NAVSHIPS 900,719

THEORY OF OPERATION

SECTION 2

MAR

RADIO TRANSMITTING AND
RECEIVING EQUIPMENT

RESTRICTED

THEORY OF OPERATION

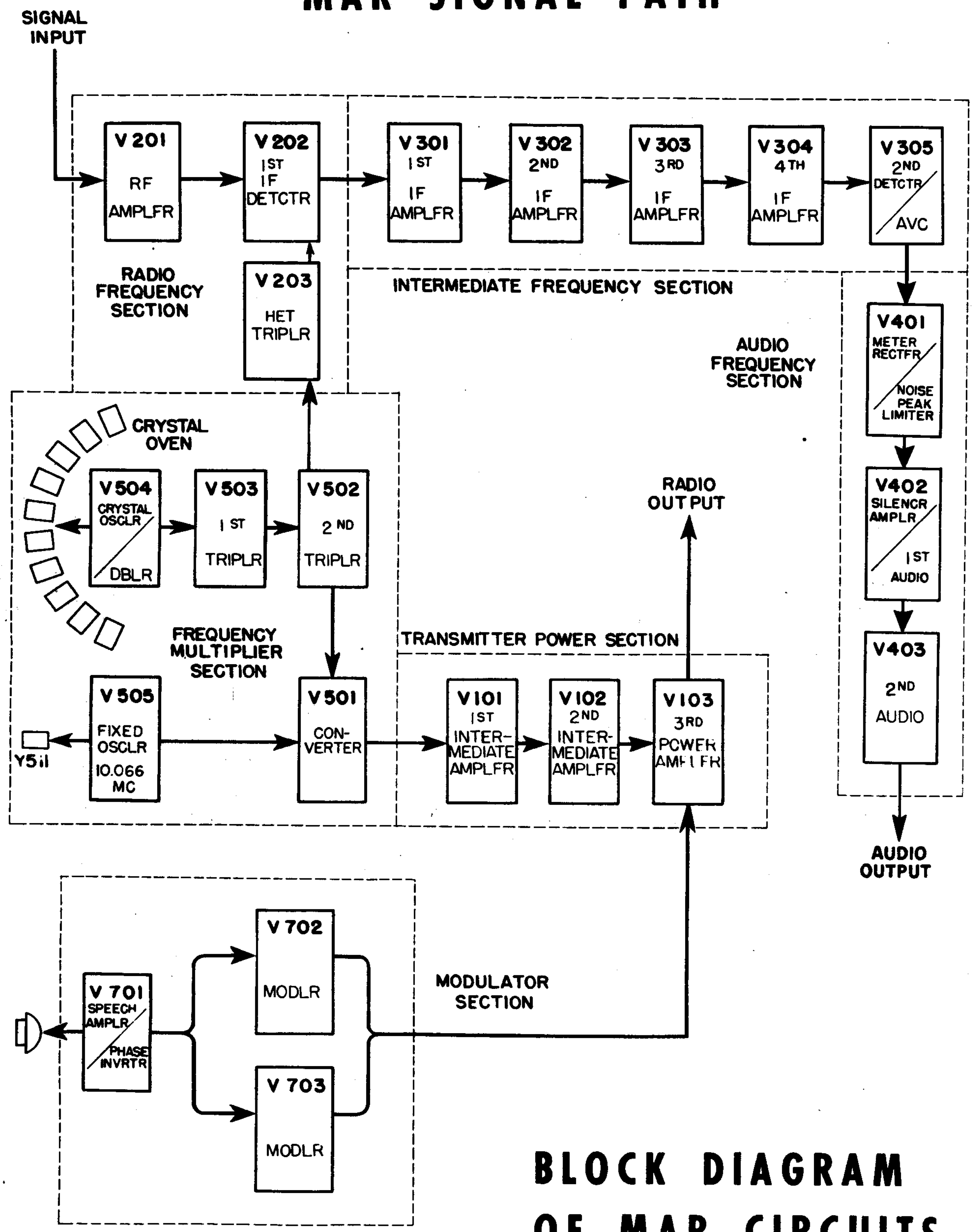
The transmitter and receiver of the MAR equipment are both crystal controlled; the transmitter to prevent frequency drift in the carrier wave and the receiver to provide the correct heterodyning frequency for each signal frequency. Since the equipment operates on preset frequencies and is automatically tuned, it is evident that stability of both channel frequency and heterodyning frequency is of paramount importance. A slight shift in either frequency causes communication to be interfered with or lost entirely.

Normally it would be necessary to employ a pair of crystals for each frequency to which the equipment can be tuned. By taking advantage of the fact that in any superheterodyne receiver the difference in frequency between the channel and heterodyning frequency is a fixed number, it is possible to incorporate a crystal-saving circuit in the MAR that covers ten frequencies with but eleven crystals.

In addition; automatic tuning, remote control, and the very high frequencies employed have also presented problems of mechanical design and electrical functioning that must be considered for a thorough understanding of the operation of the equipment.

The block diagram on the following page is intended to give an overall view of the functions and grouping of the various tubes in the equipment. The individual functions of the various sections and tubes are fairly obvious, but the circuits employed are worthy of thorough consideration. In conjunction with the partial schematic diagrams shown with text, frequent reference should be made to the unit schematic diagrams given at the end of this section.

MAR SIGNAL PATH



BLOCK DIAGRAM OF MAR CIRCUITS

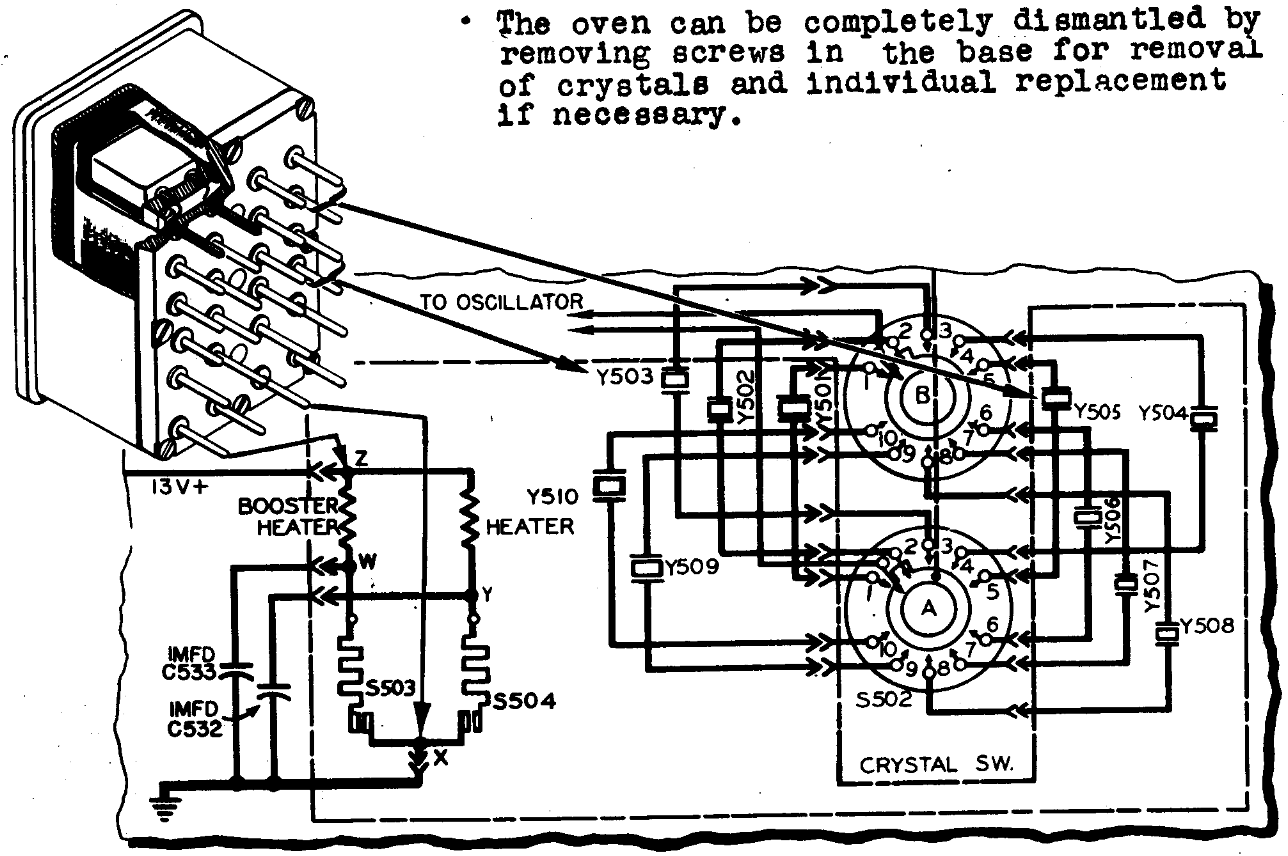
FREQUENCY DETERMINATION

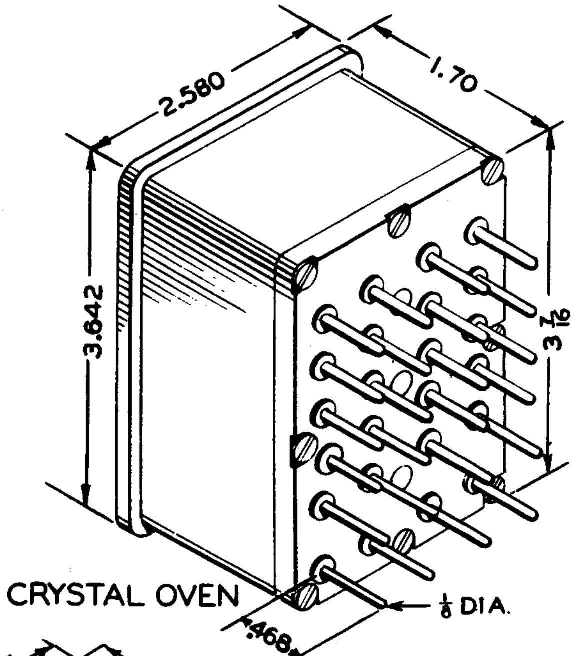
The illustration below shows the details of the switching circuit employed to bring the proper crystal into the oscillator circuit for any given setting of the channel selector switch. A cutaway view of the crystal oven shows the connection of the crystal holders to the pins protruding from the base of the crystal oven.

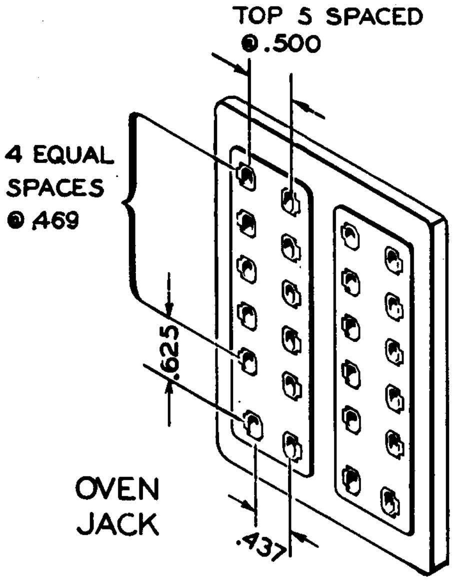
Ten pairs of the pins are used to make connection to the ten crystals in the oven. The other four pins serve as terminals for the two heating elements attached to the metal enclosure surrounding the crystal group. The temperature of the oven is controlled by two thermostats in the oven. The space between the metal case over the crystals and the outer case of the oven forms a dead air space to prevent rapid loss of heat from the oven.

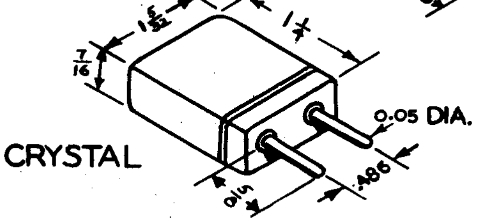
The twin-wafer switches S502A and B are mounted behind the jack plate in the transmitter-receiver panel into which the oven is plugged. These switches are driven by the tuning mechanism. The switch blades are rotated by the mechanism when a channel frequency change is being made. Thus, when a tuning cycle is completed, the switches will have brought into the circuit the correct crystal for the selected channel frequency.

- The oven can be completely dismantled by removing screws in the base for removal of crystals and individual replacement if necessary.



