is shifted rather than the modulation. The motor drive tube positions the servo motor so that the 135-cps resolver output is 90° out of phase with the 135-cps modulation.

4-118. BEARING B MODULE. (See figures 4-24 and 4-25.)

4-119. COUPLING AMPLIFIER V401A AND 135-CPS FILTER. The output of the peak rider in the Bearing Decoder module is applied to the grid of coupling amplifier V401A. V401A supplies two outputs: from the plate, the composite audio signal (135-cps and 15~cps modulation) is fed through C401 to the Bearing A module; and, from the cathode, the signal is fed to a 135-cps filter. The phase-shift of stage V401A is adjusted by coarse bearing adjustment R401. The 135-cps filter is a tuned tank circuit consisting of L401A, C404, and C405. The 135-cps modulation signal is then fed to a phase-shifting bridge network consisting of C407, C408, R408, R407, and R409, The phase of the 135-cps modulation is adjusted by fine bearing adjustment R408, The 135-cps modulation is amplified by V401B and is fed through C409 to the Bearing A module.

4-120. AMPLIFIER V402. Amplifying tube V402 is divided into two sections and serves two functions, The 135-cps reference sawtooth is fed to the tuned tank circuit of L401B, C412, and C413 in the grid circuit of section V402A. (The tank is tuned to resonate at 135 cps.) The 135-cps reference sine wave is amplified: the output is tapped off at the cathode and fed to the 135-cps resolver in the Bearing Mechanical module. The phase-shifted 15-cps modulation outputs of the sine-cosine potentiometer are added by R416 and C417 (at 15 cps the impedances of R416 and C417 are equal) and amplified by section V402B. The amplified 15-cps phase-shifted modulation is fed through C419 to the Bearing A module and through C421 to a phase adjusting bridge circuit. This circuit consists of C434, C435, R452, R453, and R454, and serves to center the 40° gate on the 15-cps reference ringing burst, The phase of the 15-cps phase-shifted envelope is adjusted by varying R454. The output of the bridge circuit is fed to the grid of amplifier V405B.

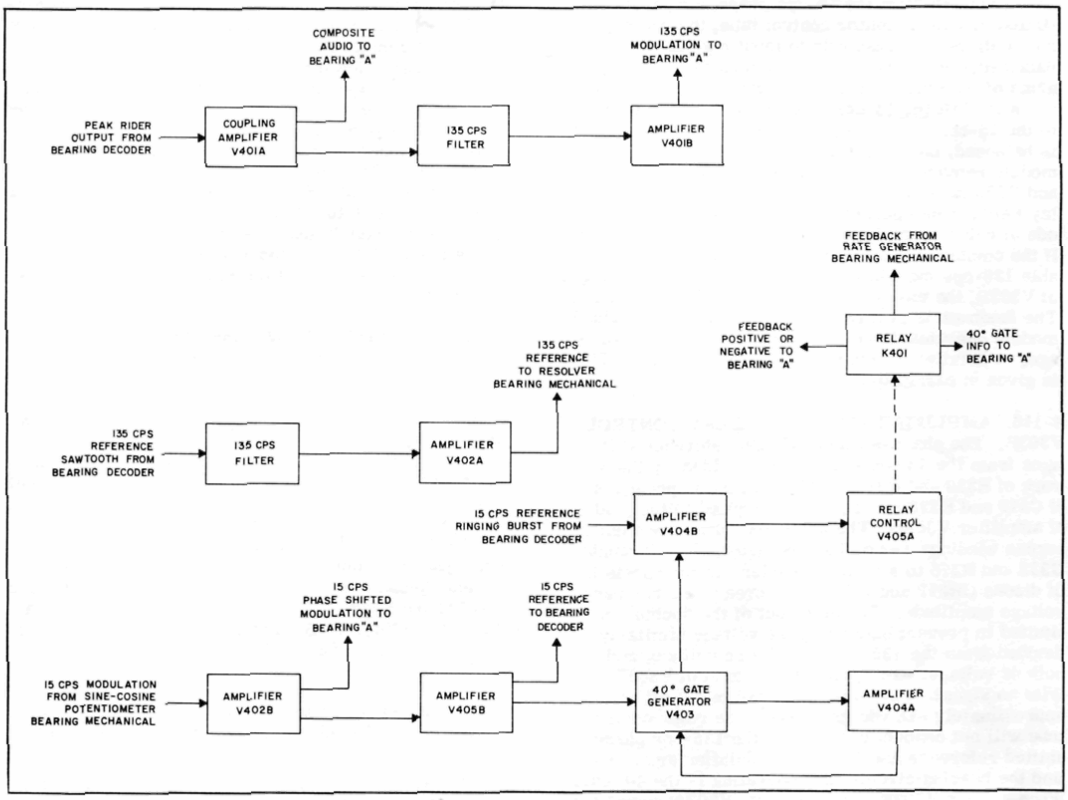


Figure 4-24. Bearing B Module, Block Diagram

4-121, 40° GATE GENERATOR V403. The 15-cps phase- shifted modulation is amplified by section V405B and passed to the 40° gate generator tube, The combination of R421, R422, and CR401 permits only the negative portion of the 15-cps phase-shifted modulation to appear on the suppressor grid of V403. The 40° gate generator tube can be considered to operate as two tubes. One is made up of cathode, suppressor grid, and plate; the other of cathode, control grid, and screen grid. With no signal, the tube is in conduction and the cathode current is divided between the plate and screen grid. When the negative signal (the negative portion of the 15-cps phase-shifted modulation) is impressed on the suppressor grid, the flow of current to the plate ceases and the plate voltage rises. Amplifier stage V404A is normally cut off by a positive bias developed across R429 and applied to the cathode. The rising plate voltage of V403 is passed through C426 to the grid section of V404A, causing conduction. Conduction of V404A causes its plate voltage to drop. This drop in plate voltage is passed by C427, appears at the control gird of V403, and cuts off the screen current. This causes the voltage at the screen grid to rise forming the leading edge of the 40° gate. Since V403 is now cut off, capacitor C427 begins charging in the reverse direction through V404A and resistors R424 and R423. During charging, the control grid of V403 rises exponentially towards + 120 v. Before this is reached, however, conduction occurs at the screen grid. This drops the voltage at the screen and forms the trailing edge of the 40^{e}gate„ The width of the gate is adjusted by varying R424) the gate width adjustment, The positive 40° gate is fed through C424 to the grid of V404B.

4-122. RELAY CONTROL V405A. Without an applied signal, amplifier stage V404B is cut off by a large fixed negative bias on its grid. When signals are received, the 40° gate and the 15-cps reference burst are applied to the grid of V404B. One of these signals alone is not sufficient to bring V404B into conduction. However, coincidence between the two signals will cause V404B to conduct. The signal at the plate during coincidence consists of a burst of closely spaced, large negative pulses. These pulses are fed to the clamping circuit of C428, CR402, R436, R437, and R439. This circuit effectively clamps the most negative excursion of the pulses at the junction of CR402 and C428 to O v and, therefore, the Signal at the junction consists of a positive de voltage with negative pulses, occurring at the time of the north reference burst, extending to zero volts. Without a signal, relay control tube V405A is cut off by the fixed negative grid bias developed across R436. The clamping circuit voltage at the junction of CR402 and C428 over-conies the fixed negative grid bias and causes V405A to conduct. During the one-fifteenth of a second between successive pulse bursts, the voltage at the junction of CR402 and C428 drops slowly with a large time constant. When V405A conducts, relay K401 is energized and reverses the polarity of the feedback voltage supplied to the Bearing A module from positive to negative, and supplies the 40° gate ground to the Bearing A module. If the 15-cps signal is lost (either reference or modulation), the circuit composed of relay coil K401, CR403, C430, R437, and R438 will provide approximately 4.5 seconds of memory time before K4Ö1 releases. The effective capacitance of C430 is increased by the gain of V405A.

4-123. BEARING MECHANICAL MODULE. (See figure 4-26 and 4-27.)

4-124. BEARING MOTOR-GENERATOR MG1701. The bearing motor-generator is a two-phase, 400-cps unit. In the motor section, the voltage for one phase is supplied from the 26-vac fixed-frequency 400-cps source and for the other phase from the bearing magnetic amplifier. The former voltage is the reference or fixed phase, and the latter voltage is the control voltage. The phase of this control voltage, with respect to the reference phase voltage, determines the direction of rotation of the bearing servo motor. The rms value of the control voltage determines the speed of motor rotation. The motor directly drives the rate generator and through gearing drives the 135-cps resolver, the differential transmitter, the wiper *of* the sine-cosine potentiometer, and the hearing indicator on top of the Bearing Mechanical module. The generator section fixed phase is connected to the 26-vac fixed-frequency 400 cps source. The voltage at the output winding of the generator is 400 cps with a rms value directly proportional to the hearing motor-generator speed. This voltage is fed to T402 in the Bearing B module for use as feedback. The feedback is positive while searching and negative during operation on a 15-cps or 135-cps signal.

