THEORY OF OPERATION

NOTE: THIS DOCUMENT WAS EXTRACTED FROM 68P81015E70-C, "MICOR SOLID-STATE MOBILE FM TWO-WAY RADIO, 406-420 AND 450-512 MHz"

1. INTRODUCTION

The radio set can be broken down into the following sections.

--Injection
--Transmitter
--Receiver
--Antenna Network
--DC Switching, Regulation, and Filtering
--Frequency Selection
--Accessories

The following explanation refers to the block and schematic diagrams in the DIAGRAMS section of this instruction manual.

2. INJECTION

Refer to the receiver schematic diagram in the DIAGRAMS section of this instruction manual. The radio set obtains its transmitter and receiver oscillator frequency from a common injection train. Thus, the need for two oscillator circuits (channel elements) is eliminated. This injection train consists of a crystal controlled oscillator (channel element) and three doubler circuits. The injection train is located on the receiver rf and i-f circuit board.

a. Oscillator (Channel Elements)

Channel elements are highly stable crystal-controlled oscillators. They use unheated crystals in an oscillator circuit that is temperature compensated over the entire temperature range of -30° to +60°C (-22° to +140°F). A variable warp capacitor for fine frequency adjustment in the base of each channel element is accessible through holes in the rf and i-f circuit board. Each channel element is a factory sealed, plug-in module.

The rf and i-f circuit board accepts up to twelve channel elements. In single-channel radio sets, only one channel element is required and the dc ground path is continuously applied. In multi-channel radio sets, one channel element is required for each channel. The external control head channel selector switch completes the dc ground path to the desired oscillator. Only one channel may be selected at a time; that is, one transmit frequency and one receive frequency. Operation is possible on as many as twelve separate channels. Operation of the selected channel element may easily be checked with a Motorola portable test set on selector switch position 1.

b. Multipliers

The third harmonic of the crystal controlled channel element is selected by the input tuned circuits of the first doubler. The signal is then multiplied eight times by three doubler stages before being applied to the injection filter on the rf deck casting. The output frequency is below (low side injection) the rf carrier frequency. The injection filter has two outputs. One output connects directly to the receiver mixer. The other output connects via an rf connector and coaxial cable to the transmitter mixer.

3. TRANSMITTER

The transmitters used in the mobile UHF "Micor" radio sets may be standard or wide-spaced models. The standard models provide for communications between a mobile and a base station. In the 450-470 MHz band, the mobile transmitter signal for mobile to base station communications is 5 MHz above the mobile receiver frequency. In the 470-512 MHz band, this signal is 3 MHz above the mobile receiver frequency. The wide-spaced models provide for both mobile-to-base and mobile-to-mobile communications. The wide-spaced transmitter signal for mobile-to-mobile communications is at the mobile receiver frequency.

The Transmitter used in 406-420 MHz "Micor" FM radio sets may be either a standard channel or a wide-spaced channel model. Wide-spaced channel model exciters make the radio set adaptable to communications systems in which the transmit and receive frequencies differ by a few MHz, as in some repeater systems. Radio sets equipped with wide-spaced exciters can also communicate directly with other mobiles without going through a repeater. This is done by switching the radio set into the "standard" mode, in which the transmit and receive frequencies are the same.

a. "Private-Line" Encoder

(1) Tone Oscillator

The tone oscillator operates continuously when power is applied to the radio set. The outputs of the differential amplifier, formed by Q701 and Q702, are identical but 180° out of phase. The amplitudes of these collector signals are independent of frequency. A positive feedback signal is coupled through C701 and R708 to sustain oscillation. When the radio is turned on, C710 begins to charge through R728 which biases Q710 on through R727. To quickly bring the tone output up to full output, Q710 acts as a shunt around R708, which increases the positive feedback. After approximately 1.5 seconds (voltage across C710 reaches 9.0 volts) Q710 turns off and has no further effect on circuit operation. The output of Q701 is applied to feedback amplifier Q708 through C704 and R712. When the signal level exceeds a fixed amount, Q708 is biased into operation. It provides a negative feedback signal which keeps the oscillator out of limiting, thus providing a sinusoidal wave output. The "Vibrasender" resonant reed is the frequency determining device of the oscillator. It acts as a very high Q, narrow bandpass transformer, coupling only its resonant frequency and blocking all others. At its resonant frequency, the reed vibrates to couple energy from the primary to the secondary winding.