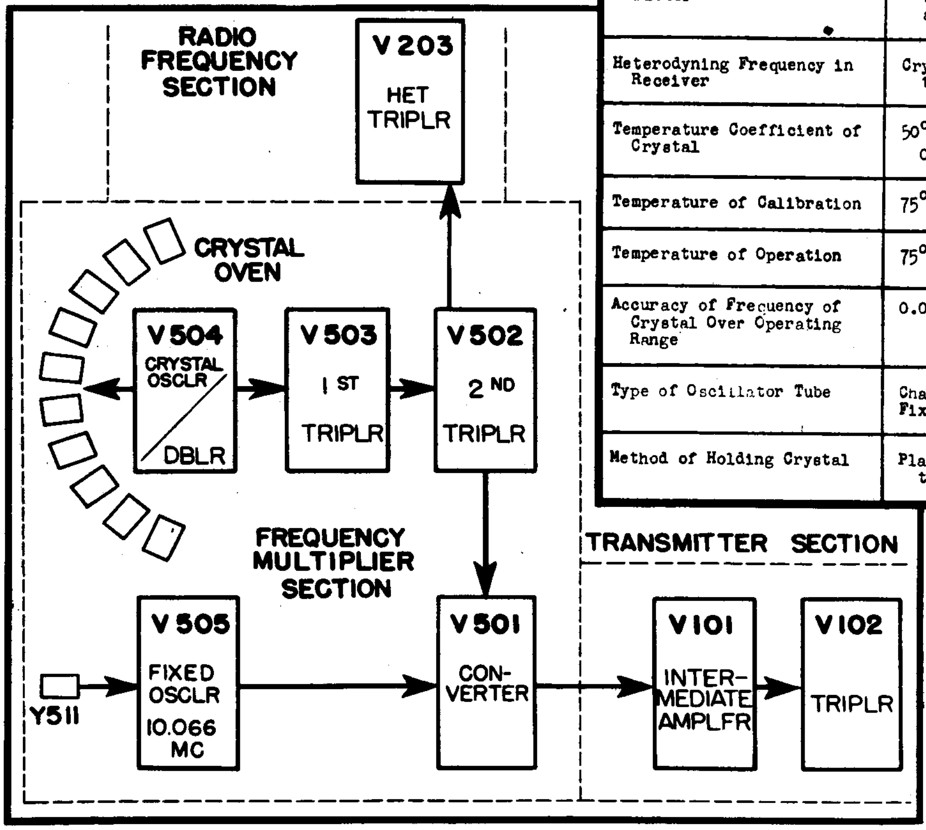






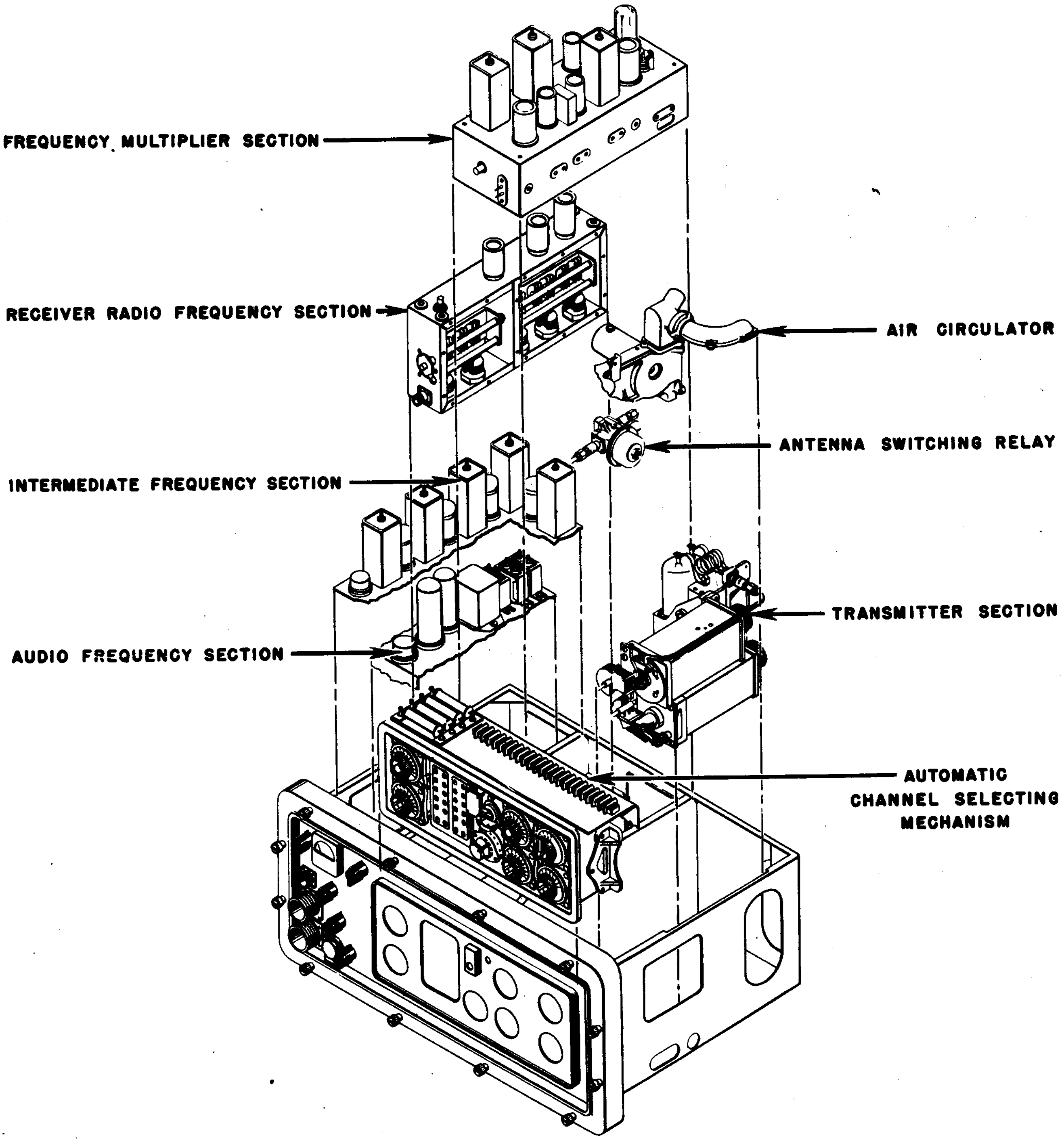
CRYSTAL CHARACTERISTICS

Frequency Range of Crystal Circuit	Channel Frequency Crystals 4814.815 kc to 7777.778 kc Fundamental. Fixed Oscillator 10066.7 kc- 3rd Harmonic.
Output Frequency of Transmitter	Crystal frequency doubled, tripled twice, heterodyned and tripled.
Heterodyning Frequency in Receiver	Crystal frequency doubled then tripled three times.
Temperature Coefficient of Crystal	50°C(122°F) to 90°C(194°F) 0.007%
Temperature of Calibration	75°C(167°F)
Temperature of Operation	75°C(167°F) ±3%
Accuracy of Frequency of Crystal Over Operating Range	0.004%
Type of Oscillator Tube	Channel Frequency 6AG7 Fixed Oscillator 6C4
Method of Holding Crystal	Plated crystals, cemented to coil springs and sealed

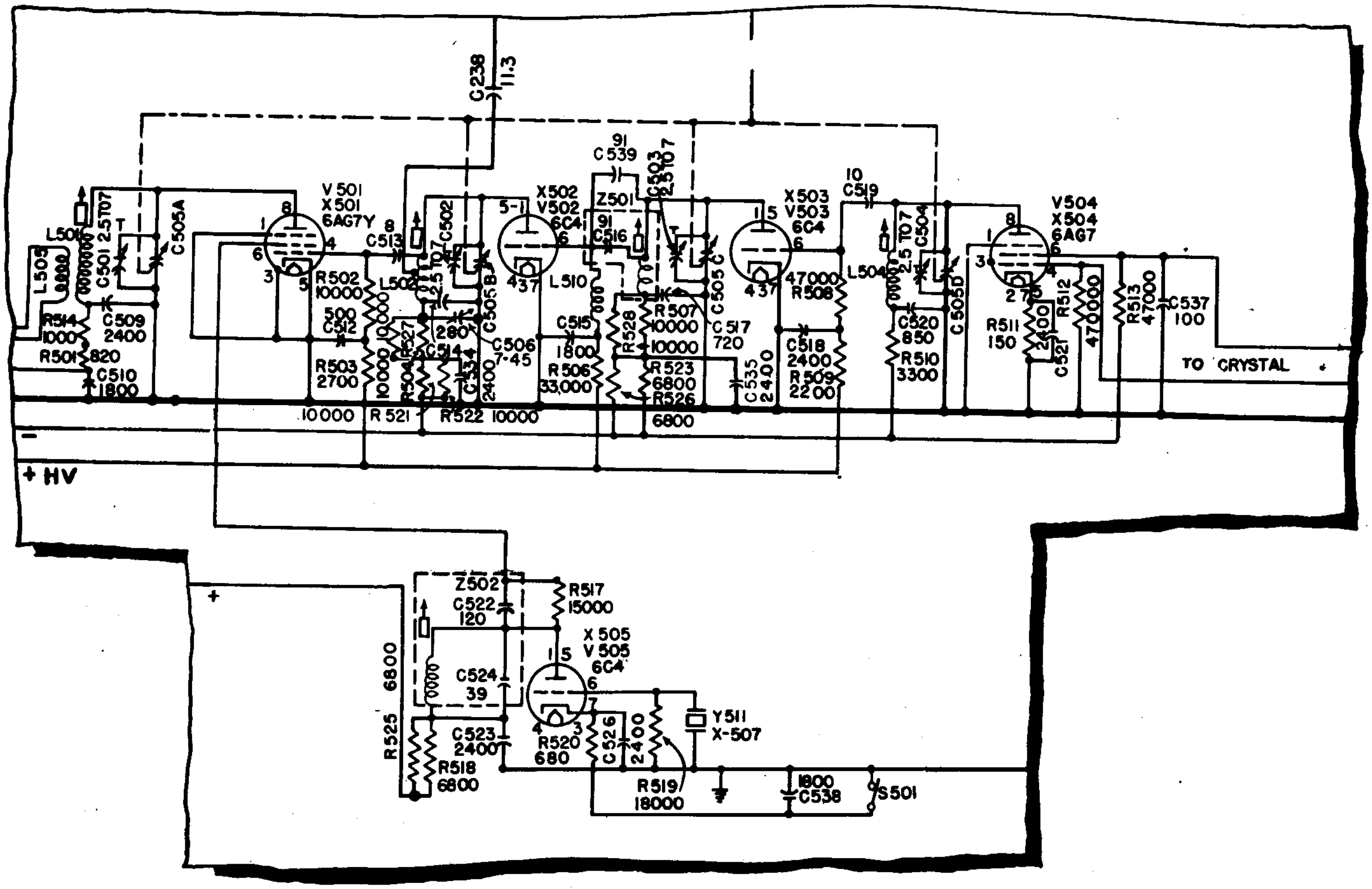


The block diagram illustrates the manner in which the frequency developed by each crystal in the oven is heterodyned by a fixed crystal oscillator to provide two frequencies, differing after tripling by 30.2 megacycles, for transmitter channel and receiver heterodyning frequency respectively.

FUNCTIONAL ANALYSIS OF TRANSMITTER - RECEIVER



The Transmitter-Receiver chassis is shown sectioned in the cascade view above. The operation of each section will be discussed in detail.



FREQUENCY MULTIPLIER SECTION

The function of the frequency multiplier is to develop the necessary channel and heterodyning frequencies from the fundamental frequency of the crystals employed with the equipment. This method of developing extremely high frequencies is necessary because it is impossible to manufacture crystals with fundamental frequencies even approaching the 225 to 390 megacycle range employed in the MAR equipment.

Referring to the illustration, the crystal selected by the switching mechanism is connected to the grid and screen of the oscillator section of V504 to form a Pierce oscillator.

The frequency generated in the oscillator section is the fundamental frequency of the crystal and through electronic coupling this frequency is impressed on the plate circuit of the same tube. The plate circuit is tuned to twice the frequency of the fundamental by L504 and C505D with the result that the frequency is doubled in the plate circuit.

The output of V504 is coupled by means of the capacitor C519 to the grid of tube V503. This tube has its plate resonated by Z501 and C505C to three times the input frequency, hence, a tripling action takes place to give an output frequency three times that of the input.

In turn, the output of V503 is coupled to the second tripler V502 through capacitor C516 and C539 where the tripling action is repeated by the plate circuit of V502 being properly tuned by L502 and C505B. The plate and grid circuits of both triplers are filtered by resistors and capacitor combinations as shown to prevent intercoupling or feedback and self-oscillation. To assure the proper operation of these frequency tripling tubes under conditions of varying voltages, a ballast resistor is connected in the heater circuits of V502 and V503 to maintain a practically constant current in the heaters. At this point in the frequency multiplication it will be noted a tap is taken on L502 in the plate circuit of V502. A portion of the output of the second tripler V502 is diverted and coupled through capacitor C238 to a tripler tube in the R F section, to provide the heterodyning frequency for the receiver. The balance of the output from the second tripler V502 in the multiplier section is fed to the grid of the converter tube V501.

A separate fixed oscillator will be noted at V505 which operates at a frequency of 10.066 megacycles, the fundamental frequency of the crystal Y511 in the grid circuit. The output from the plate circuit of the fixed oscillator is coupled into the screen grid of the converter tube V501 through the resistor-capacitor combination R517 - C522.

From the above it is evident that two frequencies are being fed into the converter tube V501, one from the second tripler V502 and the other from the fixed oscillator V505. The plate circuit of V501 will thus contain side-band frequencies equal to the sum and the difference of the two frequencies. Of these, the lower or difference frequency is selected by the plate tuning elements L501 and C505A of V501.

By this procedure there is obtained a frequency for the transmitter that is 10.066 megacycles lower than the heterodyning frequency supplied to the receiver. Regardless of the frequency originally developed in the first oscillator the two resultant frequencies will always differ by 10.066 megacycles at the multiplier output. By tripling in both receiver and transmitter this difference is raised to 30.2 megacycles, which is the frequency to which the intermediate frequency amplifier in the receiver is tuned.

The output of the converter tube V501 is coupled to the input of the transmitter amplifier by an untuned link circuit, comprising L505 inductively coupled to L501 and leads to L101.

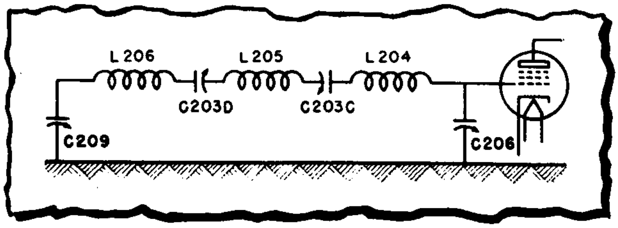
There will be noted a frequency test switch S501 in series with the cathode bias lead of oscillator tube V505 which on being opened renders the 10.066 megacycle oscillator inoperative. The switch takes the form of a pushbutton mounted on the selector panel to the right of the panel light and is used to check the frequency output of the converter tube. Under some conditions it is possible to tune the input circuit of the 1st IPA, V101, to the carrier frequency instead of to the side-band frequency from the converter tube, resulting in a reduced output from the 1st IPA tube at an improper frequency. When the 1st IPA stage is thus improperly tuned, cutting off the fixed oscillator by means of the switch allows the 1st IPA tube to continue operating. When tuned correctly, the 1st IPA stage becomes inoperative when the switch is opened, because there is no heterodyne output from the converter tube.

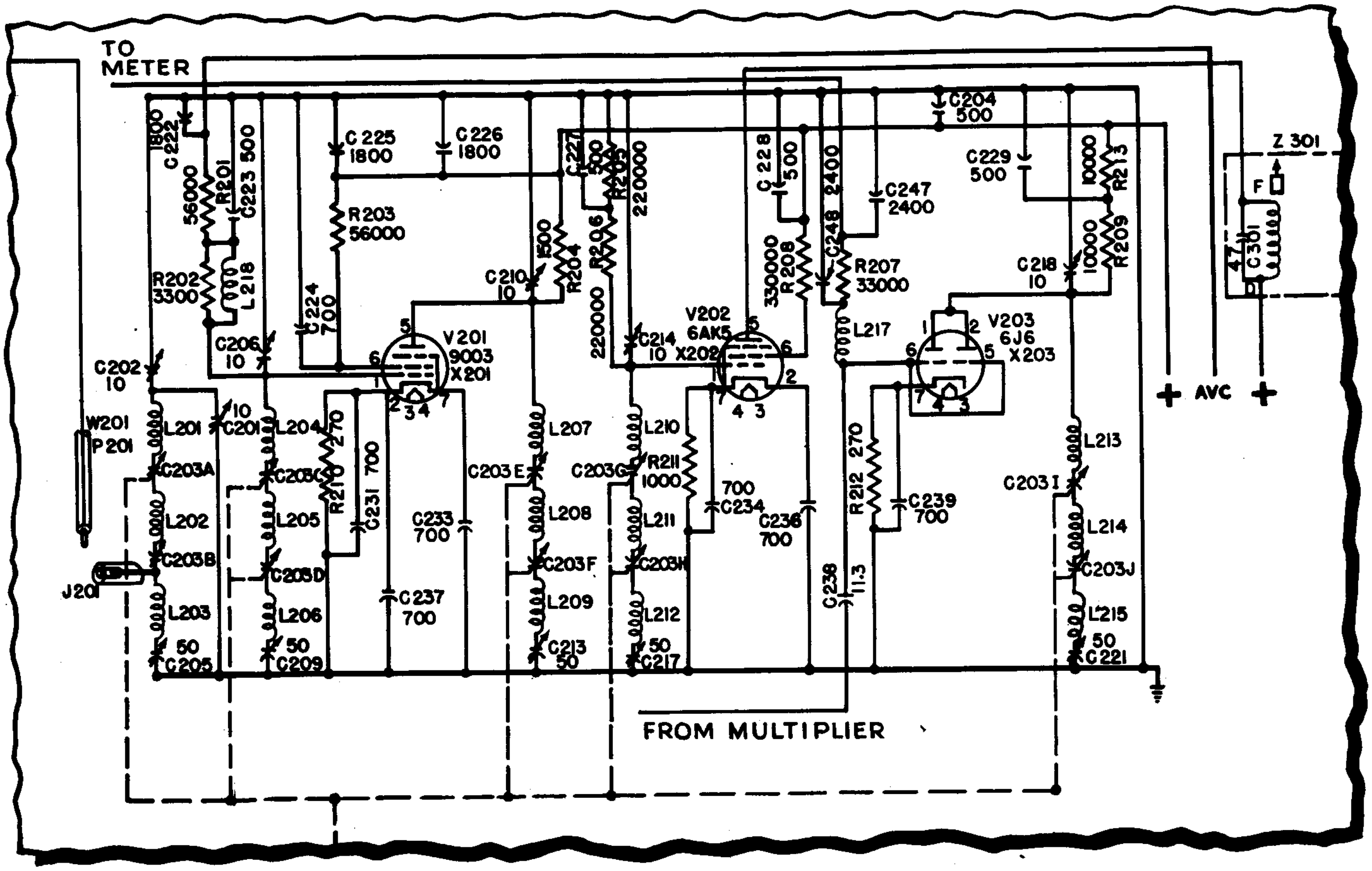
The four tuned circuits in the frequency multiplier are simultaneously tuned by the multiplier selector dial on the panel. The circuits are aligned, to assure proper tracking at all frequencies, by adjustable cores in the shielded tuning inductances, and padding capacitors.