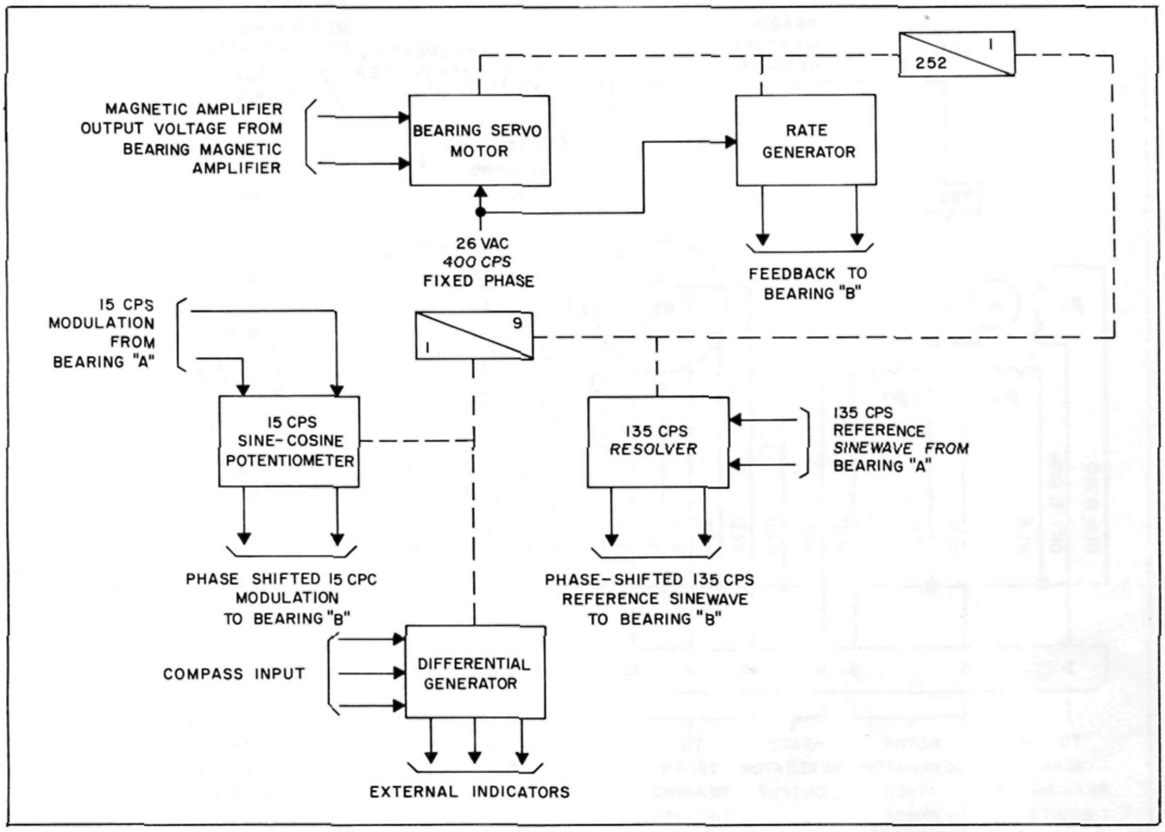


Figure 4-26. Bearing Mechanical Module, Block Diagram

4-125. 135-CPS RESOLVER. The 135-cps resolver receives the 135-cps reference signal from the Bearing B module on the rotor and supplies from its two stator windings a sine and cosine component of the 135-cps reference sinewave. These components are combined by the phase Shift network in the Bearing A module to produce a phase-shifted 135-cps reference sinewave. For each revolution of the resolver, the 135-cps reference sinewave is shifted to 360 degrees.

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4-126. 15-CPSSINE-COSINE POTMETER. The sine-cosine potentiometer consists of a resistance card wound with parallel wires. Two brushes placed 90° apart move in a circle on this card. The brushes are driven by the hearing motor-generator through two gear trains. The two inputs of the card, 180 degrees apart are fed by the outputs of the 15-cps phase inverter in the Bearing A module. The output at each brush is a trigonometric function of the angular position of the brush with respect to the card. The two outputs are combined by a phase shifting network in Bearing B module to produce a phase-shifted 15-cps modulation sine wave. The sine-cosine potentiometer shifts the 15-cps modulation 360° for each revolution of the brushes.

4-127. DIFFERENTIAL TRANSMITTER. The differential transmitter is a three-phase synchro transmitter. A three-phase magnetic compass voltage is fed to the rotor. This signal is phase-shifted by the Tacan bearing and appears at the stator where it is fed to PHI-4.

4-128. MAGNETIC AMPLIFIER MODULE. (See fig-ure 4-28.)

4-129. RANGE MAGNETIC AMPUFIER L2201. Refer to paragraph 4-90 for the theory of operation of the range magnetic amplifier L2201.

4-130. BEARING MAGNETIC AMPUFIER L2202. {See figure 4-29.) The detailed operation of the bear-ing magnetic amplifier is best explained along with that of bearing motor drive tube V304 and hearing motor-generator MG1701. The phase and rms value of the bearing magnetic amplifier output is deter-mined by the output of V304 and controls, respectively, the direction and speed of rotation of MG1701.

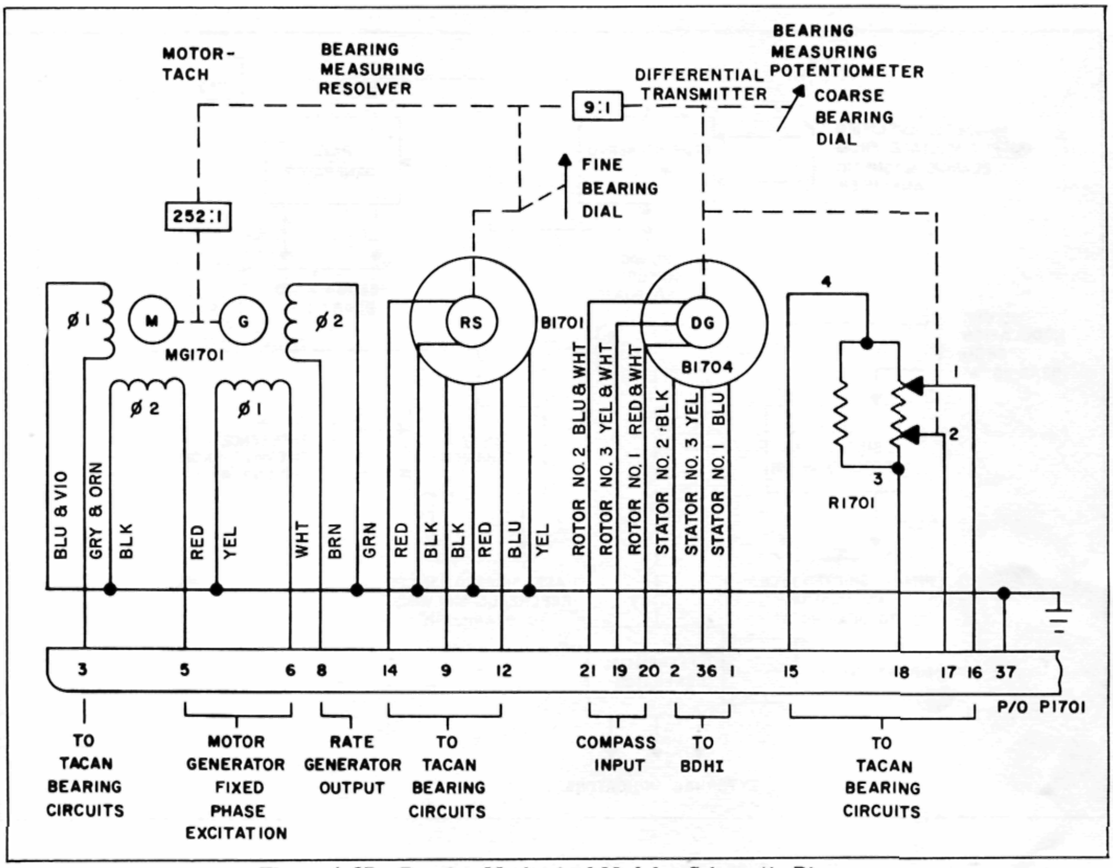

Figure 4-27. Bearing Mechanical Module, Schematic Diagram

4-131. The bearing magnetic amplifier consists of two cores, A and B, each wound with three windings. With the bearing circuits not receiving any bearing information from the beacon, V304 is unbalanced with V304B conducting heavily and V304A cut off as explained in paragraph 4-115. The magnetic fields caused by the current flow through the power and control windings of the A core are additive and in phase. The A core saturates and no output is induced in the A core output winding. However, the B core does not saturate since there is no current in its control winding. This causes a voltage to be induced in the B core output winding to control bearing motor-generator MG1701. The phase of the control voltage fed to MG1701, compared with the fixed-phase, 400-cps, 26-vac signal supplied to MG1701, determines the direction of rotation. The rms value of the control voltage determines the speed of rotation.