The "Vibrasender" resonant reed is a precision built device which maintains its frequency within ±0.15% of that specified. It consists of a tuned cantilever reed of special steel mounted on a rugged base with a coil and two permanent magnets. The entire assembly is spring-mounted and hermetically sealed in a metal housing to insure long life at peak performance under all types of conditions. The design of the reed eliminates the need for servicing throughout its useful life. The reed is a plug-in device which may be easily removed and replaced for circuit testing or to change frequencies. Reeds are available in specific frequencies in the 67-210 Hz range. No circuit adjustments are required when changing reeds.

NOTE

"Private-Line" tone frequencies are assigned by Motorola Systems Engineering to prevent duplication or interference between tones in the same area. Consult them before changing frequencies.

(2) Reverse Burst Timing Circuit

In the unkeyed transmitter condition, delay generator, Q706, is forward biased through CR703 and R719 to A- placing A+ across R721. This voltage is coupled to the base of the delayed turn-off switch (Q707) by R722, and Q707 is biased "off".

When the P-T-T button is closed, keyed filtered A+ is applied to R716 and turns on the keying switch, Q705. With Q705 acting as a short circuit:

--Q707 is biased "on" through R723, CR702 and Q705 to A-.

--Keyed, filtered A+ is applied through Q707 to turn on the transmitter.

--C708 charges from the filtered A+ line through Q706 base-emitter junction, CR703 and R718.

--The PL switch gate, Q709, is turned on by bias current through R726 and Q705. This action turns off PL tone gate, Q703.

Note that Q706 has not changed states and is still turned on by bias current through R719.

When the P-T-T button is released, the keyed, filtered A+ bias is removed from Q705 and it turns off. The transmitter continues to receive A+ from Q707 during the following sequence of events; with Q705 turned off:

--The PL switch gate, Q709, is turned off, activating the PL tone gate, Q703, which passes the reverse burst tone signal.

--C708 discharges through R718, R719, R721, R722 and R723, back biasing CR703 and turning off Q706.

--With Q706 off, Q707 remains on by receiving base bias through R722 and R721.

--After approximately 150 milliseconds, the voltage across C708 decreases to the point where Q706 turns on again and applies A+ across R721.

--The A+ across R721 turns off Q707 which removes the delayed keyed filtered A+ from the transmitter.

(3) Tone Output Circuit

When the transmitter is keyed, PL gate switch Q709 is turned on. Q709, in turn, gates 9.6 volts to PL tone gate Q703, turning it off. When Q703 is turned off, only the output of Q701 is coupled to emitter follower Q704. When the transmitter is unkeyed, Q709 is turned off and Q703 is turned on which completes the tone path from Q702 to C703. The two tone signals 180° out of phase, combine through the phase shift capacitors to produce a signal to the emitter follower that is 240° out of phase with the original tone. Emitter follower Q704 provides impedance matching in a low impedance output and isolates the tone oscillator from the external circuit to which the tone output is applied.

b. Exciter, 450-512 MHz

(1) Functional Description

Refer to the block diagram in the DIAGRAMS section of this instruction manual. Voice audio from the microphone is applied to the IDC circuit which clips all voice peaks over a certain level to a constant amplitude. The IDC adjustment sets the desired amount of deviation produced by the voice audio. This signal is then amplified and applied to the offset oscillator to accomplish direct frequency modulation. In "Private-Line" (PL) radios, the "PL" tone is also applied to the offset oscillator and provides a constant amount of "PL" tone modulation. The frequency-modulated offset oscillator signal is applied to a dual gate MOS FET mixer, along with the receiver derived high frequency injection frequency to generate the transmitter signal. The mixer output is amplified and the transmitter signal selected from the mixer spectrum by the exciter output filter. Two oscillator mixer-amplifier channels are required in the exciter for wide-spaced transmitters. A dc switching circuit automatically selects the correct exciter channel when a frequency is selected by the operator at the control head.

(2) Transmitter Frequency Stability

The standard transmit frequencies are developed by the use of a 16.7 MHz offset oscillator in the 450-470 MHz band and by the use of a 14.7 MHz offset oscillator in the 470-512 MHz band. On models in the 450-470 MHz band with option W184, a standard 11.7 MHz offset oscillator is used. The wide spaced models use an 11.7 MHz offset oscillator for the full 450-512 MHz band. The overall transmitter carrier frequency is defined by the following formula:

$$f_t = 24 f_c + f_o$$

where

f_t = transmitter frequency

f_c = channel element frequency

f_o = offset oscillator frequency

The offset oscillator frequency (f_o) is either 11.7 MHz, 14.7 MHz, or 16.7 MHz, while the multiplied channel element frequency (24 f_c) is equal to the receiver frequency minus 11.7 MHz. For the 450-512 MHz range, 24 f_c will vary from 438.3 MHz (receiver frequency of 450 MHz) to 497.3 MHz (receiver frequency of 509 MHz). Since 24 f_c is much greater than f_o, the transmitter frequency is much more sensitive to the channel element frequency error than to the offset oscillator frequency error. This fact permits the use of a relatively low stability offset oscillator (approximately 10 to 15 PPM) to be combined with the stable injection frequency to generate the highly stable transmit frequency. The contribution of the offset oscillator to the transmitter carrier frequency error is never more than 0.5 PPM.

(3) IDC circuit

The Motorola IDC circuit processes the microphone audio to prevent over-deviation while giving the modulator the proper audio drive for full deviation over a wide range of audio amplitudes. It does so over the entire 300-3000 Hz voice communications audio range with a very low amount of distortion.

The transistorized microphone requires a dc supply voltage for operation. This voltage is provided by the exciter through a voltage divider network from the keyed +9.6-volt input. The dc voltage to the microphone and the audio signal from the microphone are carried on the same conductor.

The microphone audio is coupled through a pre-emphasis network which couples 300 to 3000 Hz audio signals and provides a 6 dB per octave pre-emphasis characteristic; that is, as frequency doubles the amplitude increases 6 dB. The pre-emphasis network shapes the typical speech signals for more equal amplitude of lows and highs before their application to the clipper amplifier.

In the clipper amplifier portion of the integrated circuit IC301, the voice signal is amplified and all voice peaks which exceed a fixed limiting level are clipped. In normal operation, some voice peaks have sufficient amplitude to be clipped. Clipping of the voice peaks will produce undesired harmonics which are greatly attenuated by the splatter filter portion of IC301. The output of IC301 is further filtered and amplified with discrete component circuitry. The IDC potentiometer adjusts the maximum level of audio coupled to the modulator thus setting the amount of deviation. Additional audio voltage is supplied to the varactor modulator by coupling the signal from the audio amplifier emitters to the varactor anode. This signal is not influenced by the IDC potentiometer and results in a residual deviation of about 1.5 kHz when the IDC is set for minimum deviation (counter-clockwise from the foil side of board).

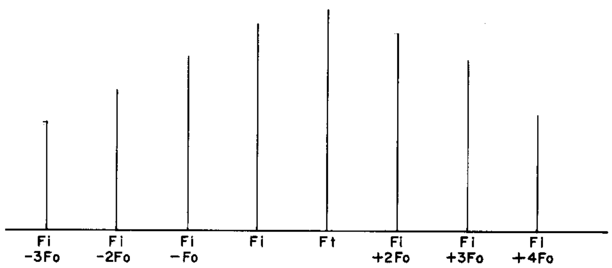
In "Private-Line" radios, a low amplitude "PL" tone is continuously injected into the "IDC" amplifier from the "PL" encoder. This tone, which is a specific frequency in the 67 to 210 Hz range, will produce between 0.5 to 1.0 kHz deviation.

(4) Offset Oscillator, Modulator, and Amplifier

The audio output of the IDC circuit is applied to the modulator directly frequency modulating the offset oscillator. Modulation is accomplished by using the IDC audio output swing to vary the potential across a reverse-biased varactor diode in the oscillator feedback circuit. The capacitance of the varactor varies at an audio rate causing the oscillator frequency to vary at the same audio rate. The amount of frequency deviation is limited by the amount of audio swing applied to the varactor. The larger the swing, the larger the deviation. Without modulation, the frequency of the oscillator is set by the adjustment of a slug-tuned inductor in series with the varactor. The oscillator output is coupled to an N-channel junction FET in the source follower configuration. The high input impedance of the FET minimizes loading on the oscillator. A bipolar transistor follows the FET and feeds the mixer through a low-pass filter to reduce oscillator harmonics. The output of the bipolar transistor is sampled and detected for use at meter position 4.

(5) Offset Mixer Amplifier, and Output Filter

A dual gate MOS FET is used for the mixer because of its high gain, stability at UHF frequencies, and absence of higher order non-linearities in its transfer characteristics. These characteristics significantly reduce the generation of spurious outputs. Gate 2 of the FET is at 3.8 volts dc and rf ground while the output of the oscillator amplifier low-pass filter and injection frequency are applied at gate 1. The output circuit of the FET is a narrow band tuned circuit which is coupled to a wide band two stage 20 dB amplifier. Due to the nature of the mixer, the output spectrum of the FET will consist of a band of frequencies as shown in the EXCITER OUTPUT SPECTRUM diagram.