RECEIVER RADIO FREQUENCY SECTION

The radio frequency tuning section of the receiver employs five resonant circuits, simultaneously tuned by the R F dial on the selector panel. Four of the circuits are utilized to tune the channel frequency being received, the fifth resonating the output of the heterodyning frequency tripler tube included in this unit.

As shown in the illustration of a portion of the schematic and a simplified schematic, the tuned circuits consist of three inductances in series, with variable capacitors between the sections. Two tuned circuits precede the R F amplifier tube, V201. The input from the antenna is tapped into inductance L203 to provide sufficient input into the first tuned circuit without excessive loading that might affect the tracking of this circuit when tuned to different frequencies. To neutralize any such effects, a compensating capacitor is connected as shown at C201 and is individually controlled by a knob on the panel through a system of geared shafts.





The tuned antenna circuit is coupled to the tuned grid circuit of the RF tube V201. Coupling between these circuits is fixed and is such that the required selectivity and gain are maintained throughout the operating range of the equipment.

The tuning circuits employed for all the tubes in this section are rather interesting and may be best explained by a consideration of the simplified schematic. The frequencies employed in the receiver are in the very high-frequency range and the use of lumped capacities and inductances is impractical, for the leads would represent an appreciable inductance value.

Refer to the simplified schematic on page 2-8 as representative of the input circuit to the RF tube. The three inductances L204, L205 and L206 are of such a value that when the capacitors C203C and C203D are at minimum setting, a resonant half-wave line is formed, with respect to the ground, for the frequencies at the high end of the tuning band. The inductances L204 and L206 have electrical lengths of less than one-half and one-quarter wavelength respectively, in order to avoid resonance in the tuning band.

As the capacitors C203C and C203D are increased in value, the additional inductance L205 is gradually introduced into the line. This has the effect of electrically lengthening the line and making it resonant to lower frequencies. Alignment is obtained by adjustment of a trimming capacitor, C206 in the circuit shown, which is connected to L204 at the point of current maximum for the high frequency end of the band. An additional trimmer, C209 for the circuit under discussion is provided for service alignment at the point between the middle and the high end of the band.

Returning to the consideration of the operation of the receiver R F section as a whole, it will be noted that the output or plate circuit of the R F amplifier is tuned and also coupled inductively to the input circuit of the 1st detector V202.

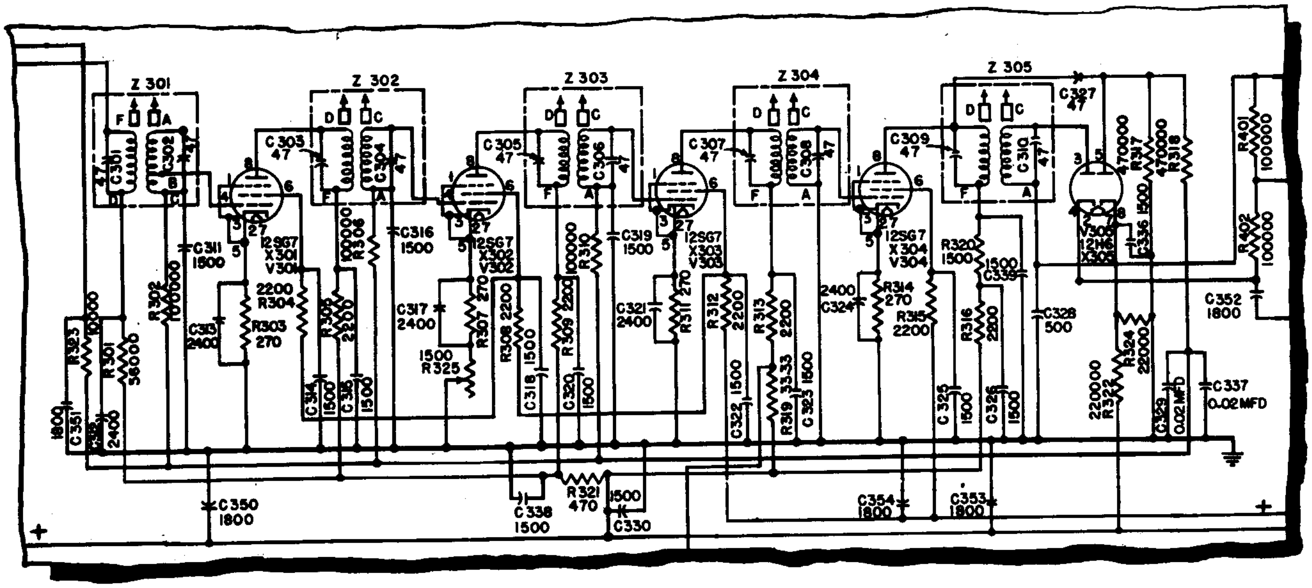
A portion of the output of the second tripler in the frequency multiplier section is fed to V203 in the R F section. An inductance, L217, connected to the grids of the V203 tube and the coupling capacitor C238, form a filter that assures uniform coupling to the tripler at all frequencies.

The plate circuit of this heterodyning tripler tube is resonated in the same manner as that employed with the R F tuning V301, V302, V303 and V304. The transformers are partially resonated by fixed capacitors which are connected in parallel with the primary and secondary windings. Final alignment is obtained by adjusting the movable cores.

RECEIVER INTERMEDIATE FREQUENCY SECTION

The intermediate frequency amplifier consists of four stages of amplification employing fixed-tuned transformers Z301, Z302, Z303, and Z304 as coupling between the associated tubes V301, V302, V303 and V304. The transformers are wound with their coupling a little greater than critical to broaden the top of the resonance curve and partially-tuned by fixed alignment through adjustable cores.

The plate output of the 1st detector V202 is connected directly to the primary of the first intermediate transformer Z301, the secondary being tapped for the input to the first intermediate amplifier tube to obtain better overall stability of the amplifier. The three following stages are identical, particular care having been taken to stabilize the circuits by the use of resistance-capacity filters in the current supply circuits and the use of chokes in the filament circuits. The screen grid potentials of the first three tubes are dropped through resistors in series, with bypass capacitors at points of connection. This method of filtering avoids overall feedback. A variable resistor R325 in the cathode return of the second tube permits the adjustment of the AVC threshold value to obtain a practically-flat audio output level at all signal input levels above 75% of maximum capability of the amplifier.



The last tube V305, in the section is a double diode, one section is utilized as the 2nd detector, the other section functioning to provide automatic volume control. The detector section is connected to the secondary of the last intermediate frequency transformer Z305, the rectified audio frequency potentials appearing across the plate-load resistors R401 and R402. The audio frequency potentials across R401 are then fed to the noise-peak limiting tube V401 in the audio frequency amplifier section and thence to the audio amplifiers.

The right-hand section of V305 is the automatic volume control rectifier that furnishes bias voltage to the grids of the tubes to control the gain of the intermediate and radio frequency amplifier stages. Signal input to the AVC section is through capacitor C327 from the plate circuit of the last intermediate frequency amplifier tube.

A delay in the action of the AVC circuit is obtained by biasing the cathode of the AVC section of V305 positive by the voltage drop across resistor R324, which is connected in series with the AVC rectifier tube load resistor R317. The positive bias is sufficiently great to prevent conduction through the rectifier at signal intensities up to approximately 75 percent of the maximum power capabilities of the amplifier. Beyond this point the signal input to the AVC section of V305 becomes great enough to override the positive bias and the tube conducts current. This current flow results in a potential appearing across the load resistor R317. The negative end of the load resistor R317 is connected through R318 to increase the bias voltage applied to the grids of the R F amplifier tube V201 and the first three stages, V301, V302, V303, of the intermediate frequency amplifier to reduce their gain.

The circuit values are so proportioned that further increases in signal intensity result in the delivery of increasingly-greater biasing voltages to the tube grids so that the gain falls off more rapidly. This results in a relatively constant audio output level for wide variation of input above 75% of full capacity of the amplifier. The rapidity of response of the AVC is determined by the time constant of the R-C network formed by resistors and capacitors R317, R318, C329, and C337. The time constant is made as small as possible without introducing distortion at low modulation frequencies.

RECEIVER AUDIO FREQUENCY SECTION

In addition to providing the two desired stages of audio frequency amplification, this section includes a noise peak limiter, meter rectifier, and silencer circuit. All these functions are performed by three tubes.

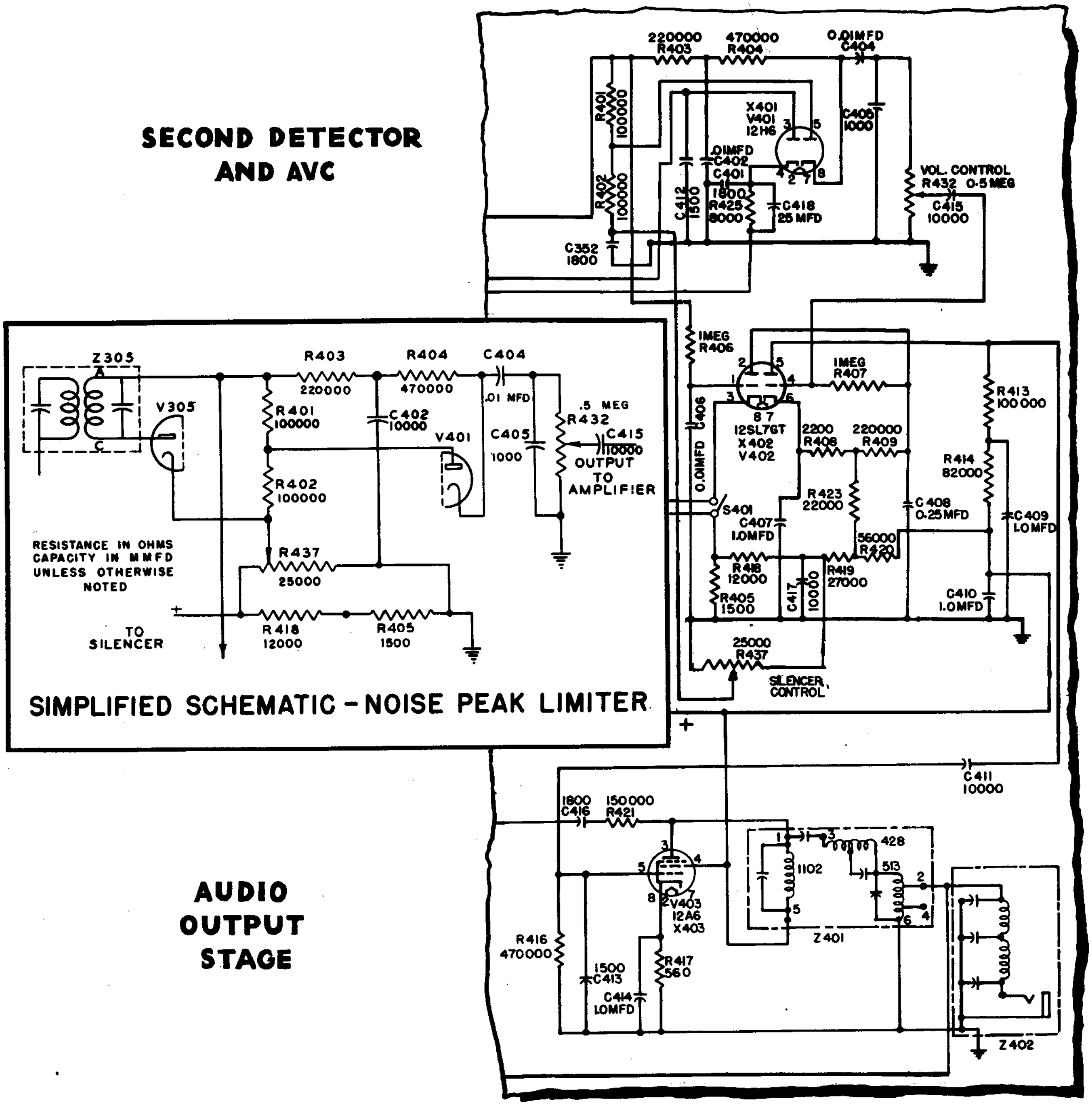
Considering first the V401 tube, a double diode, the left-hand section is the meter rectifier, used in connection with the meter on the panel to take voltage readings on a-c filament current when the Universal Power Supply is being used as power for the equipment. The resistor R425 is the series resistor for the meter movement to give correct scale readings on alternating current.

NOISE PEAK LIMITER—

The other diode in V401 is used as a noise peak limiter and its functioning may be better understood from the simplified schematic given herewith. The 2nd detector V305 and its load resistors R401 and R402 are shown to aid the explanation.

The audio output of the 2nd detector is developed across the load resistors R401 and R402, as previously mentioned. The plate of the limiter section is biased positive by a potential, developed across R401 when a signal is applied to the second detector, V305, and is thus made conducting. Under this condition the negative audio potentials at the midtap can pass through the conducting diode and by reason of capacitor C404 appear as audio-frequency voltage changes across the volume control R432.

This condition exists as long as normal signal levels prevail but a high level noise impulse will result in a high negative potential appearing at the midtap of the detector load resistors R401 and R402, thus rendering the plate of the diode negative with respect to its cathode and the tube non-conducting. The cathode is held at its normal potential by virtue



SECOND DETECTOR AND AVC

SIMPLIFIED SCHEMATIC - NOISE PEAK LIMITER

AUDIO OUTPUT STAGE

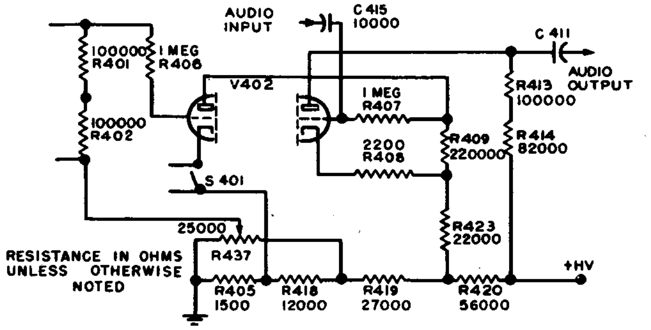
of the time constant of the R-C network R403 and C402. This cuts off all signal impulses to the output with the result the noise peak is barred from the amplifiers. On cessation of the noise impulse, the circuits return to their previous condition and the normal signals may pass through the tube to the audio amplifiers.