4-132. The rotation of MG1701 causes a feedback voltage to be generated. This is fed through relay K401 and transformer T402 to the grids of motor drive tube V304. When the bearing circuits are operating out of the 40° gate, relay K401 is set as shown in figure 4-28 and the feedback is positive; when the bearing circuits are operating in the 40° gate, relay K401 is energized and the feedback is negative.

4-133. When a signal is received, the output of the 15-cps phase comparator is fed to both grids of V304. This causes the bearing motor-generator to be driven in the direction which yields the shorter angular coverage to obtain operation in the 40° gate. Although V304 is not balanced both grids now receive signals 180° apart. These signals, along with the positive feedback from MG1701, determine the

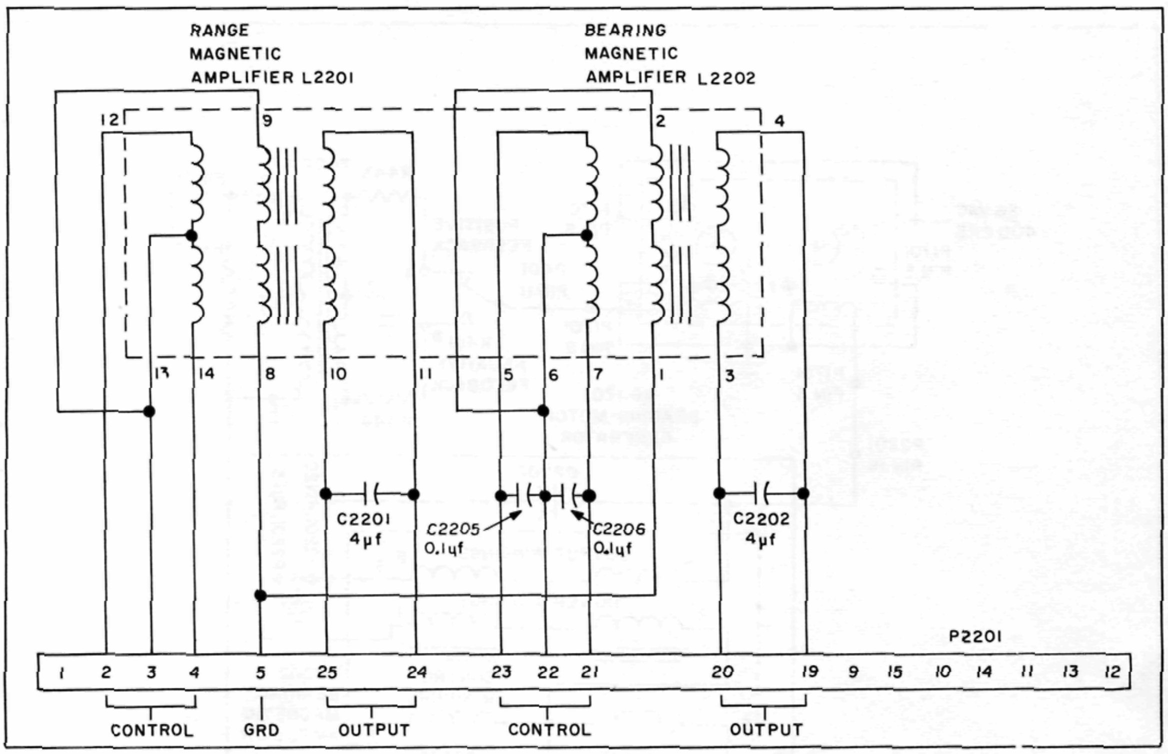

Figure 4-28. Magnetic Amplifier Module, Schematic Diagram

conduction of V304. The conduction in each section of V304 determines the amount of current flowing through the respective portions of magnetic amplifier output windings. Since this is the algebraic sum of currents 180 out of phase, the net voltage developed across the output winding has an amplitude and phase directly related to the grid voltages of V304.

4-134. Balance is obtained when equal signals are applied to both grids. However, before balance is reached in 15-cps operation, the bearing circuits switch to 40° gate operation. This causes the connections to V304 to be balanced by switching the ground from P301 pin 19 to P301 pin 20 in Bearing A module. If reliable 135-cps signals are being received, V303 conducts, operating relay K302 which, in turn, operates relay K301. Consequently, the output of the 135-cps phase comparator is connected to the grids of V304. The 135-cps phase comparator signals cause the bearing magnetic amplifier to sup-ply a control signal to MG1701. The control signal causes MG1701 to position the 135-cps resolver to phase-shift the 135-cps reference so that balanced signals are supplied to V304. When this occurs MG1701 is no longer driven and the actual bearing-to-beacon information is supplied to external indicators.

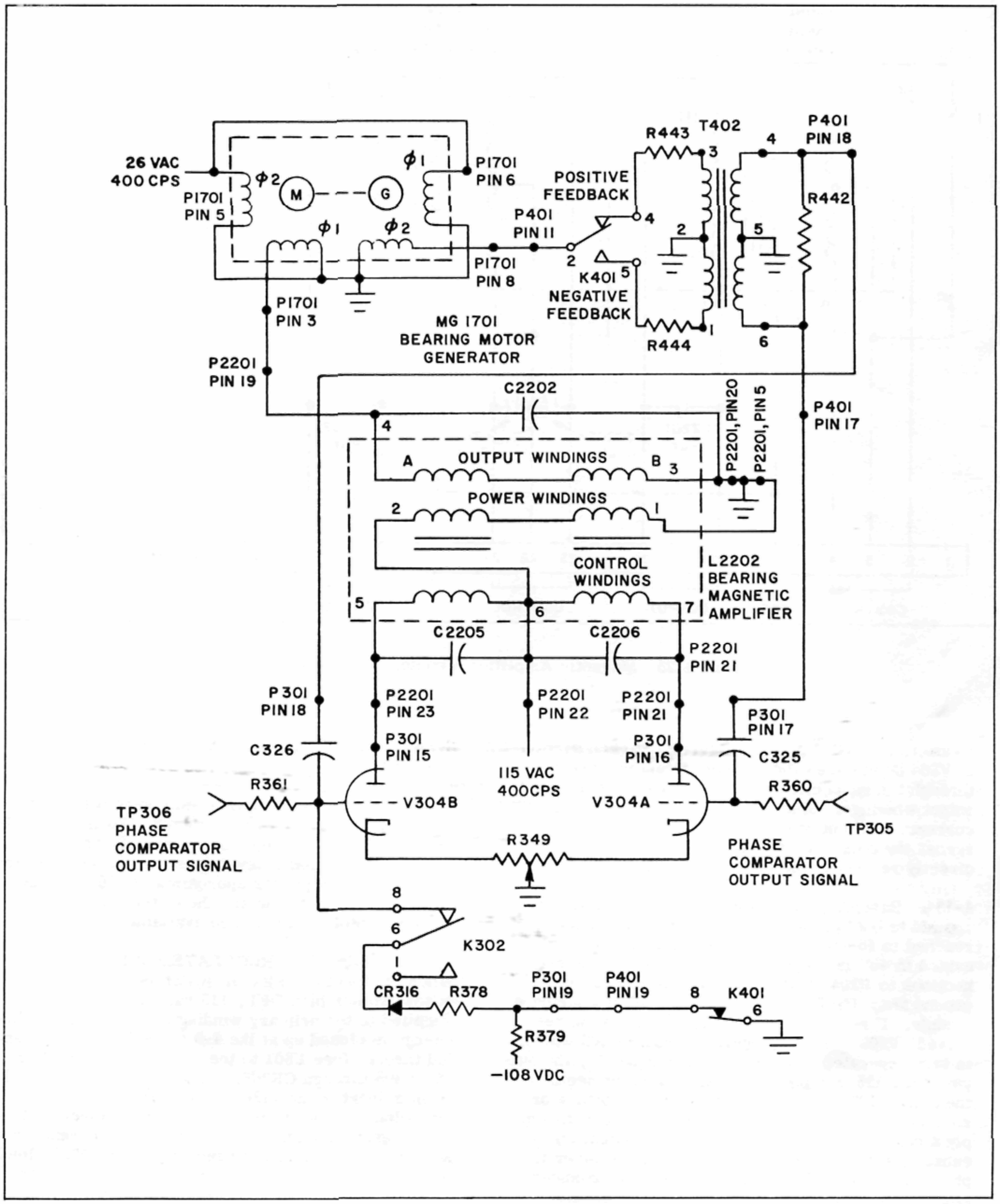

Figure 4-29. Bearing Motor Generator Control Circuit, Schematic Diagram

4-135. POWER SUPPLY MODULE. (See figures 4-30 and 4-31.)