Exciter Output Spectrum

This spectrum is defined by $f_i \pm N f_o$ where

f_i = injection frequency

f_o = offset oscillator frequency

N = any integer

The desired overall transmit carrier frequency f_t is defined by the following formula

when N = 1

$f_t = f_i + f_o$

It is at f_t to which the FET output circuit is tuned. The entire spectrum of frequencies is amplified by the 20 dB amplifier and coupled to the exciter output filter by the cable on the foil side of the exciter printed circuit board.

The exciter output filter is a six-section filter which is tuned to the transmit frequency (f_c) and provides at least 85 dB rejection of other frequencies generated in the mixer. The output of the filter is approximately 1 mW at the transmit frequency and is coupled to the following low level amplifiers. At the input to the filter the signal is detected and measured at meter 2 (standard channel) or meter 3 (wide-space channel).

c. Exciter, 406-420 MHz

(1) Transmitter Frequency Development

In all "Micor" radio sets the transmitter frequency depends on the selected channel element frequency in the receiver and the frequency of the crystal in the offset oscillator.

The offset oscillator in a standard transmitter uses an 11.7 MHz crystal, making the transmitter carrier frequency the same as that of the receiver. A carrier frequency for a wide-spaced transmitter may be from 3 MHz below to 9 MHz above the receiver frequency. Therefore, an offset oscillator crystal frequency in wide-spaced channel models will be between 8.7 MHz and 20.7 MHz.

The transmitter carrier frequency is defined by the following formula:

$$f_t = 24 f_c + f_o$$

where

f_t = transmitter frequency

f_c = channel element frequency

f_o = offset oscillator frequency

The offset oscillator frequency (f_o) is either 11.7 MHz or 8.7 MHz to 20.7 MHz, while the multiplied channel element frequency (24 f_c) is equal to the receiver frequency minus 11.7 MHz. For the 406-420 MHz range, 24 f_c will vary from 394.3 MHz (receiver frequency of 406 MHz) to 408.3 MHz (receiver frequency of 420 MHz). Since 24 f_c is much greater than f_o, the transmitter frequency is much more sensitive to the channel element frequency error than to the offset oscillator frequency error. This fact permits the use of relatively low stability offset oscillators (approximately 10 to 15 PPM) to be combined with the stable injection frequency to generate a highly stable transmit frequency. The contribution of the offset oscillator to the transmitter carrier frequency error is never more than 0.5 PPM.

Selection of the correct receiver channel element and offset oscillator crystal for a given transmit-receive frequency pairing is accomplished either through the universal switching board, or the control (interconnect) board and a diode matrix board. Refer to the FREQUENCY SELECTION portion of THEORY OF OPERATION section for a detailed description of the selection process.

(2) IDC Circuit

The theory of operation for the IDC circuit from the microphone to the IDC control is the same in 406-420 MHz model "Micor" radio sets as that in 450-512 MHz models.

In standard 406-420 MHz exciters, the IDC potentiometer adjusts the maximum level of audio applied to the modulator. Additional audio voltage is supplied to the varactor modulator by coupling the signal from the audio amplifier emitters to the varactor anode. This signal is not influenced by the IDC potentiometer and results in a residual deviation of about 1.5 kHz when the standard IDC is set for minimum deviation (counter-clockwise from the foil side of board).

In wide-spaced 406-420 MHz exciters, an inverter is added to supply the higher level audio needed to drive the modulator. Unlike standard exciters, there is no residual deviation in wide-spaced exciters when the wide space IDC control is set for minimum deviation.

In "Private-Line" radios, a low amplitude "PL" tone is continuously injected into the "IDC" amplifier from the "PL" encoder. This tone, which is a specific frequency in the 67 to 210 Hz range, will produce between 0.5 to 1.0 kHz deviation.

(3) Offset Oscillator, Modulator, and Amplifier

The audio output of the IDC circuit is applied to the modulator directly frequency modulating the offset oscillator. Modulation is accomplished by using the IDC audio output swing to vary the potential across a reverse-biased varactor diode in the oscillator feedback circuit. The capacitance of the varactor varies at an audio rate causing the oscillator frequency to vary at the same audio rate. The amount of frequency deviation is limited by the amount of audio swing applied to the varactor. The larger the swing, the larger the deviation. Without modulation, the frequency of the oscillator is set by the adjustment of a slug-tuned inductor in series with the varactor. The oscillator output is coupled to an N-channel junction FET in the source follower configuration. The high input impedance of the FET minimizes loading on the oscillator. A bipolar transistor follows the FET and feeds the mixer. The output of the bipolar transistor is sampled and detected for use at meter position 4.