Output to the audio amplifiers is controlled by the setting of the output level control R432 which in turn determines the output of the receiver. A capacitor C405 connected across the output level control potentiometer R432 is intended to by-pass the higher frequency audio currents to reduce hiss in the output.

SILENCER—

The second tube, V402, in the audio amplifier section is a double triode and functions both as silencer amplifier and 1st audio amplifier. The signal output of the noise-peak limiter V401 is coupled to the grid of the right-hand section of V402 by means of capacitor C415 as shown in the simplified schematic, which also includes the detector plate load resistors R401 and R402 for ease of explanation.

Plate current to the audio amplifier section of V402 flows through R413 and R414 which act as the plate load for the tube. Variations of plate current appears as voltage changes across these resistors. These potentials are coupled through C411 to the output stage.



SILENCER SIMPLIFIED SCHEMATIC

Normal grid bias for the audio amplifier is obtained from R408, connecting through R423 to the voltage-dropping resistors shown. However, R409 is included in the grid circuit of the audio amplifier and in the plate circuit of the left hand or silencer amplifying section of the tube.

The silencer amplifier grid is connected across the output of the second detector V401 as shown. The grid of the silencer amplifier, V402, is biased positive by the variable resistor R437, which permits current to flow in the plate circuit of V402. This results in a voltage appearing across R409 that biases the audio amplifier grid beyond the cutoff point and renders the tube inoperative. Thus, no sound is heard in the output of the receiver.

When a signal of sufficient intensity reaches the output of the detector that the audio output potential across R401 and R402 are sufficient to override the positive bias on the grid of the silencer amplifier, the grid will become negative, cutting off the plate current. With the reduction of plate current, the biasing voltage across R409 will decrease and allow the audio amplifier to function normally and pass the signals. When the signals cease, the silencer amplifier grid will again become positive, allow the plate current to flow and bias the audio amplifier to the cutoff point, rendering the receiver silent between signals.

The Silencer control setting on the panel determines the point at which signals can pass through. The control should not be set higher than will permit the weakest signal to be received to override the positive bias on the amplifier and be heard. A switch, S401, is provided on the panel to render the silencer circuit inactive; no plate current can flow in the silencer amplifier section when this switch is opened.

AUDIO OUTPUT—

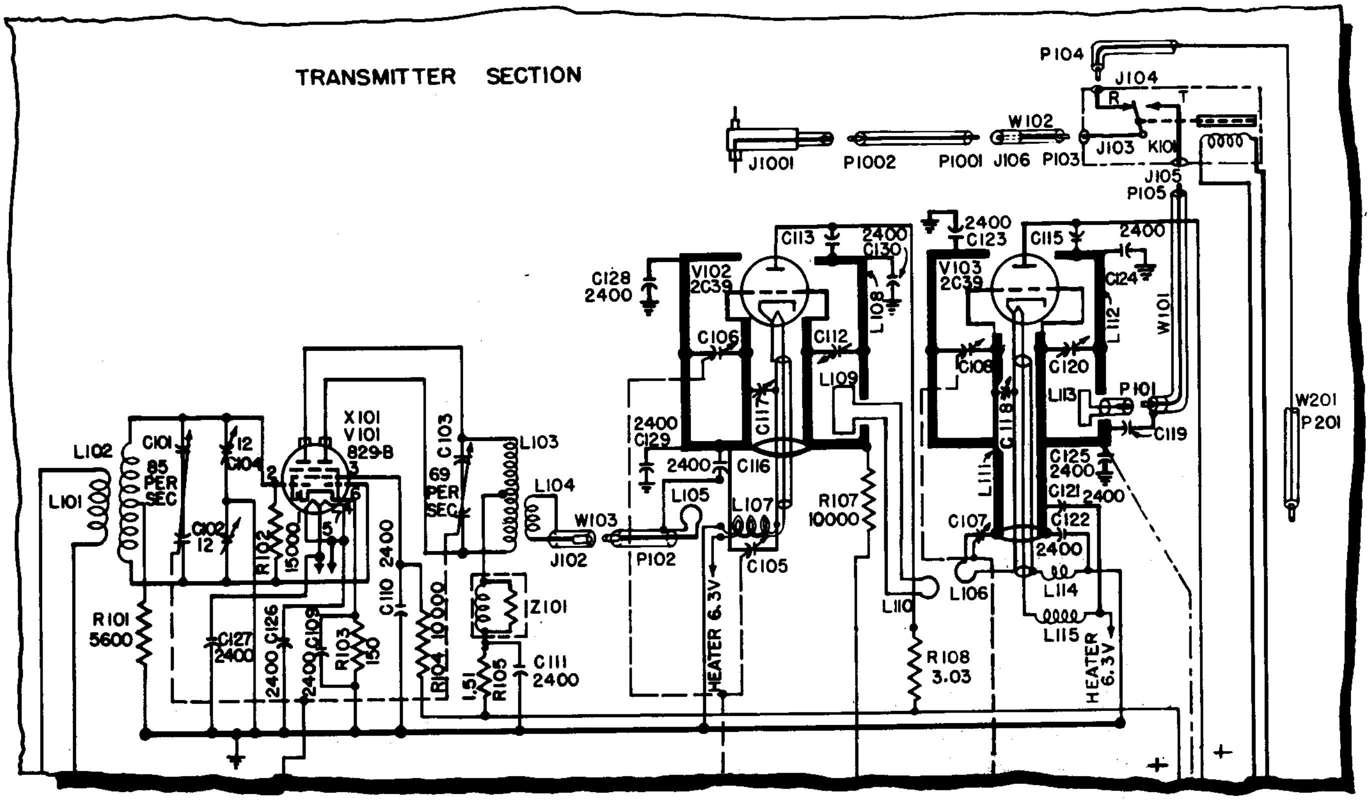
The signal output of the first audio amplifier stage in V402 is coupled by capacitor C411 into the grid circuit of the audio output stage V403. A capacitor C413 is connected across the input to this tube to by-pass the higher frequency components of the audio currents.

A filter and coupling network Z401 is connected into the plate circuit of the output tube V403. From the impedance in the plate of the tube, the audio output is coupled to the audio frequency band-pass filter in the network in Z401. This network passes frequencies between 300 and 3000 cycles to a R F filter Z402 and thence to the local headset jack associated with the filter. The R F filter is used to prevent radio frequency currents picked up by the headset cord from entering the equipment at this point and setting up disturbances in the receiver circuits.

The output of the audio filter in the last audio stage is also connected, through the cable between Transmitter-Receiver and Modulator-Dynamotor units, to the headset jack on the panel of the latter unit.

TRANSMITTER SECTION

On page 2-16 is shown a schematic diagram of this section. The output of the converter tube in the Frequency Multiplier section is coupled by means of the inductance L101, to the input of the 1st Intermediate Power Amplifier V101. The frequency, as explained on page 2-7, is 10.066 megacycles below the frequency fed to the RF section.



1ST INTERMEDIATE POWER AMPLIFIER—

The 1st IPA tube, V101, is connected in a conventional push-pull circuit, with low bias and high power gain, the frequency remaining the same in the output as in the input. Both input and output circuits of the tube are tuned by variable capacitors C101 and C103 respectively, controlled by the 1st IPA selector dial on the tuning panel, with associated center-tapped inductances L102 and L103.

The output of the 1st IPA tube, V101, is coupled to the input of the frequency tripling 2nd intermediate power stage V102 by means of two loops, L104, L105, and a coaxial line with the outside conductor grounded. Since the frequency is tripled in this tube, special arrangements must be made to obtain circuit resonance at the very-high frequencies now involved.

2ND INTERMEDIATE POWER AMPLIFIER—

The tube itself, a 2C39, known as a "lighthouse" tube, is fitted into a metal case with a hollow center conductor, which forms the resonant grid-plate circuit L108 as indicated by the heavy lines in the illustration. The grid of the tube is at ground potential and forms a shield across the end of the inner hollow conductor and shields the cathode from effect of the plate of the tube.

The input circuit to the tube consists of the inductance L107 and capacitor C105. The inductance L107 is a coiled concentric lead, the outer conductor connecting to cathode and one terminal of the heater, the center lead acting as heater return. The tuning capacitor C105 is, in effect, connected across the inductance L107. The outer coaxial cathode lead and the inner tubular conductor of the case connecting to the grid, form a concentric input line to the grid and cathode with the cathode at the high radio frequency potential end of the input circuit. A trimmer capacitor C117 is arranged to compensate for any variation in grid-cathode capacity when tubes are changed.

The resonant grid-plate circuit, L108, formed by the metal case is a quarter-wave line, capacitively shortened down by the tuning capacitor C106. For radio frequency potentials, the plate is held at ground potential through capacitor C113, while the grid is connected to the free end of the inner conductor and is at high radio frequency potential with respect to the plate. A capacitor C112 is provided in this circuit to compensate for variations in grid-plate capacity of the tubes. Capacitors C106 and C105 are ganged together and adjusted by the 2nd IPA selector dial on the panel.

The tube in this circuit functions in the following manner. With the cathode biased five volts positive with respect to the grid, the plate current flow to the cathode is practically cut off. When current of the proper frequency is coupled into L107, the cathode swings positive and negative with respect to the grid. With the cathode positive (the grid negative) there is no current flow through the tube. When the cathode swings negative, the positive potential on the grid, of some 100 volts, is in series with the positive potential between plate and grid.

A pulse of both plate and grid current then surges into the resonant plate-grid circuit to set up oscillations. The plate-grid resonant cavity is tuned to a frequency three times that of the input circuit. The plate-grid circuit is kept in oscillation by receiving a pulse of current every third oscillation. By thus applying the grid excitation potentials in series with the plate voltage, high plate efficiency is obtained from the tube.

In resonant circuits of this type there are no R F potentials on the outside of the tank assembly, all current present flowing on the interior surfaces of the cavity and the resultant electromagnetic field existing only in the space between inner and outer conductors.

For the above reason the coupling between the tripler, which in this case acts as a driver, and the PA tube is by means of a single loop L109 located in the space between the conducting surfaces forming the resonant plate-grid circuit, a short open line and a second loop L110. The latter inductively couples to L106 in the input of the Power Amplifier V103.

POWER AMPLIFIER—

The plate-grid circuit of the Power Amplifier V103 is identical with that employed in the Tripler. A variable capacitor C120 is arranged to compensate for variations of plate-to-grid capacity met with in replacing tubes.

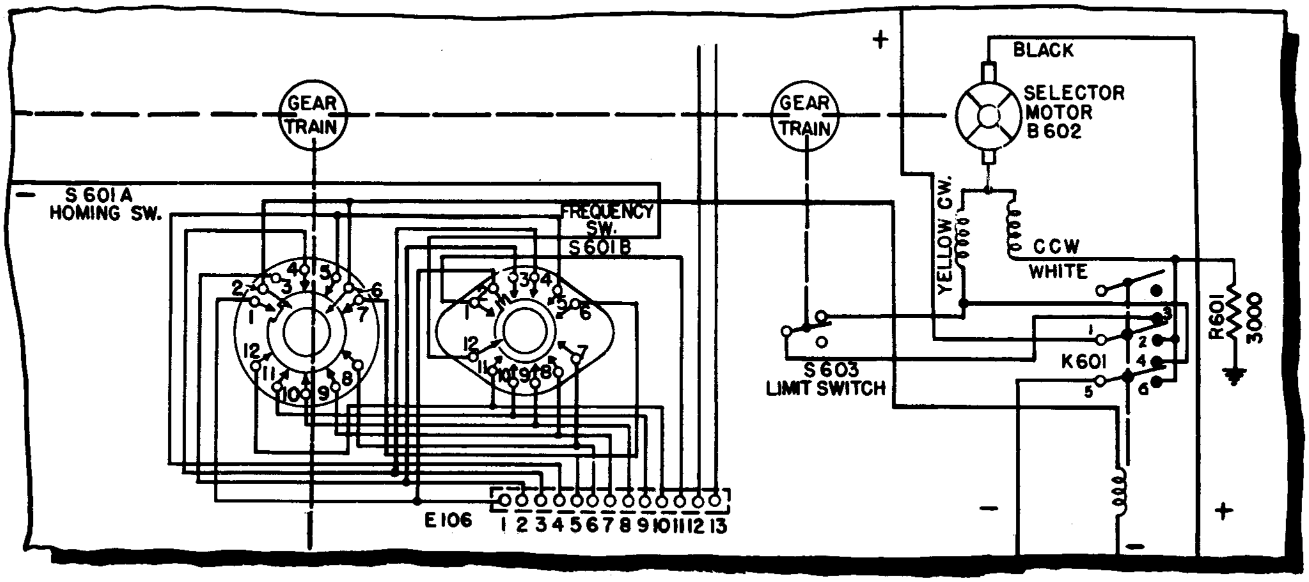
The input circuit differs considerably from that of the 2nd IPA or tripler. The input must operate at channel frequencies and is built in the form of a half-wave resonant line by utilizing the outer conductor of the cathode-heater leads and the extended inner conductor of the plate-grid assembly. A series L-C circuit formed by L106 and C107 is connected across the open end of the line for tuning. Both cathode-grid and plate-grid circuits are tuned simultaneously by the PA selector dial on the panel, capacitors C107 and C108 being ganged for this purpose. The heater of the tube is fed through chokes L114 and L115 to isolate the heater input from the R F potentials developed at the cathode.

The functioning of the tube is similar to that of the tripler. The tuning phenomenon in the input is of interest. With the series variable capacitor C107 at minimum the resonant input line is functioning as a half-wave line and resonates at the lower frequencies. As capacitor C107 increases in value the series circuit consisting of C107 and L106 approaches series resonance, and at maximum setting neutralize each other, the open resonant line is then effectively shorted down to a quarter-wave line loaded by tube and stray capacities. The input is then resonant to the high frequency end of the tuning band.

The action within the tube itself is similar in all respects to that in the tripler except there is no change in frequency. The grid remains at ground potential and when the cathode swings negative with respect to the grid, both grid and plate furnish current momentarily to the resonant plate-grid tank to maintain oscillations.

A single loop inductor L113 arranged within the plate-grid assembly serves to pick up the energy in the grid-plate space and feed it to the transmission line and antenna. This loop is mounted on a pivot and is adjusted by the Ant. selector dial so the degree of coupling to the resonant plate-grid circuit can be varied. This permits adjustment of the load on the tube output to obtain optimum output power without overloading the tube.

AUTOMATIC CHANNEL SELECTING MECHANISM



Built into the panel at the right of the Transmitter-Receiver is the mechanical system for automatically tuning the equipment to any frequency selected by the Frequency Selector switch. The four selectors grouped at the right of the panel are for transmitter tuning, the two at the left for the receiver and the multiplier section, common to both transmitter and receiver circuits. The center of the assembly mounts the jack plate for the Crystal Oven and the switches that control the functioning of this unit.