4-136. The Power Supply module supplies the Receiver-Transmitter with regulated +120 vdc and -108 vdc and 400-cps voltages of 6.3 vac, 26 vac and 50 vac. A thermal relay delays the +120 vdc and the 50-v 400 cps output for approximately 90 seconds after both the -108 vdc and the 6.3-v 400 cps filament voltage outputs are available.

4-137. +120-VOLT REGULATED SUPPLY. When the function selector switch is in any position other than OFF, 115 vac, 400 cps is supplied to the primary winding (1-3) of T801. This energy is picked lip at the 4-5 secondary winding and fed through fuse F801 to the diode bridge rectifier of CR803 through CR806, Fuse F801 protects T801 from a short in the +120-v line. The rectified output voltage is fed through L801 to the collector of series gate transistor QB01. Initially, thermal relay K801 is deenergized and hence resistors R802, R803, in shunt are connected in series into the collector circuit of Q801. These resistors reduce the input voltage to the collector of Q801 by more than 90 percent thereby reducing the +120 vdc output.

4-138. Thermal relay K801 operates to 6. 3 vac, after a 90 second (nominal) time delay, completing the ground return path for relay K802, operating the relay. Operation of K802 shorts out R802 and R803 and removes them from the collector circuit of Q801. The time delay action of K801 provides for a 90 second warm-up time for tubes in the Receiver-Transmitter before the application of plate voltage. The output o! Q801 is fed from its emitter to a sensing bridge circuit consisting of four resisters (R810, R812, R814, R815), potentiometer R813, and zener diode CR809.

4-139. Deviation from desired output voltage are sensed by the sensing bridge consisting of resistors R811, R812, R813 (potentiometer), R814 and R815. Such deviation is applied to the bases of Q805 and Q806. Transistors Q805 and Q806 are connected in a temperature compensating circuit. The base of Q805 is connected to zener diode CR809 maintaining the base at 9. 3 vdc above the negative terminal. Since the emitters of Q805 and Q806 are common, the voltage at the base of Q806 represents the voltage necessary lo make the base

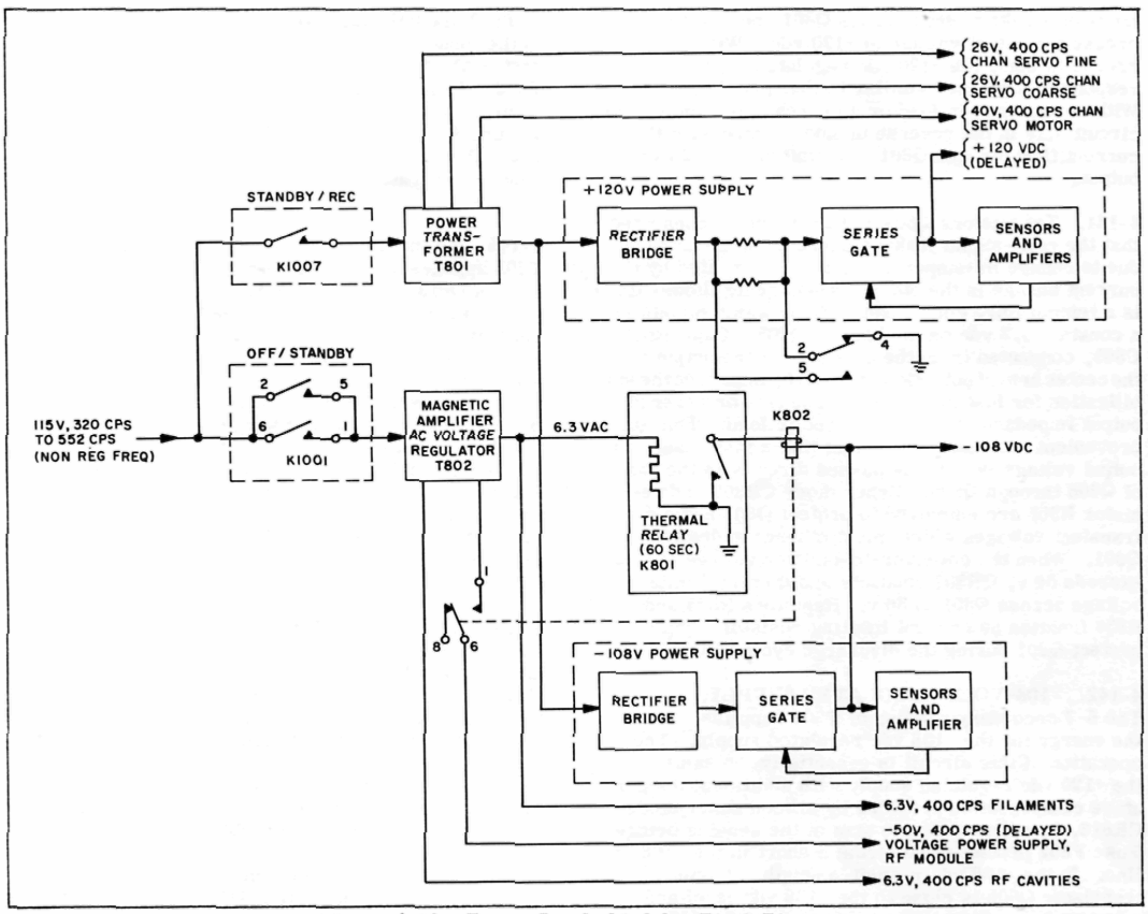

Figure 4-30. Power Supply Module, Block Diagram

voltage at Q805 equal to that at Q806. The output voltage at the collector of Q805 is fed to amplifiers Q804 and Q803. Transistors Q803, Q804, Q805 and Q806 are operated at or near zero de potential while Q801 and its driving transistor Q802 are operated at or near a de level of +120 volts. Zener diode CR808 is placed in series with the signal path for de isolation between these two circuits. The amplified error signal is further amplified by Q802 and fed to the base of the series gate Q801.

4-140. If the input voltage at the primary of T801 increases, the de voltage level at the emitter of Q801 will also increase. This voltage increase is passed to the sensing bridge where it causes the voltage at the center arm of R813 to increase. Here the increase is reduced to about 10 percent of the output change. The small increase in the voltage at the base Of Q806 causes a drop in the current flow through Q806. The voltage on the emitters of both Q805 and Q806 will then rise slightly. This causes more current to flow through Q805 since the base of Q805 is held at a constant voltage. An increase in current flow through Q805 is amplified in Q804 and Q803 and appears at the base of Q802 as a drop in voltage. The drop in base voltage reduces the collector current in QB02, thus delivering less drive to Q801. This allows more of a voltage drop across Q801 and tends to de-crease the output voltage to +120 vdc. With a de-crease in load, the +120 vdc regulated supply will respond in a manner similar to that just described. With an increase in load or a decrease in supply, the circuit acts in the reverse manner, increasing the current flow through Q801 to maintain the +120 vdc output.

4-141. Transistors Q805 and Q806 are so connected that the zero-signal leakage current change in each, due to change in temperature, is compensated by the current change in the other. Also, zener diode CR809 is a temperature compensated diode which maintains a constant 9. 3 vdc on the base of Q805. Capacitor C805, connected from the plus side of the output to the center arm of potentiometer R813, improves the stabilization for fast input voltage changes or lowered output impedance for fast changes in load. This improvement is caused by the fact that a fast change in output voltage is initially passed directly to the base of Q806 through Q805. Zener diode CR807 and resistor R805 are employed to protect Q801 against transient voltages which might otherwise destroy Q801. When the collector-to-emitter voltage of Q801 exceeds 56 v, CR807 conducts and thereby limits the voltage across Q801 to 56 v. Resistors R834 and R835 function as current limiting resistors which protect Q801 during the discharge cycle of C801.