(4) Offset Mixer Amplifier, and Output Filter

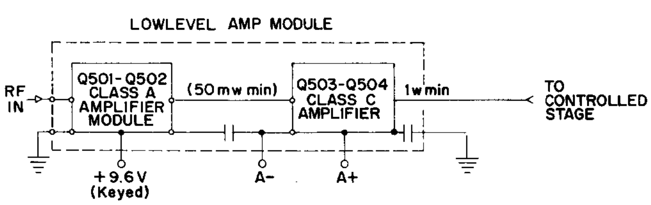
A dual gate MOS FET is used for the mixer because of its high gain, stability at UHF frequencies, and absence of higher order non-linearities in its transfer characteristics. These characteristics significantly reduce the generation of spurious outputs. Gate 2 of the FET is at 3.8 volts dc and rf ground while the output of the oscillator amplifier and the injection frequency signal are applied at gate 1. The output circuit of the FET is a narrow band tuned circuit which is coupled to a wide band two stage 20 dB amplifier on standard exciters.

In wide-spaced exciters the selectivity of the two-stage 20 dB amplifier is increased by the use of an additional tuned circuit.

The exciter output is coupled to a six-section filter which is tuned to the transmit frequency (f_t) and provides at least 85 dB rejection of other frequencies generated in the mixer. The output of the filter is approximately 1 mW at the transmit frequency and is coupled to the following low level amplifiers. At the input to the filter the signal is detected and measured at meter 3 (standard exciters) or meter 2 (wide-space exciters).

c. Low Level and Power Amplifiers

Refer to the following LOW LEVEL AMPLIFIERS diagram and to the block and schematic diagrams in the DIAGRAMS section of this instruction manual.



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Low Level Amplifiers

In standard transmitter model radio sets, the low level amplifiers are fed directly from the standard channel exciter filter. In wide-space transmitter model radio sets, the low level amplifiers are fed from a combiner network used to combine the output from the two exciter filters. In both cases, the low level amplifiers require 1 milliwatt input from the exciter. This input is amplified by two stages of class A amplifiers, Q501 and Q502, to reach a saturated 50 milliwatt level. The amplifier saturation stabilizes signal level to the following stages and removes exciter amplitude modulation. The output of Q502 is then amplified by two low level class C stages, Q503 and Q504, to reach a 1.3 watt level at the low level amplifier output connector. All low level amplifier input and output impedances are 50 ohms.

All power amplifier deck circuits (Q506 through Q513) use quarter-wave microstrip transmission line matching. This steps up the device impedance to the 50 ohm input and output impedance of each stage.