The twin-wafer Crystal Switch S502 (A and B) is mounted behind the jack panel and was described in detail in connection with the crystal oven. Note here that it is coupled to the same shaft that drives the Homing Switch S601A. The latter is a closed-circuit switch, in that the rotating member makes contact with all stationary contacts but one.

The Channel Selector Switch S601B is manually operated by a knob on the panel and has 11 stationary contacts, the moving arm contacting one at a time. Ten of the contacts are for frequency selection; the extra contact is to transfer control of the equipment to any remotely-mounted switch of a similar type, connected to a terminal board E106 mounted on the bottom of the assembly.

When a change of channel frequency is to be made, the selector switch S601B is moved to a point corresponding to the channel desired. This will close the circuit from the 20-volt negative lead, through relay coil of K601, the homing switch, and then to ground.

The relay closes and contacts 2 and 3 complete the circuit through one field and the armature of the motor to cause it to run in a counterclockwise direction. The motor-driven gear system picks up and drives the selector mechanisms through the pin on the spur gears on the selectors and the stops on the drums.

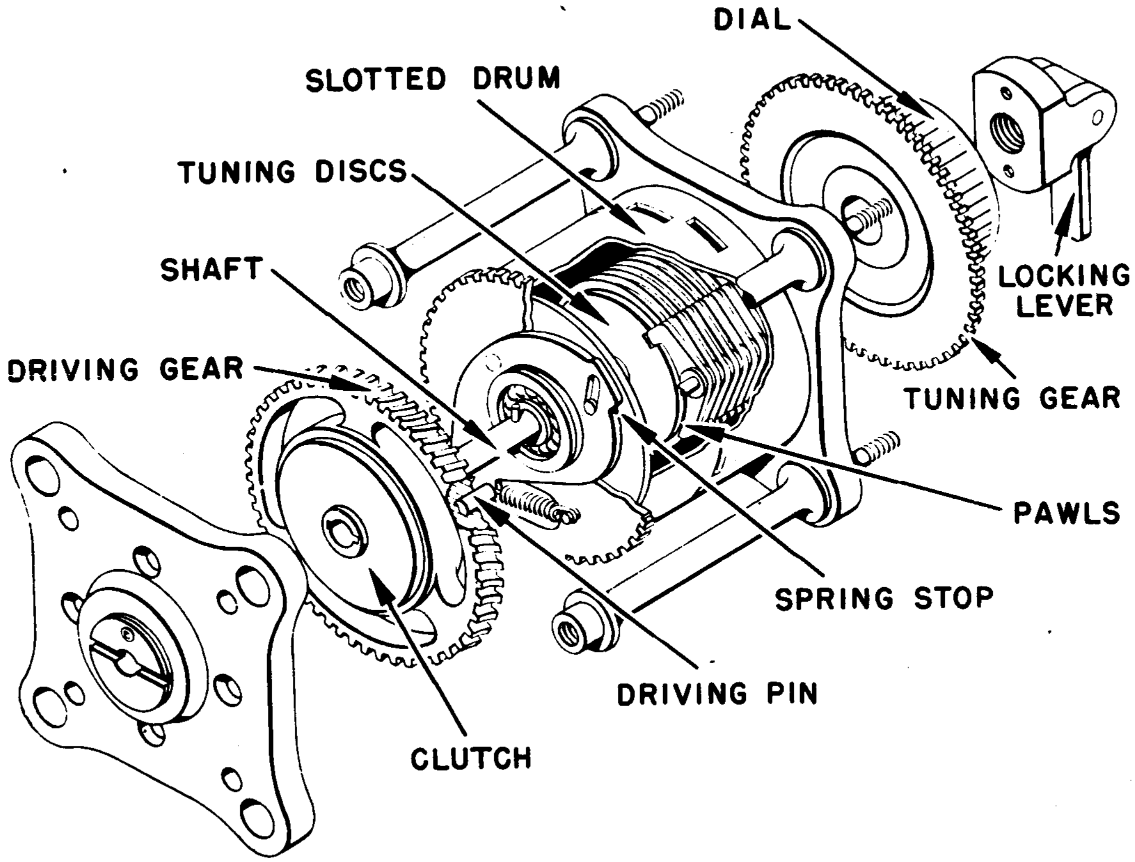
The limit switch S603 is allowed to close by rotation of the cam. The homing switch also rotates until it reaches the point where its rotor position corresponds to that of the selector switch. The circuit to the relay will be opened by the homing switch and the relay armature will drop back. This action has advanced the slotted drums of the selectors to the proper position for the frequency desired.

The relay armature, on release, closes contacts 2 and 1 and current flows through the limit switch to the other field of the motor. The motor reverses its direction and the selector drums remain properly positioned, but the shafts of the tunable elements rotate till they are locked in their proper position. At this point, a slipping clutch permits the motor to continue running until the cam opens the limit switch and stops the motor in its original position. This completes the tuning cycle, requiring 10 seconds or less to complete.

It will be noted that the relay K601 carries a second set of contacts, the moving contact 5 acting to connect the coil of a voltage-regulating relay K702, located in the modulator-dynamotor, across the motor terminals when the motor is operating by means of contacts 4 and 6. The contacts of relay K702 are connected across a resistor R804 in series with the motor lead. This combination acts as a voltage regulator on the motor, to compensate for any change in output voltage of the dynamotor. The relay contacts are normally closed but are held open when the motor is switched on and resistor R804 is in the circuit. Should the voltage across the motor terminals drop below 140 volts, the relay armature will drop back and short out the resistor to increase the voltage to the motor. Should the voltage exceed 190 volts, the relay armature is pulled up and the resistor R804 placed in the circuit. This arrangement keeps the motor voltage between 140 and 190 volts to assure proper functioning of the motor without danger of stalling from low voltage or burning out from overvoltage.

The resistor R601 performs an important function in this circuit. The voltage for the operation of relay K601 is obtained across the bias resistors R715 and R727 in the negative lead of the high voltage output of the dynamotor as shown in the modulator-dynamotor schematic diagram on page 2-37, 38. This voltage is dependent upon the load drawn by the receiver tube circuits. When the selector motor is in operation, any drop in voltage due to the motor load will be reflected in a drop in current drawn by the receiver. In turn this will reduce the voltage drop across the bias resistors R715 and R727, possibly to the point where relay K601 would fail to function for lack of voltage. To prevent this, the resistor R601 is in the circuit at such times as the motor is running, with the relay energized, and current is drawn through this resistor to ground, that must in turn flow through resistors R715 and R727 to the negative terminal of the dynamotor. The negative lead to the selector motor is connected to the center terminal of the two bias resistors to increase current through R727 when the motor is operating. In this manner the bias voltage is maintained at the proper value to operate the relay K601

FUNCTIONING OF TUNING SELECTORS

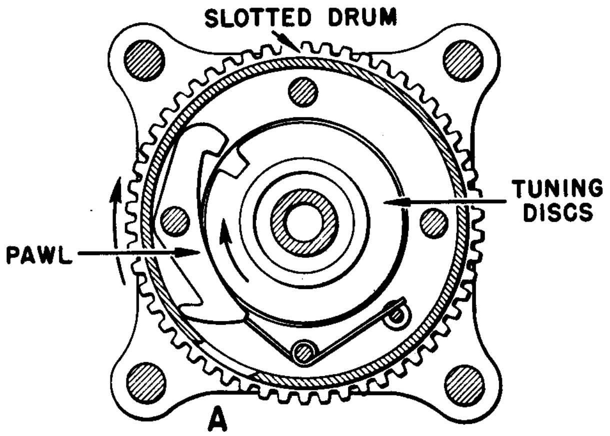


The tuning selectors are compact mechanical devices that consist essentially of an outer drum with ten slots, equally-staggered diagonally around the drum. Within the drum, and pivoted on a post extending from the front plate of the selector, are a series of ten spring-accuated pawls. As the drum revolves, each slot in turn passes over its respective pawl, the end of each pawl being forced into the slot in the drum by a spring, but continued rotation of the drum forces the pawl free of the slot.

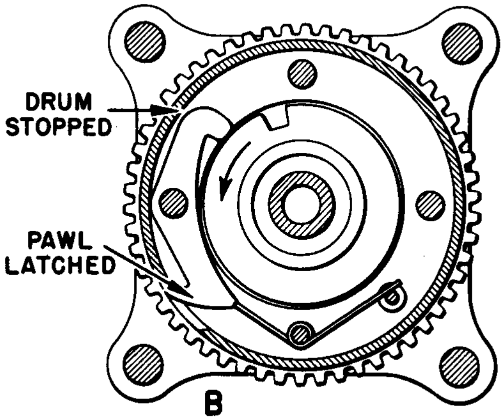
In the center of the drum, and spaced on the shaft connecting to the tunable elements, is a series of ten notched discs. These discs are clamped tightly to the shaft by a cam-and-lever locking arrangement attached to the selector knob, but can be released by raising the lever on the knob so any disc can be adjusted in relation to the shaft independently of the others.

The shaft and discs are driven by a friction clutch mounted in the large driving gear at the rear end of the selector, the end distant from the dial. The tension on this clutch is sufficient to drive the shaft in either direction unless the shaft is locked by the action of a pawl engaging a notch in one of the discs. The slotted drum is driven by a pin in the driving gear engaging a spring stop on the end of drum, arranged to drive the drum in one direction, that is, only when the motor is running forward in the first half of the tuning cycle.

The relative positions of the drum, pawls, discs, and gear are shown in the illustration and the sequence of operation is as follows.



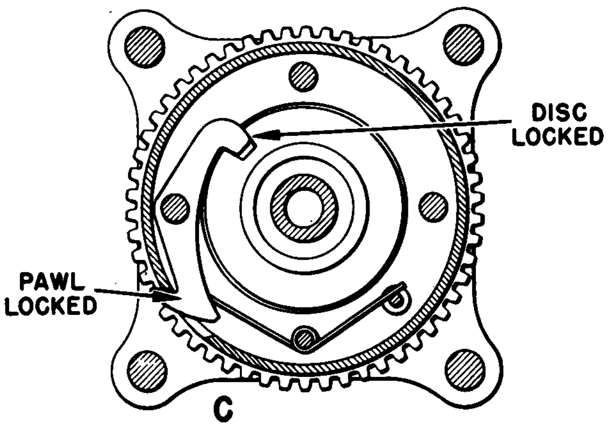
A



B

When the motor is energized, the worm gear of the gear train drives the large selector driving gear, which in turn rotates the drum, by means of the pin and stop, and the shaft and grouped discs are driven through the clutch in the gear hub. This action, as viewed from the front end of the selector, is shown A in the illustration, the direction of rotation of the parts being indicated by arrows. The slots in the drum ride over the free end of the pawls.

When the drum has reached its proper position, as determined by the homing switch opening the relay circuit, the motor will stop. The end of a pawl will extend into its associated slot in the drum as shown at B.

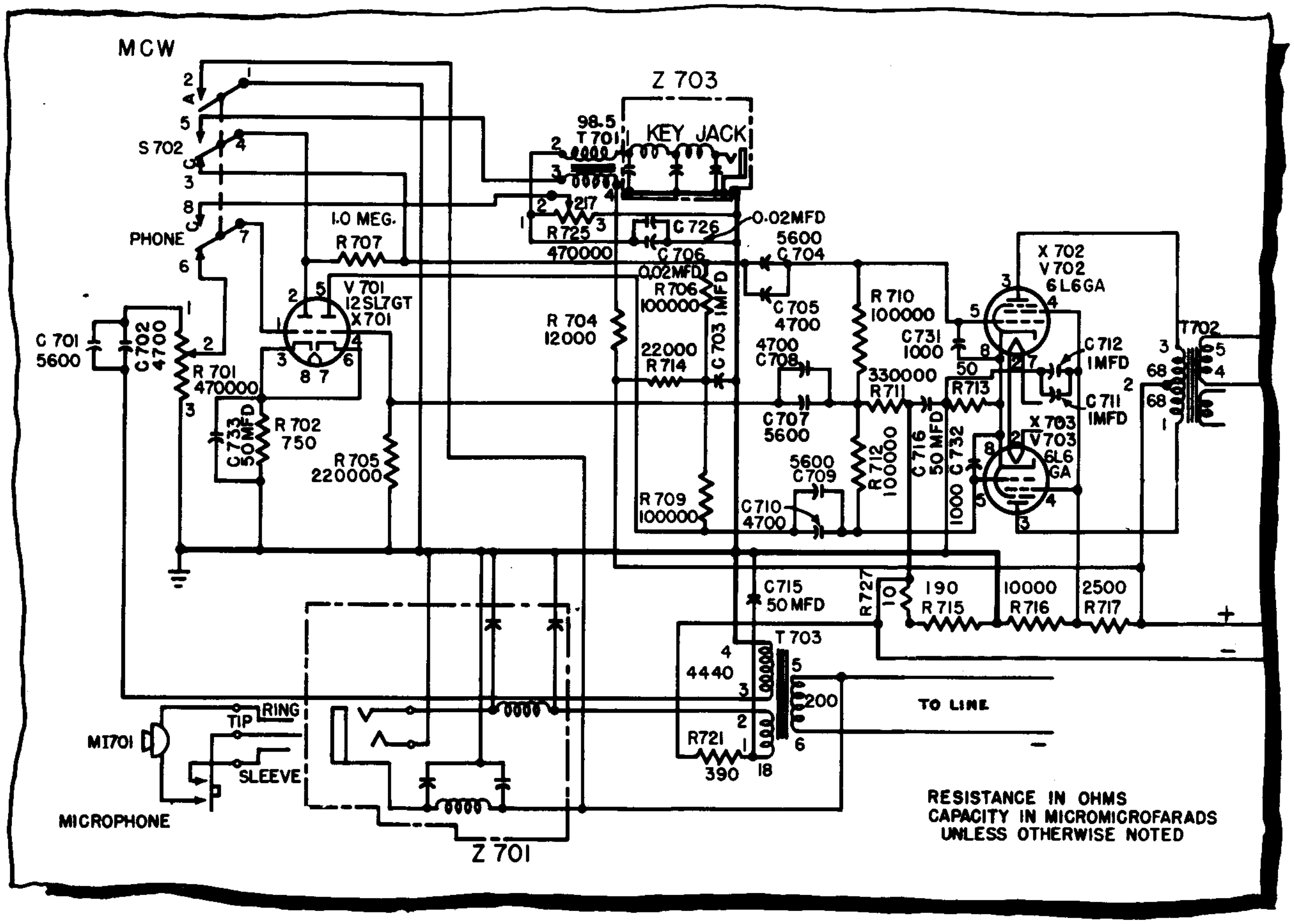


As the motor is reversed by the relay contacts and the gear of the selector reverses, the drum retains its position. The inner end of the pawl is now contacting the edge of its associated disc on the shaft. The shaft and discs are turned back with motor because of the clutch drive in the gear hub, as indicated by the arrow at B. This continues until the notch in the disc comes under the cocked pawl. As the pawl drops into the notch, the free end of the pawl extends further through the slot in the drum and rotation of the discs and shaft are stopped in the proper position as shown at C. The gear drive continues, but the clutch comes into play and allows the shaft to remain fixed in position as the motor continues to run in the reverse direction until stoped by the action of the limit switch. The tuned element is now properly adjusted to the frequency for which it was preset.