4-142. -108-VOLT REGULATED SUPPLY. The 6-7 secondary winding of T801 supplies the energy for the -108 vdc regulated supply. The operation of this circuit is essentially the same as the +120 vdc regulated supply with additional temperature compensation provided by silicon zener diode CR816, in series with one arm of the sensing bridge. Fuse F802 protects T801 from a short in the -108 vdc line. In the -108 vdc regulated supply, driving transistor Q808 is close to the -108 vdc level and is connected as an amplifier in cascade with Q809 and Q810. Q808 drives the series regulating transistor, Q807, through zener diode, CR814. Zener diode CR824 protects QB07 from voltage surges caused by the manipulation of the function selector switch.

4-143. AC VOLTAGE SUPPLY. The regulation for the ac voltage supplies is provided by magnetic amplifier series regulator T802 in the input circuit of T803. The secondary winding of T803, besides supplying the necessary ac voltages, supply a sensing circuit for the magnetic amplifier through the 3-4 winding. The ac output of winding 3-4 is rectified by the diode bridge rectifier of CR819 through CR822 and applied to the sensing bridge. This bridge consistsofR829, R830, R831, and the 5-6 winding of T802 as one side, and R833 and zener CR823 as the other side. Zener CR823 is a temperature compensated diode operating at 5.6 v.

4-144. The detecting portion of the bridge consists of Q814 and Q813 connected in a temperature compensating configuration. The positive portion of the input voltage passes through winding 1-2 of T802 and CR818 to the primary of T803, while the negative portion passes through winding 1-3 of T802 and CR817 to the primary of T803. These two windings of T802 are polarized so that the ampere turns due to the input current are additive. The collector current of Q813 flows through control winding 4-5 of T802. This current serves to reduce the degree of saturation of the core since the ampere turns of winding 4-5 buck or partially cancel those of 1-2 and 1-3. Potentiometer R830 adjusts the collector current so that rated output is supplied at rated input voltage.

4-145. An increase in supply voltage at the input of T802 appears as a small increase in the bias at the base of Q813. This change is amplified and causes the collector current which flows through the magnetic amplifier series regulator control winding 4-5 to increase. The control winding ampere turns, which are in opposition to the power winding ampere turns increase. Therefore, with an increase in control current, more power winding ampere turns are required to saturate the core, thus decreasing the conduction angle of the magnetic amplifier series regulator and, therefore, the rms voltage at the input to transformer T803. The ac output voltage is thus returned to its original value. Should a decrease in input voltage occur, the reverse of what is described above will occur.

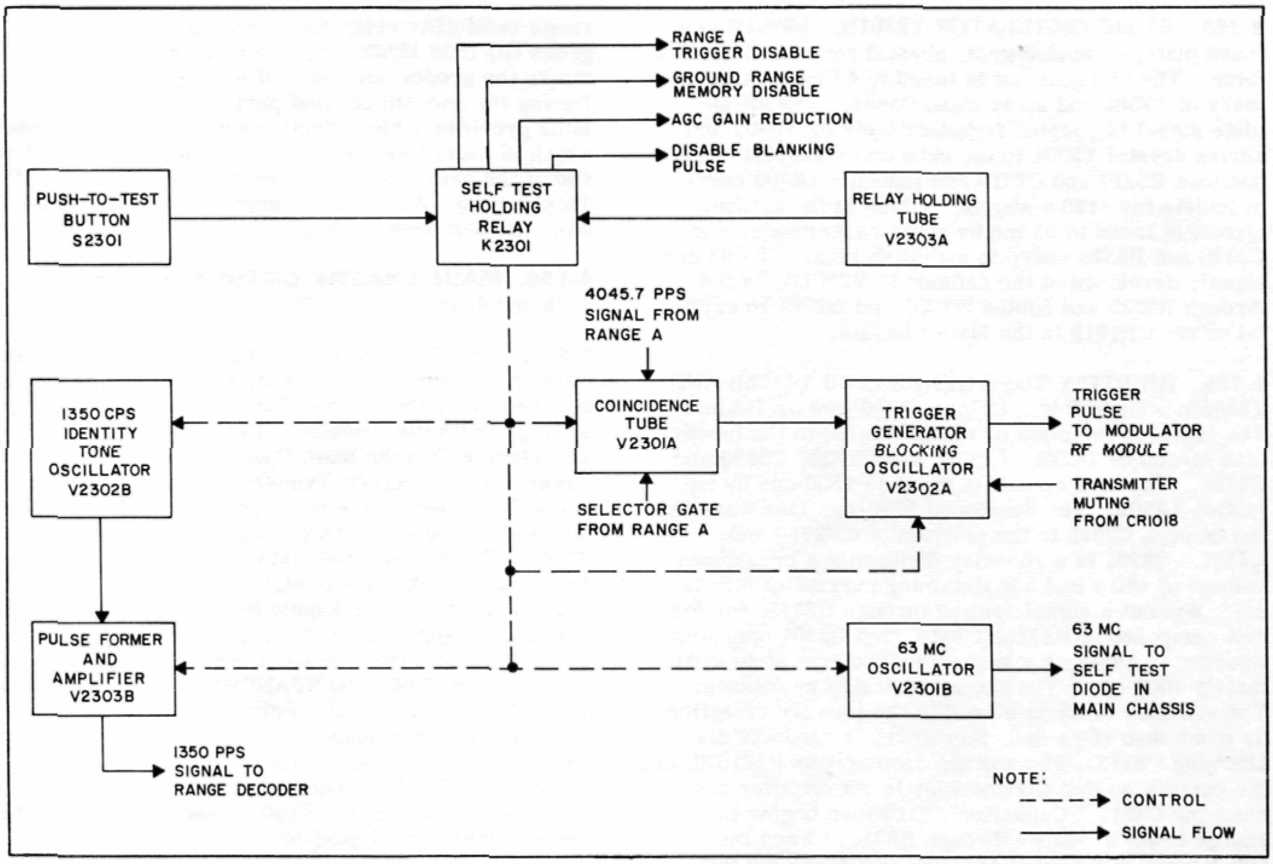

Figure 4-32. Self Test Module, Block Diagram

4-146. Transformer T801 provides 26 vac for the coarse and fine channel servo bridges, 40 vac for the channel servo motor, and 26 vac for the motor generators. Transformer T803 provides 6.3 vac for all tube filaments, 6.0 vac for the cavities, and a delayed 50 vac supply for high voltage power supply Z1501 in the RF module. The connection of the delayed 50 vac supply and the normal operation of the +120 vdc regulated supply is delayed 90 seconds by the thermal time delay relay K801.

4-147. When the function selector switch is initially set to any position other than OFF, the -108 vdc regulated supply and the ac voltage supply come into operation. Ninety seconds after the 6. 3 filament voltage is present, relay K801 connects pin 3 of relay K802 to ground, If the -108 vdc regulated supply is operating properly, relay K802 is energized connecting the delayed 50 vac supply to the RF module and the +120 vdc regulated supply for normal operation. Fuse F803, in series with the power windings of T802, protects 802 and T803 in the event of a short in the ac distribution circuitry.

4-148. SELF TEST. (See figures 4-32 and 4-33.)

4-149. GENERAL. The self test circuits check the operation of the range modules, the RF module, and the power supply module. The testing operation is initiated by toggle switch S2302 on the Self Test module. This connects +120 v and 6.3 vac to the module; red indicator 12301 on the Self Test module should light.

This indicates that the 6,3-v supply is present, PUSH-TO-TEST button S2301 on the module is then momentarily depressed. This discharges the range memory capacitor in the Range B module and connects +120 v to the tubes in the Self Test module.