The above tuning cycle is repeated for each change of frequency. A pair of wafer switches S502A and B, as previously mentioned, are geared to mechanism through a selector drum so the proper crystal is connected into the circuit of the oscillator for each frequency as selected.

When the next change of frequency is made, the gear will rotate alone until the pin on the gear engages the spring stop on the drum. The drum is then revolved and unlocks the pawl by forcing in the free end and disengaging the pawl from the notch in the disc. This allows the discs and shaft to turn with the drum until the drum reaches the position required for the new frequency. The reversal of the motor again causing discs and shaft to revolve until stopped by the pawl engaging a notch in a disc.

MODULATOR CIRCUITS



The speech amplifier for modulating the output of the transmitter is assembled in the Modulator-Dynamotor unit which includes the dynamotor for generating the high voltage plate current used in the equipment when operated on 13 volts d.c.

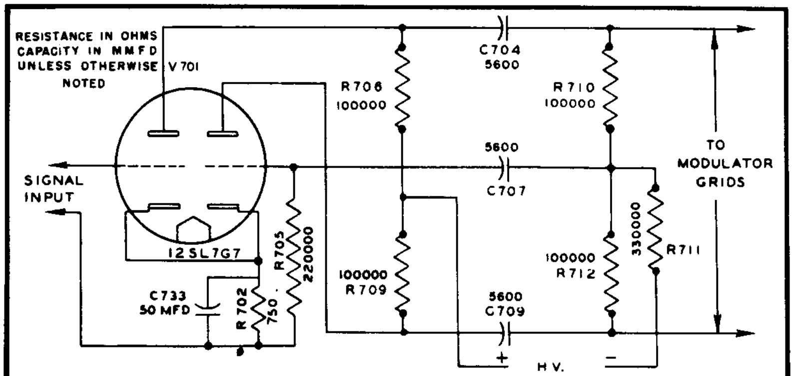
The partial schematic diagram shows the circuits involved in modulation of the carrier wave of the transmitter. The circuit as a whole is rather complicated in that it involves numerous switches and relays to perform the varied functions required of the equipment. Basically, the circuit consists of a speech amplifier tube, V701 driving a pair of modulator tubes V702 and V703 to furnish audio frequency potentials to plate-modulate the transmitter.

The normal speech input for phone transmission to the speech amplifier tube V701 is from the secondary of the input transformer T703. This transformer has two primary windings; one winding of low impedance is to match the microphone plugged into the local jack associated with the filter assembly Z701, the other primary is of high impedance to match the output of the microphone transformer at the remote box. The input to the tube is adjustable to meet average conditions by means of variable resistor R701 mounted on the chassis in the equipment.

The speech amplifier tube is a double triode and is connected into a phase inverter circuit, one triode section amplifies the voice impulses directly but is connected to operate the second triode so that its output will be 180° out of phase with the first. Thus, with the usual amplifier input it is possible to obtain an output equivalent to that of a push-pull stage.

The simplified schematic shown herewith will aid in understanding this action. The signal input is amplified in the left-hand section of the tube V701 which has a resistor R706 in the plate circuit, the signal being coupled through capacitor C704 to the grid of one of the modulator tubes. The voltage variations impressed on the grid of the modulator will appear across grid resistor R710 and resistor R711. The potential at the midpoint of these resistors will be fed back through capacitor C707 to the grid of the right-hand section of V701 to be amplified in this section and coupled by means of resistor R709 and capacitor C709 to the grid of the other modulator tube V703. For all practical purposes this action constitutes a push-pull driving action on the modulator tubes.

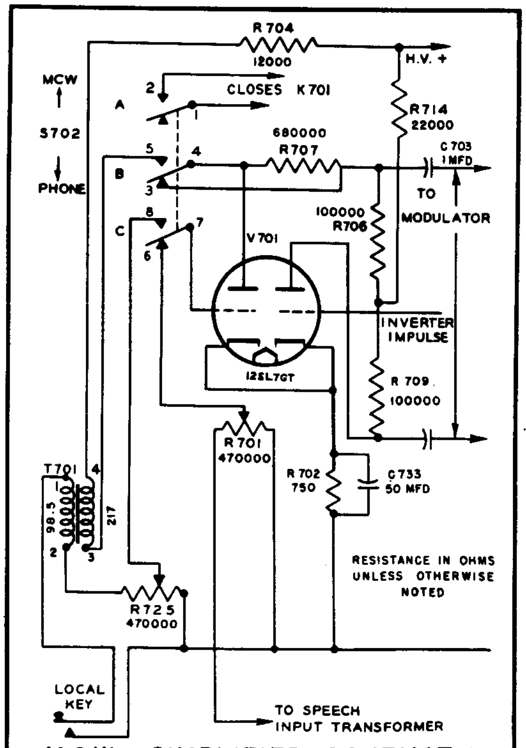
The output of the two modulator tubes V702 and V703 is coupled, by means of the modulation transformer T702, into the plate circuit of the Power Amplifier to produce modulation up to 100 per cent.



SIMPLIFIED SCHEMATIC OF THE PHASE INVERTER

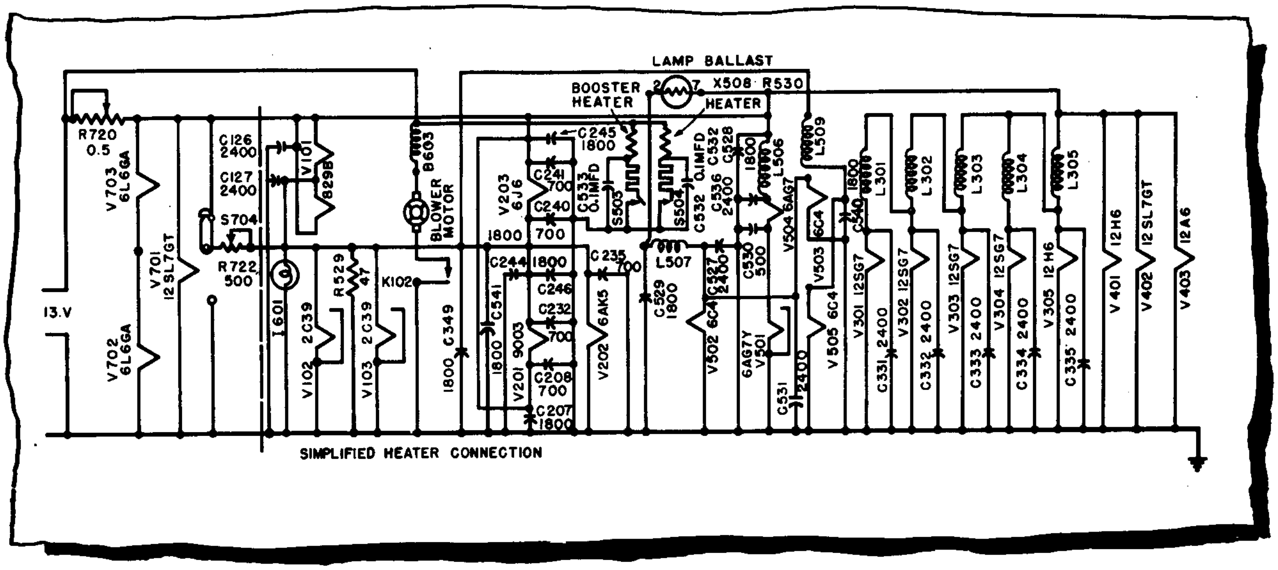
For MCW transmission, a switching system is employed to convert the input section of V701 into an audio oscillator to provide a 1200-cycle note that is fed to the modulating tubes. A simplified schematic diagram is shown below to illustrate the method employed. When the MCW-Phone switch S702 is in the phone position as shown, the grid of the speech amplifier is connected to the speech input circuit from transformer T703 through contacts C. Resistor R707, in the plate circuit, is shorted by contacts at B. Moving the switch S702 to the MCW position, causes contacts C to connect the grid of the tube V701 to the arm of the variable resistor R725 in the secondary circuit of transformer T701.

The plate of the tube V701 is parallel-connected to the primary of the transformer by contacts B which also remove the short from resistor R707. The transformer couples the plate circuit to the grid to set up 1200-cycle oscillations when the key is closed. Contacts A on the switch short the line input, to operate the relay K701 and place the equipment in transmitting condition. The input of the modulating note to the speech amplifier is set by resistor R725 on the chassis to get the proper degree of modulation.



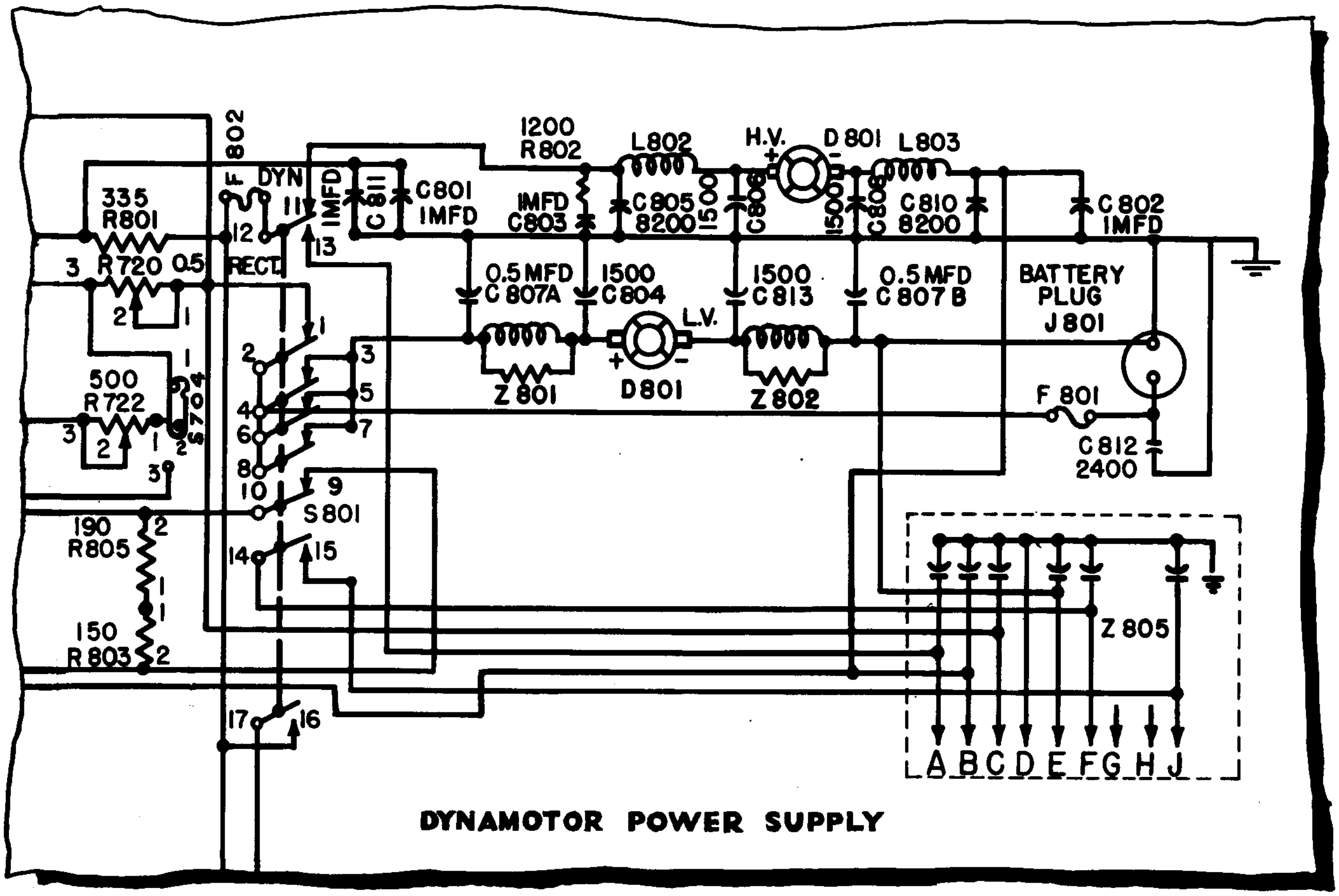
MCW SIMPLIFIED SCHEMATIC

DYNAMOTOR POWER SUPPLY



The dynamotor built into the Modulator-Dynamotor chassis is intended to furnish high voltage plate current for the operation of transmitter and receiver when a direct current source of 13 volts d-c is utilized for power.

The supply voltage is used direct to operate the tube heaters, a parallel-series arrangement as shown in the simplified heater connection is used to provide correct voltage for the tubes requiring 6.3 volts for cathode heating. Heater circuits are equipped with filter chokes and capacitors to keep R F currents from the circuits and to prevent interaction between the various tubes in the equipment.



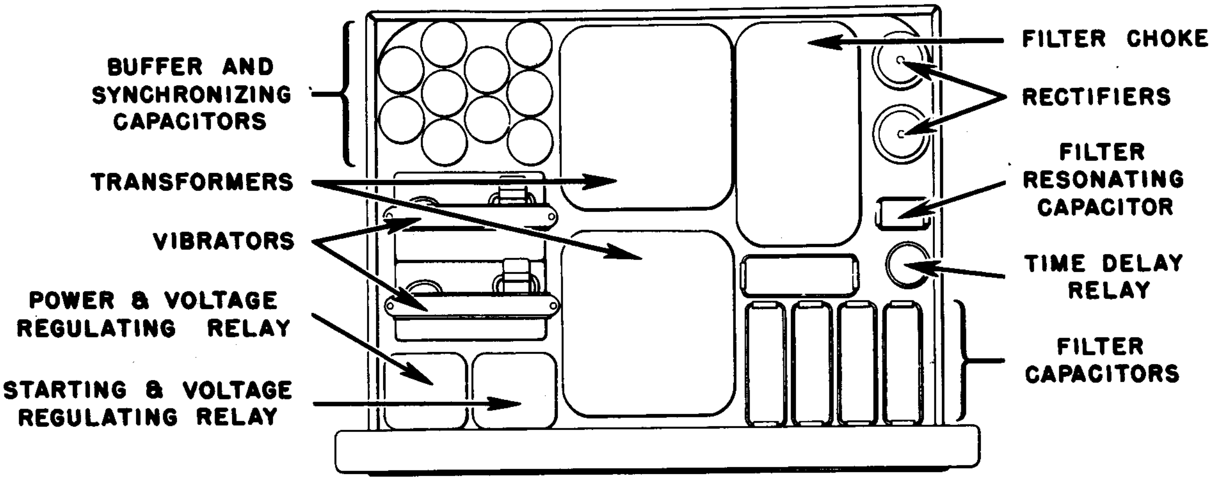
DYNAMOTOR POWER SUPPLY

A variable resistor R722 and a link transfer switch S704 are mounted beneath the chassis. Any variations in filament or heater resistance of the tubes that might unbalance the voltage across the branches of the series parallel circuits can be balanced out by switching R722 across the branch showing too high a voltage.

Two of the tubes, V502 and V503 in the multiplier section, are critical as to heater voltages so a Amperite ballast resistor R530 is mounted on the multiplier to maintain a practically constant current through the heaters of these tubes.