4-150. RELAY HOLDING TUBE V2303A. Normally, V2303A does not conduct because its plate voltage connection is open and its plate is connected to ground. When self test operation is initiated, +120V is connected through S2301 to the coil of relay K2301. Since the other side of the relay coil is connected to ground through contacts 2 and 4 of K230I, the relay energizes and removes the ground at the plate of V2303A. The +120 v applied to the coil if K2301 is now applied through the coil to the plate of V2303A. The positive jump in plate voltage is passed by C2306 to the grid of V2303A and V2303A is brought into conduction. The plate current of V2303A, during conduction, holds relay K2301 energized. The grid of V2303A is connected to a fixed negative bias voltage which is sufficient to cut off the stage. The grid of V2303A begins to drop towards this negative bias with a time constant determined by C2306, R2310, and R2311. The time constant, grid bias voltage, and the tube gain are such that V2303A holds relay K2301 energized for approximately one minute after the PUSH-TO-TEST button has been released. The grid bias voltage, and thus the holding time, is adjusted by varying R2313. During the one-minute holding period, the closed contacts 2 and 5 of K2301, shunt the grid of the AGC amplifier V504A (in the Range Decoder module), to ground via CR2307 and C2371, reducing the gain of the tube {see figure 4-34, } This is necessary to prevent an excessive AGC voltage from being developed due to the strong identity tone from the Self Test module. The ground from contacts 2 and 5 of K2301 is applied to the blanking circuits in the modulator, via CR2305, to disable the AGC circuits there and prevent a negative blanking pulse from being developed, This ground is also used to disable the Range A triggers to the modulator during self test. The ground is applied to the grid of V601B via CR2306 and R1026. In normal operation, CR2306 prevents the positive blanking pulse applied to the input of Q1514 from entering the Range A module.

4-151. COINCIDENCE TUBE V2301A. Normally, V2301A is cut off by the large negative bias developed across R2303. The selector gate and the phase-shifted 4045.7-pps signal are both applied to the grid, Coincidence of the selector gate with a pulse from the phase-shifted 4045.7-pps signal is necessary for V2301A to conduct. Conduction of V2301A produces a positive pulse across R2305 at its cathode. This pulse is fed to the trigger generator blocking oscillator through C2304.

4-152.TRIGGER GENERATOR BLOCKING OSCILLATOR V2302A, The positive pulse from V2301A is applied to the 1-2 winding of T230I and induces a positive pulse in the 5-6 winding of T2301. The positive 5-6 winding pulse brings V2302A into heavy conduction and causes a large positive pulse to be developed across R2306 in the cathode. This pulse is fed to the modulator circuit in the RF module and triggers the RF amplifier. Resistor R2331 and diode CR2308 are part of the transmitter muting circuit (refer to paragraph 4-158).

4-153. 63-MC OSCILLATOR V2301B. V2301B is a tuned plate, grounded grid, crystal controlled oscillator. The plate circuit is tuned to 63 mc by the primary of T2302 and stray capacitance. The 63-mc plate signal is coupled regeneratively by T2302 and series crystal Y2301 to the cathode of V2301B. Capacitors C2317 and C2319 and inductor L2303 serve to isolate the +120 v supply. L2304 in the cathode circuit is tuned to 63 mc by stray capacitance, and C2320 and R2326 serve to establish bias. The 63-mc signal, developed at the cathode of V2301B, is fed through R2325 and cables W1001 and W2301 to crystal mixer CR1012 in the Main Chassis.

4-154. 1DENTITY TONE GENERATOR V2302B AND V230SB. -V2302B is a Colpitts 1350-cps oscillator. The signal at the plate of V2302B is fed to the tuned tank circuit of L2301, L2302, and C2322, C2323 and C2324. The tank circuit is tuned to 1350 cps by adjusting L2302. The developed 1350-cps sine wave is fed through C2312 to the junction of CR2310 and Q23Q1. Q2301 is a shockley diode with a breakdown voltage of +60 v and a maintaining current of 5 to 12 ma. Without a signal applied through C2312, the circuit composed of R2318, C2313, and Q2301 operates in order to generate a sawtooth waveform of approximately 1000 cps.
The circuit operates as follows: The shockley diode is biased in the forward direction by more than +60 v and, therefore, it conducts discharging C2313. The voltage drop across R2318 limits the current so that the shockley is cut off after

discharging C2313. Capacitor C2313 then begins to charge towards +120 v through R2318. When the +60-v point is reached, the shockley fires and the process previously described is begun again. The 1350-cps sine wave appearing at the cathode of Q2301 synchronizes the circuit to the 1350-cps signal by using the shockley several usec before it normally would conduct. Conduction of Q2301 causes a negative pulse to be applied through C2313 to the cathode of V2303B. This causes V2303B to conduct heavily during the duration of the pulse, producing a negative pulse at the p late of V2303B. This pulse is fed through CR2303 and R2328 to the cathode of decoder tube V501 in the Range Decoder module. R2328 adjusts the amplitude of the 1350-pps signal applied to cathode resistor R503.

4-155. SELF TEST SUMMARY. During its operation, the Self Test module triggers the RF amplifier in direct synchronism with the formation of the early and late gates. A portion of the transmitted signal is tapped off and fed through cable W1002 to crystal mixer CR1012. The 63-mc signal generated by V2301B is also fed to CR1012, and it beats with the transmitter frequency to produce pulse pairs 63 me above and below the transmitter frequency. This signal is applied to the preselector cavities and, de-pending on whether the high band or the low band cavities are in operation, the signal 63 me above or below the transmitter frequency is passed by the preselector to crystal mixer CR1201 as a received signal. Since the transmitter was triggered in synchronism with the formation of the range gates, the signal passed by the receiver causes the range circuits to lock on to its own interrogation. It is possible to lock on at any 20 mile interval. Energized range reliability relay K1004 connects ground to green GO light 12302, thus energizing the light to indicate the proper operation of all tested circuits. During the one-minute test period, the identity oscillator provides a clear continuous identity tone signal which is heard over the aircraft audio system. At the end of the one-minute test period, V2303A is cut off. This releases K2301 and removes the +120 v supply from the Self Test module.

4-156. MAIN CHASSIS CIRCUITS.(See figures 4-35 and 4-36.)

4-157. The Main Chassis contains the relay circuits which control the power supplied to the equipment as determined by the Control Box mode selector switch setting. With the mode selector switch set to OFF, all relays within the Main Chassis are released and all power to the Receiver-Transmitter modules is dis-connected. Setting the mode selector to STBY completes the ground return of OFF/STANDBY relay K1001. When energized, this relay connects 115 vac, 320 to 520 cps through parallel contacts l and 6, and 5 and 2, to the Power Supply module. This causes ac power to be supplied to all tube filaments. When the mode selector switch is set to REC, the ground return of relay K1001 and STANDBY/REC relays K1002 and K1007 is completed. Relay K1002 connects the 115-vac fixed frequency power through contacts 2 and 5 to the Range B module, the Magnetic Amplifier module, and T1001. The secondary of T1001 supplies 26 vac to relay K1003, contact 5, and to the Bearing Mechanical module.

4-158. Transmitter muting (see figure 4-35) is provided during channeling to protect CR1202 from excessive transmitter pulse power by keeping the transmitter turned off during channeling. A dc voltage from the rectifier bridge in the motor control circuit of the channel servo energizes relay K1010, while the channel servo motor is operating. Minus 108 vdc is applied to R1020 via closed contacts 2 and 5 of K1010. Capacitor C1005 charges to -20 volts, as limited by zener diode CR1018, in approximately 0.04 seconds. This negative potential is applied to the grid of countdown blocking oscillator V601B in the Range A module via CR620 and R609, cutting off the tube and preventing the transmitter from being triggered tor interrogation of a ground station. The negative voltage is also applied to the grid of trigger generator V2302A in the Self Test module via CR2308 and R2331 to insure that the transmitter is muted in the event that the self test is turned on when channeling. When channeling is completed, (power removed from the channel servo} K1010 is released, removing -108 vdc from R1020. Capacitor C1005 discharges through the grid return of V601B and V2302A, keeping these tubes biased below cutoff for an additional 0.8 seconds.

4-159. When the mode selector switch is set to T/R-NOR or T/R-SHORT, the ground return of REC-T/R-REC relays K1003 and K1008, in addition to relays K1001, K1002, and KI007, is completed (refer to paragraph 4-93 for discussion of T/R-SHORT operation). Energized relay K1003 connects 50 vac to the high voltage power supply in the RF module through contacts *l* and 6; it also connects 26 vac from T100 through contacts 5 and 2 to the Range Mechanical module and contact 1 of K1006 via Z1002. When energized, relay K1008 completes the circuit through contacts 2 and 5 of the interrogation trigger pulses from the Range A module to the RF module.

4-160. Resistors R1018 and R1019 and potentiometer R1017A, R1017Bare connected as an attenuator net-work which permits setting of the identity tone power to the specified level of 50 milliwatts.

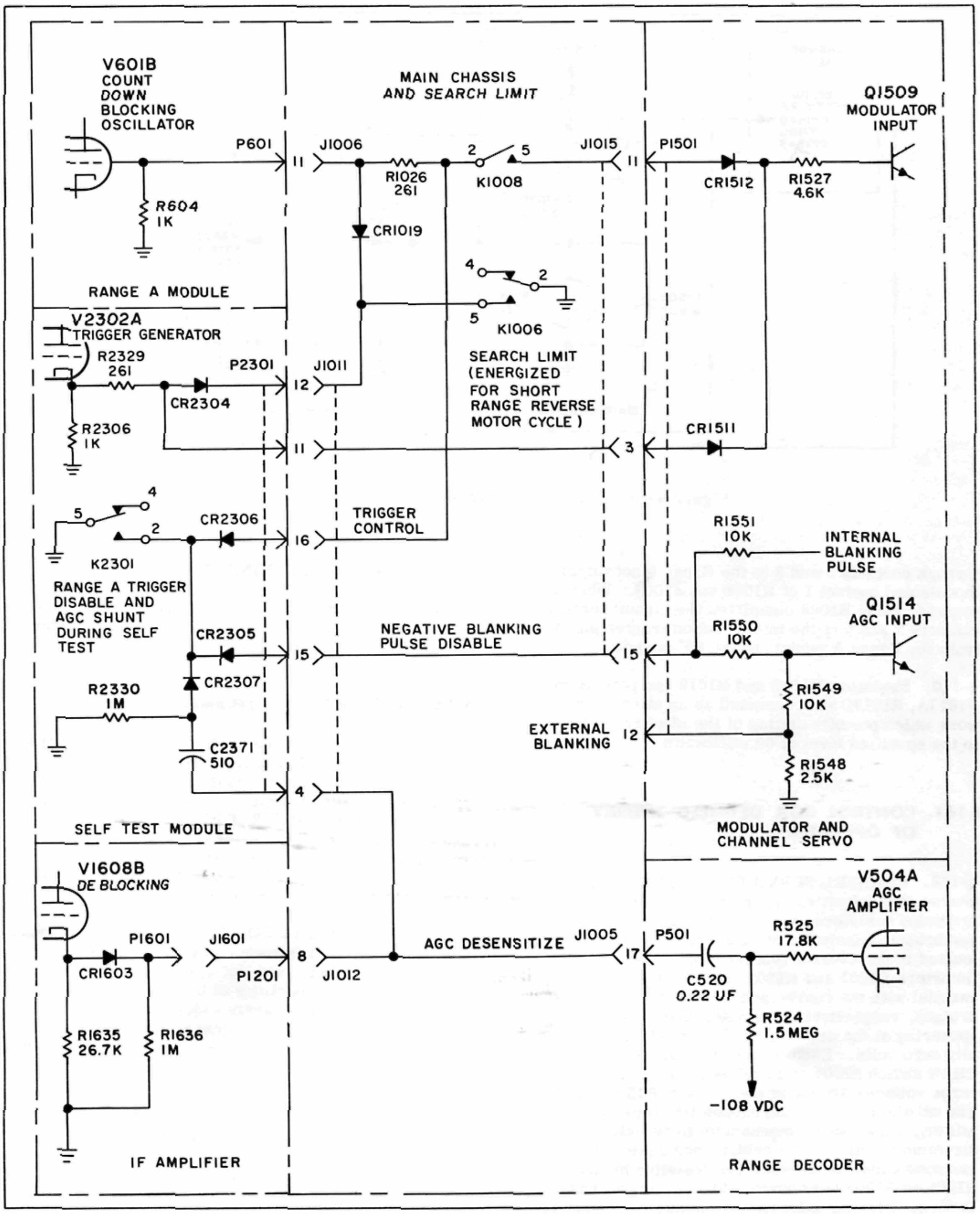

Figure 4-34. AGC Reduction and Modulator Trigger Disabling Circuit Diagram

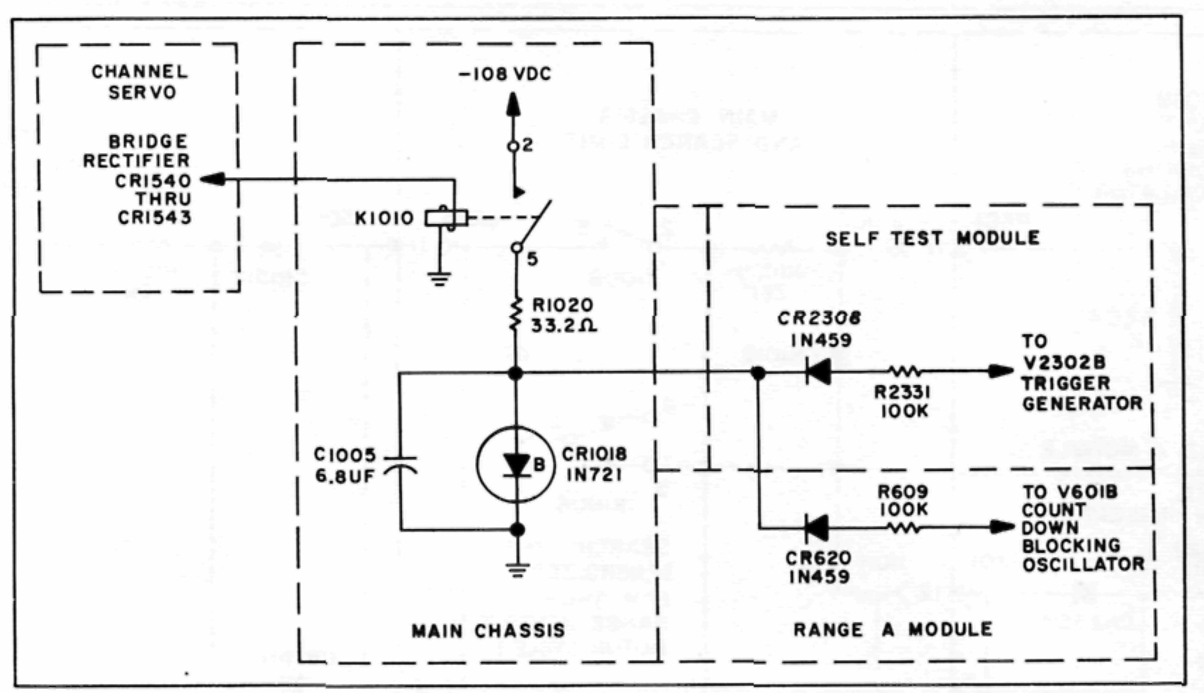

Figure 4-35. Transmitter Muting Circuit Diagram

4-161. CONTROL BOX DETAILED THEORY OF OPERATION.

4-162. CHANNEL SERVO ERROR BRIDGES. The coarse channel servo error bridge, consisting of 14 precision resistors, and the fine channel servo error bridge, consisting of 11 precision resistors, are located in the Control Box (see figure 4-37). Potentiometers R1201 and R1202, in the RF module are in parallel with the coarse and fine channel servo error bridges, respectively. At quiescence, the voltage appearing at the arms of R1201 and R1202, is essentially zero volts. Each bridge is balanced. When the CHAN switch S2001 or S2002 is set to a new channel, error voltages appear at the arms of R1201 and R1202 The unbalanced condition causes the Receiver-Transmitter channel servo mechanism to be driven in a direction to balance the bridge once again. Each balanced condition between the resistive bridges and R1201 or R1202 corresponds to a particular channel. Consequently, the pilot can select any one of the 126 channels by positioning the CHAN switches. A panel read-out indicates the channel to which the equipment is set.

4-163. MODE SELECTION. The various modes of operation : standby, receive, transmit-receive normal, and transmit-receive short range)are selected with use of the model selector switch S2003. Refer to paragraph 4-157 and 4-159 for the theory of operation.

4-164. EQUIPMENT DIFFERENCES.

4-165. RF MODULE, PART NO. 1064124G7. Differences exist in RF modules part No. 1064124G7 in the method of obtaining bias for transistors. RF modules with serial numbers 619 and lower (except 509} do not contain R1502, C1503, and CRI556. In these RF modules, transistor bias voltage is obtained from the high voltage power supply Z501 as shown in figure 4-38. All other RF modules obtain transistor bias voltage as shown in figure 4-6.

4-166, ELECTRICAL EQUIPMENT CABINET, PART NO. 2064347G1. Differences exist in Electrical Equipment Cabinet, part No. 2064347G1 (Main Chassis) in the connections of the relays K1006 and K1011. In the Main Chassis which have serial numbers 768 and 702 and lower (except 478), relays K1006 and K1011 are connected in parallel as shown in figure 4-39.