Ripple filter components and R F filters are connected into both motor and generator circuits of the dynamotor. The former are provided to remove any ripple resulting from the commutating action in the generator. The R F filters prevent radio frequency energy entering the equipment through power cables and causing disturbances.

UNIVERSAL POWER SUPPLY



The universal power supply unit is used to adapt practically all types and voltages of commercially-available electrical power to the requirements of the MAR equipment. On 115 V and 230 V d-c lines, this means converting the supply current to square wave alternating current by means of non-synchronous vibrators and then utilizing transformers and rectifier tubes to obtain the high plate voltage for the radio equipment. The same transformer system supplies 13 V a-c for the filament and heater circuits.

When operating from a-c supply it is not necessary to use the vibrators, as the transformers will function directly on the supply current. Three sets of switches are provided in the unit to take care of all necessary circuit changes in setting the equipment for use on any given power source. The operation of the equipment is as follows:

OPERATION FROM A DC SOURCE

When the MAR radio is turned on, a control relay in the power supply is closed allowing power from the source to flow to the vibrator. The coils of the vibrators are powered at the same time, and the vibrators are immediately activated. The function of the vibrator is to convert direct current to square-wave alternating current in order to utilize a transformer for voltage conversion. The vibrator accomplishes this by switching the power from one end of the primary to the other end of the primary at a rate of 120 times per second. The return circuit for the power is provided by a center tap in the primary. The transformers have several secondary windings; one winding provides the 13V a-c for tube heater operation on the MAR and the RDR equipment. Another pair of transformer windings with a center tap provides approximately 800 volts a-c to be rectified to 370 volts d-c for the plate power of the radio equipment. Full wave rectification is accomplished by means of two gas rectifier tubes. The 370 volts d-c from the rectifier tubes contains a large proportion of a-c voltage which would interfere with prop r operation of the equipment. Therefore, a filtering system is provided to reduce this a-c voltage to a level inaudible in the radio receiver.

Since the power supply must give the correct output voltages under four different conditions of load, it is necessary to control the high-voltage current by means of relays and series resistors. Thus, when only a receiver is operating, there is approximately 200 ohms of resistance in series with the equipment plate supply. When the load is increased by the operation of the transmitter, part of this resistance (180 ohms) is short-circuited by means of a series relay. When the load is still further increased by the added operation of the RDR receiver, the balance of the resistance is shorted out by means of a second series relay. Thus, good voltage regulation is maintained over the full range of operating conditions.

Two vibrators are used simultaneously and each carries approximately one-half of the total load. The load division is accomplished by the use of balancing coils and connecting the high-voltage windings of the transformers in series. Each transformer supplies one filament output; thus, one transformer supplies the power for RDR equipment filaments and the other for the MAR equipment filaments. The two vibrators are held accurately in phase with each other by a synchronizing circuit.

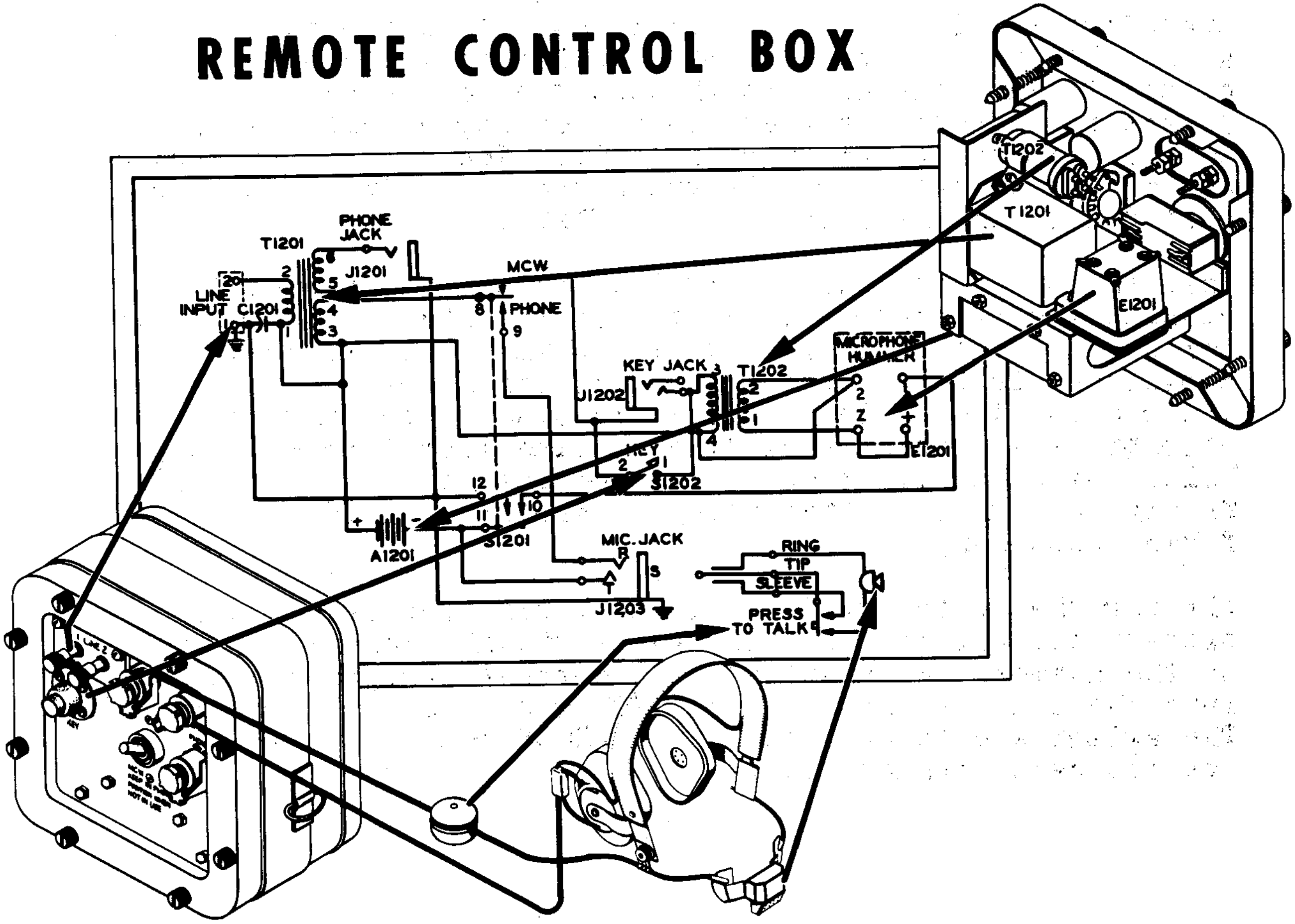
On the 230-volt d-c operation, power is supplied to the vibrator center reed through a 200 ohm resistor. When the vibrator is in operation, the 200 ohm resistor is no longer required and is removed from the circuit by the starting relay.

OPERATION FROM AN AC SOURCE

The a-c current is connected directly into the transformer for voltage conversion. The circuit functions are identical with those described in connection with d-c operation except that the vibrators are not in use.

With operation on all types of supply current, a time delay relay is connected in the output of the unit to prevent load being applied to the rectifier tubes before the cathodes of the tubes have reached operating temperature.

REMOTE CONTROL BOX



The illustration associates the components of the remote box with their respective positions in the schematic diagram. Power for operation of this unit is obtained from three flashlight cells as shown at A1201.

A transformer T1201 has one winding connected to the line terminals, which are connected to the radio equipment by a two-conductor cable or twisted telephone wire. A second winding on the transformer connects to the phone jack. A headset plugged in at this point gives reception of signals over the line and permits sidetone listening to all transmission from the remote box. The third winding is used as the input for both MCW and phone transmission.

For phone communication, a jack is provided for plugging in the microphone and extension cord with press-to-talk switch as shown. A MCW switch on the panel allows signaling by means of the key S1202 built into the box or the loose key plugged into the key jack.

For MCW communication a local source of audio frequency current for modulating the transmitter is necessary and consists of the "microphone hummer" E1201 and its associated transformer T1202. The hummer is essentially a buzzer using a variable resistance element, similar to a microphone button to vary the current through the coil winding. The pulsating potential across the hummer magnet coil is applied to the primary of transformer T1202. The key in the secondary of the transformer interrupts the audio frequency current fed to the line transformer T1201.

When the MCW-Phone switch S1201 is in the phone position, closing the press-to-talk switch on the microphone extension cord places the battery in series with the line, across capacitor C1201, to assist in operating relays in the radio equipment. The battery circuit is also closed through microphone and primary winding on line transformer T1201. Voice currents will then be coupled into the line, flowing freely through capacitor C1201 in series with the transformer secondary.

Placing the switch S1201 in the MCW position closes the battery circuit to the line, as previously mentioned, and to the hummer. Modulating audio currents are then coupled into the line by transformer T1201 when the key is operated. The switch should be left in the PHONE position when signals are not being transmitted.

CONTROL CIRCUITS

The MAR equipment must operate under conditions that require a minimum of effort on the part of the operator in changing channels, transmit-receive switching, and shifting to code communication as circumstances demand. Much of this switching is done by a system of relays built into the equipment. When the equipment is switched on and is in the receiving condition, the relays will be in the positions shown in the schematic on page 2-35.

With the microphone and press-to-talk switch plugged into the modulator-dynamotor unit, closing the press-to-talk switch will draw current from the -20 volt line through L701 and the coil of K701, as well as closing the microphone circuit through T703. Relay K701 pulls up and operates the four sets of contacts and puts the transmitter into operation.

Contacts 6 and 7 on relay K701 energizes relays K101 and K102, the former to transfer the antenna from receiver to transmitter, the latter to start the blower motor and also switch current into transmitter plate circuits. Note th t K702 removes potential from the frequency selecting motor circuits so that it is impossible to change channels while the transmitter is in operation.

When relay K701 is energized, it also opens contacts 8 and 9 that normally connect the output of the receiver to the line terminals through capacitor C730. Contacts 2 and 3 of the relay short out resistor R801 at the same time, if the IC-Operate switch is in the operate position, to increase the plate voltage to the transmitter tubes V101, V102, and V103. Contacts 4 and 5 of the relay close the plate circuit to tubes V701, V702 and V703 in the modulator section. Releasing the press-to-talk switch allows all relays to drop back to receiving position.

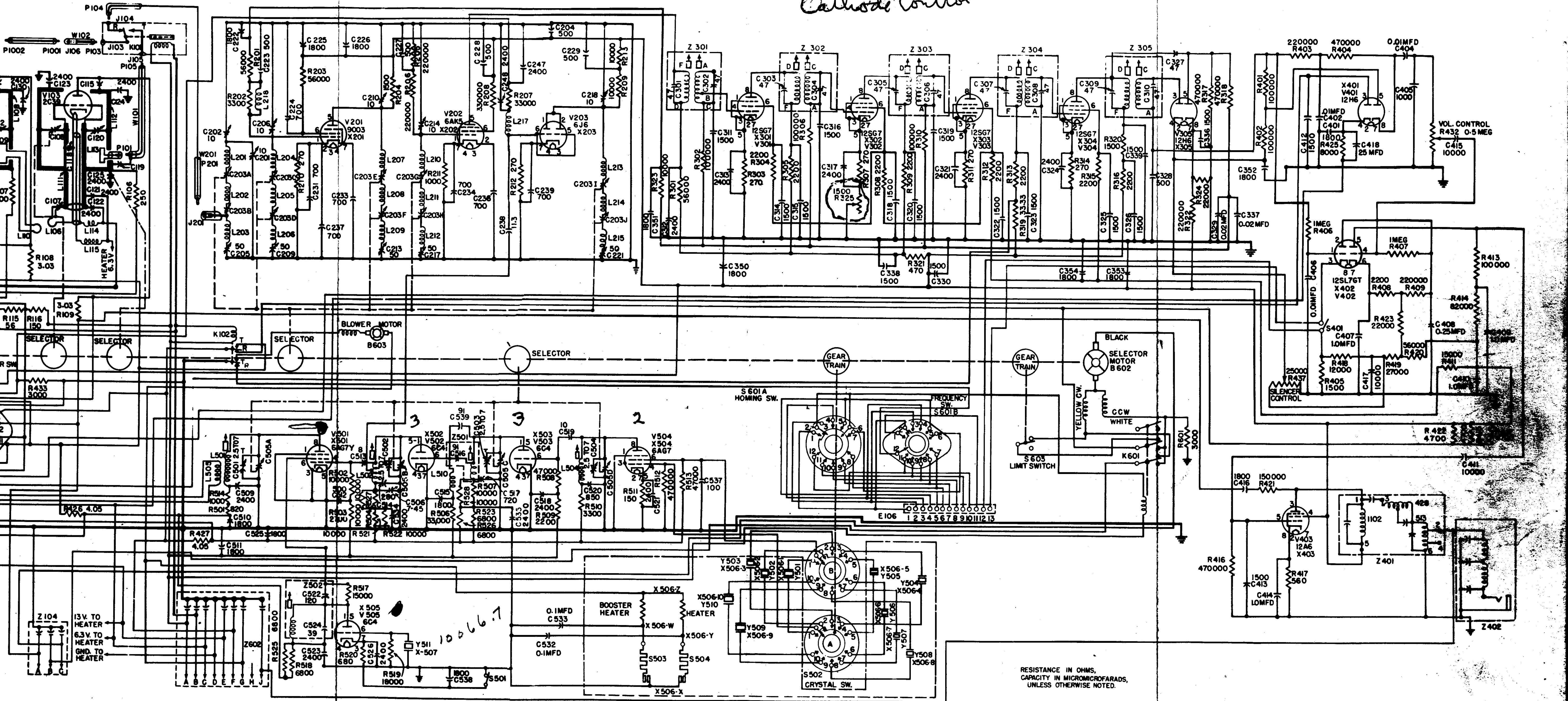
A similar relay action is obtained when the press-to-talk switch is closed on the microphone cord at the remote box. The one exception is that the local 4.5V battery in the remote box is switched into the line in series with the current derived in the equipment, to offset the voltage drop in the line to the remote box and to assure satisfactory operation of relay K701.

When the MCW-Phone switch on the modulator-dynamotor panel is moved to MCW position, a contact on this switch completes a circuit through the coil of relay K701 to place the transmitter in operation while keying. The switch must be moved back to Phone position for reception.

At the remote box, the MCW-Phone switch also connects l cal battery to the line and actuates K701 to switch on the transmitter. In MCW communication from the remote box, the audio frequency currents from the microphone transformer are superimposed on the direct current in the line holding relay K701. Such currents pass freely through blocking capacitors C1201 in the remote box and C717 and C718 in the modulator circuits and appear as potentials across one primary winding of speech transformer T703.