Note

Since the Receiver-Transmitter nameplate is affixed to the Main Chassis, the above Main Chassis can also be identified by the Receiver-Transmitter serial numbers. The serial numbers of the Receiver-Transmitters corresponding to

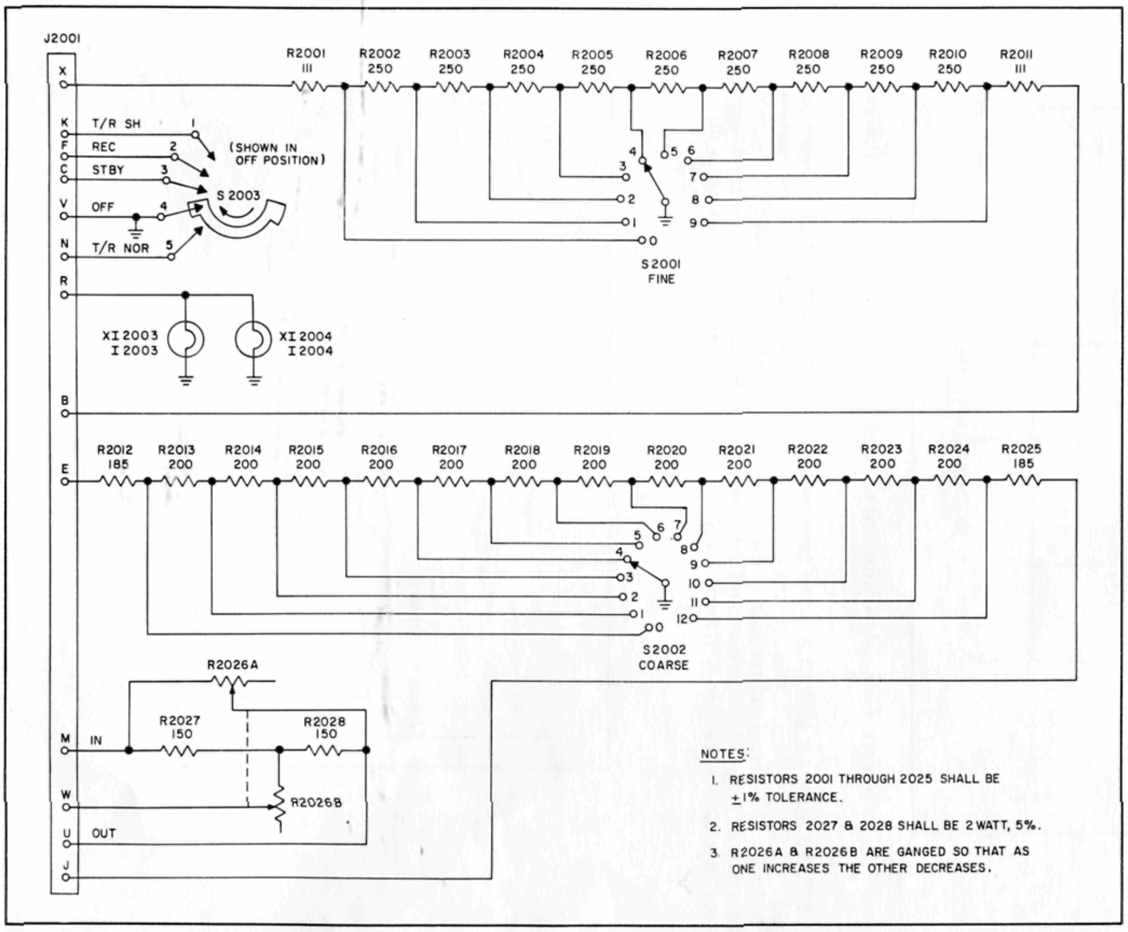

Figure 4-37. Control Box, Schematic Diagram

the above Main Chassis serial numbers are 429 and lower (except 373).

4-167. POWER SUPPLY MODULE. The 2064493G2 and 2062290G2 Power Supply Modules are electrically identical. Electrical differences in the 1076165G1 Power Supply Module are covered in the Difference Data Sheets (Section VU) for Part No. 1052207G5. Differences exist in all three power supply modules in the parts used and location of parts in the module. Refer to the Illustrated Parts Breakdown, Technical Manual, T. O. 12R5-4-47-4 for specific detail

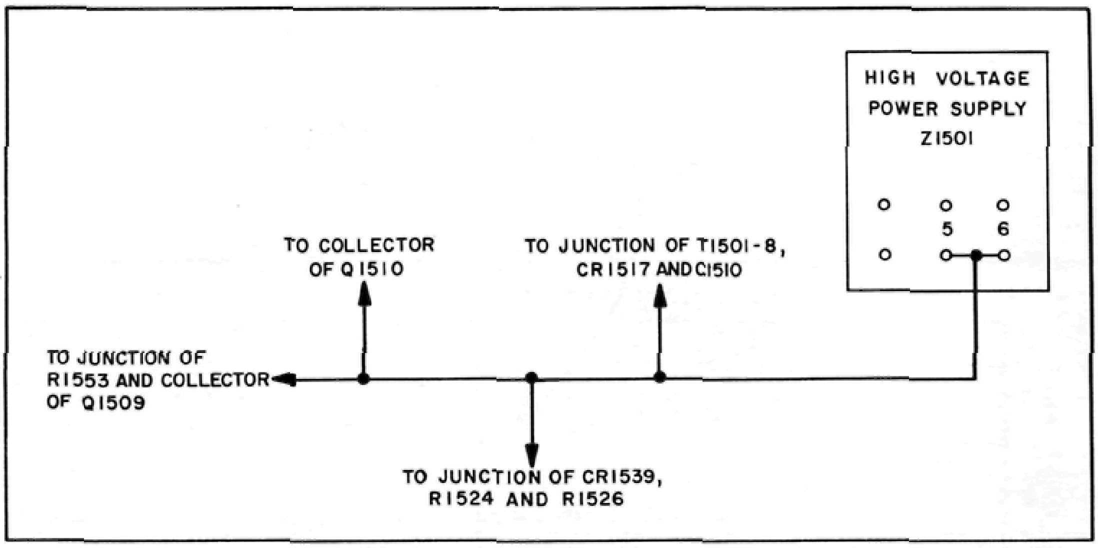

Figure 4-38. Modulator and Channel Servo Partial Schematic Diagram

parts differences.

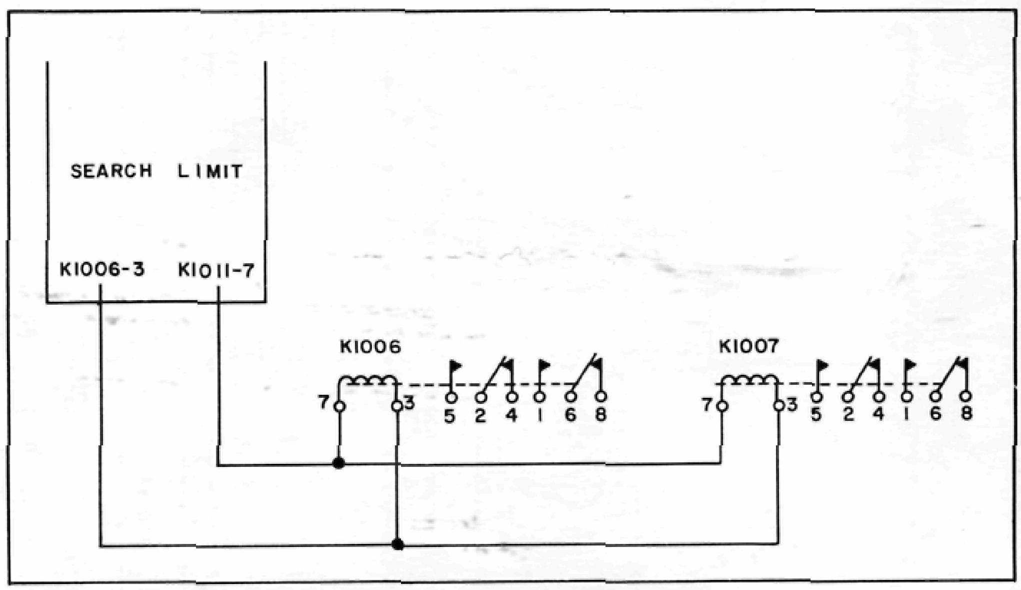

Figure 4-39. Main Chassis Partial Schematic Diagram