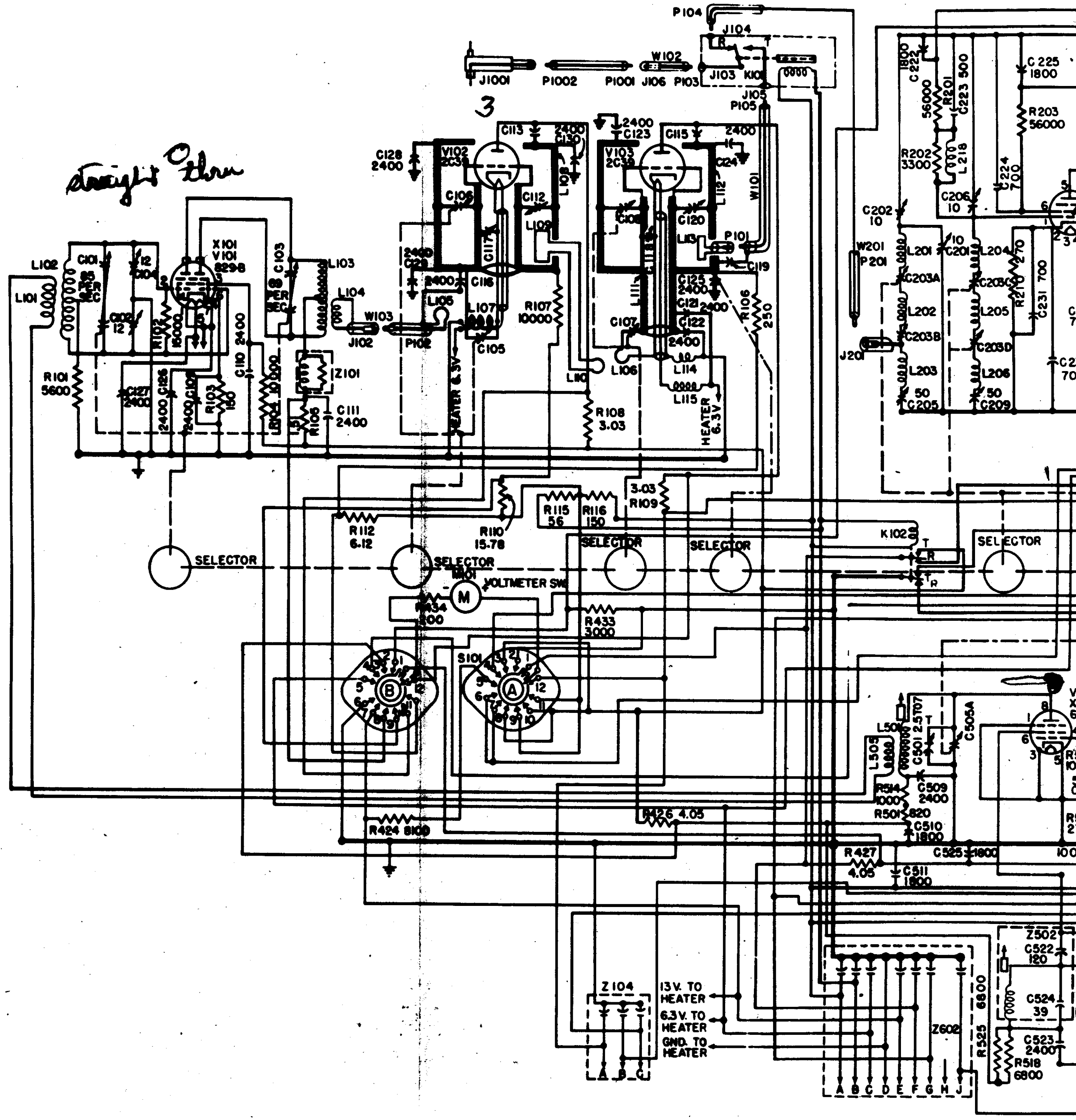
The voltage regulating relay K702 is to regulate the voltage applied to the selector motor B602. The coil of the relay is connected across the motor terminals by contacts on relay K601. Should the voltage across the motor exceed 190V, the relay draws up its armature and opens the contacts to place resistors R804 and R806 in series with the motor to reduce the applied voltage. Should the voltage across the motor fall to 140V, the relay drops its armature and the contacts close to short out resistors R804 and R806 and increase the voltage to the motor.

R325
Cathode Control

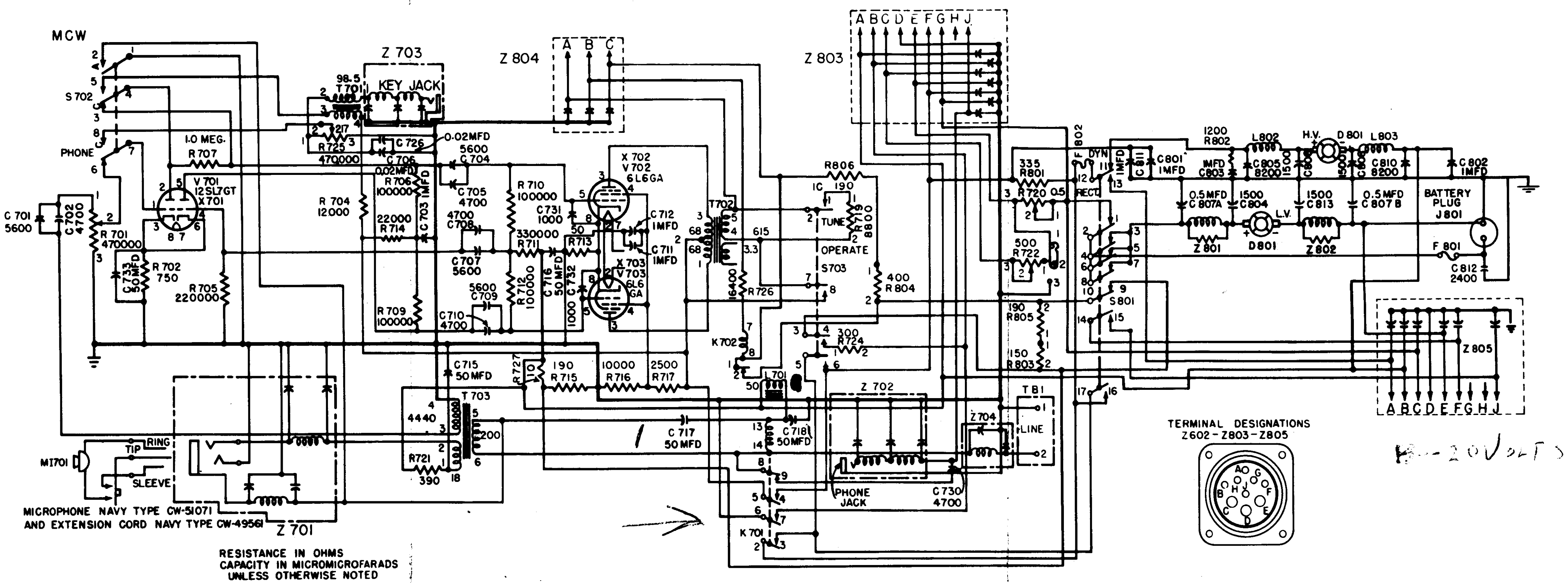


RESISTANCE IN OHMS,
CAPACITY IN MICROMICROFARADS,
UNLESS OTHERWISE NOTED.

SCHEMATIC DIAGRAM
TRANSMITTER-RECEIVER
W-308630

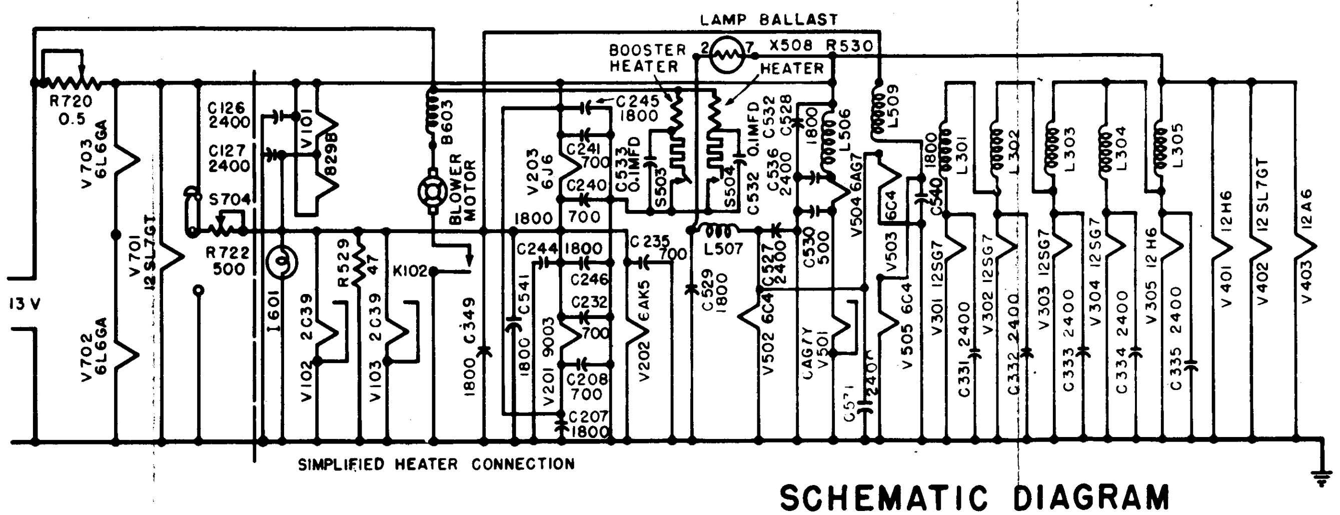

straight thru
3
P104
J104
J1001
P1002
P1001
J106
P103
W102
J103
K101
J105
P105
C128 2400
V102 2C39
C113
2400 C130
C112
L108
L109
C117
C116
R107 10000
V103 2C39
C115
2400 C123
C124
C120
L112
L113
W101
P101
C119
C125 2400
C121
C122
2400
L114
L115
HEATER 6.3V
R106 250
R108 3.03
L110
L106
C107
L107
C105
HEATER 6.3V
L105
P102
J102
W103
L104
L103
C103 68 PER SEC
Z101
C111 2400
R105
R104 10000
C110 2400
X101
V101 6298
R103 150
R102 15000
C106
C126 2400
C127 2400
C102 12
C104 12
C101 68 PER SEC
L102
L101
R101 5600
SELECTOR
R112 6.12
R110 15.78
R115 56
R116 150
R109 3.03
SELECTOR
M101
VOLTMETER SW
M
R434 300
R433 3000
S101
A
B
R424 8100
R426 4.05
K102
T
R
SELECTOR
R427 4.05
C511 1800
C525 1800
C510 1800
R501 820
R514 1000
C509 2400
L506
L501
C501 25T07
C505A
Z104
13 V. TO HEATER
6.3 V. TO HEATER
GND. TO HEATER
A B C
Z602
A B C D E F G H J
R525 6800
Z502
C522 120
C524 39
C523 2400
R518 6800
W201
P201
J201
C202 10
R202 3300
56000
R201
C222 1800
C223 500
L218
C206 10
C224 700
C225 1800
R203 56000
L201
C201 10
C203A
L202
C203B
L203
50 C205
L204
C203C
L205
C203D
L206
50 C209
R210 270
C231 700

A-20 Volts.



RESISTANCE IN OHMS
CAPACITY IN MICROMICROFARADS
UNLESS OTHERWISE NOTED

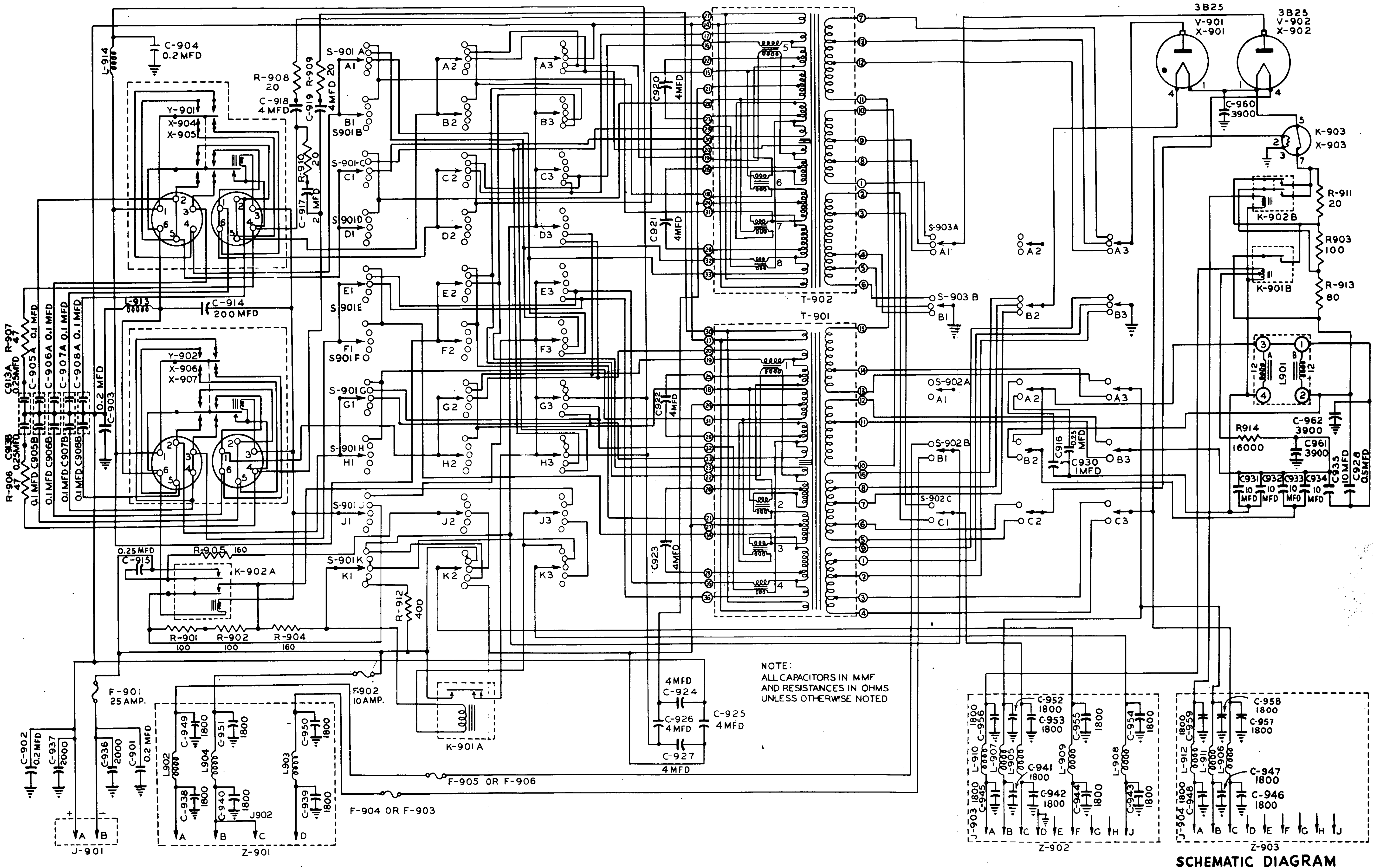
A-20 Volts



SIMPLIFIED HEATER CONNECTION

RESISTANCE IN OHMS,
CAPACITY IN MICROMICROFARADS,
UNLESS OTHERWISE NOTED

SCHEMATIC DIAGRAM
MODULATOR-DYNAMOTOR
W-308631



NOTE:
ALL CAPACITORS IN MMF
AND RESISTANCES IN OHMS
UNLESS OTHERWISE NOTED

SCHEMATIC DIAGRAM
UNIVERSAL POWER SUPPLY
T-618857

REVISED--SEE ERRATA AT THE FRONT OF THIS BOOK