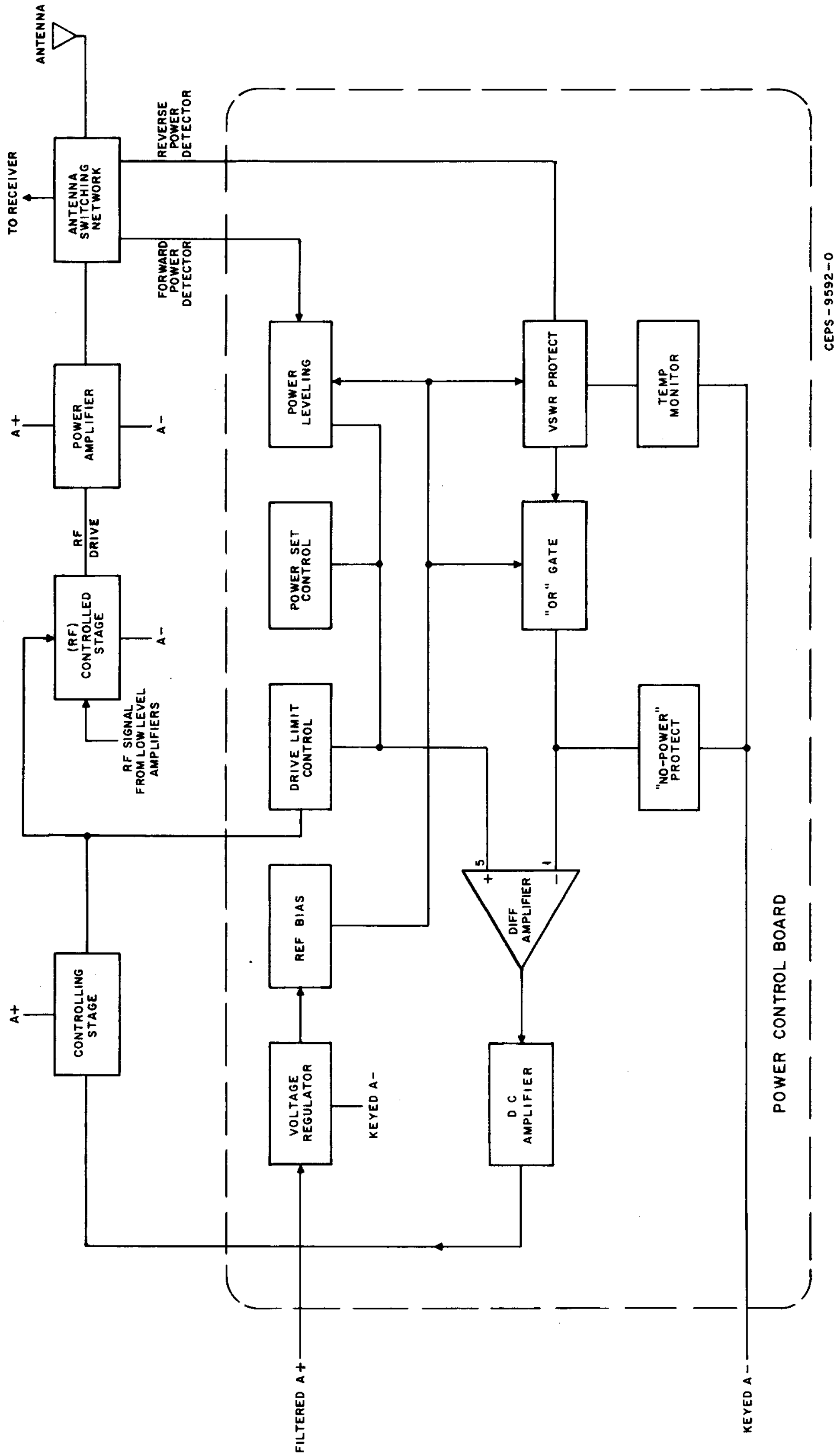
The output of Q504 is fed to the controlled amplifier stage, Q506. The transmitter power control circuit controls the gain of this stage by its dc input to Q505. Q505 is located in the collector of Q506 and determines the collector voltage of Q506. The output of controlled stage Q506 is fed to pre-driver stage Q507 for additional amplification.

On 25 watt models, the pre-driver output is amplified by a single-stage power amplifier, before being fed to the antenna network. This single stage amplifier is also used as the driver for the 75 watt models.

On 45 watt models, the pre-driver output is fed to a two-device direct parallel amplifier, Q508 and Q509. These amplifiers are used as the final power amplifier in the 45 watt models and as the driver in the 100 watt model.

The final power amplifier for the 75 watt and 100 watt power amplifier use four devices directly in parallel, Q510 through Q513.

The service metering receptacle monitors the following functions. Pin 1 monitors dc current to the low level class C amplifier Q503 and Q504. Pin 2 monitors the dc current to the pre-driver Q507. Pin 3 monitors current to the driver in the 75 and 100 watt models. Pin 5 monitors the voltage difference between A+ and the voltage at the controlled stage collector. A lower reading on meter 5 will correspond to a higher collector voltage and thereby higher power output from the controlled stage. Reference po-



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sition A on the portable test set uses pin 7 of the metering socket as an A+ reference against which the outputs of pins 1, 2, 3, and 5 are checked. The power amplifier output stage current in all models is monitored by the meter socket on the power control board.

e. Power Control

(1) Function Description

Refer to the POWER CONTROL CIRCUIT block diagram. The power control circuitry provides drive regulation and protection for the transmitter power amplifier transistors. Six functions are provided; power leveling, VSWR protection, drive limiting, temperature protection, forward and reverse power metering, and no power output protection circuitry.

The circuitry operates as a control loop which continually monitors the output from the final stages of the transmitter power amplifier and controls that output by regulating the gain of the first stage of the power amplifier. The output of the integrated circuit differential amplifier, amplified by the dc amplifier, is the controlling input for the control transistor in the power amplifier section.

The output of the differential amplifier is determined by the potentials present on the non-inverting (+) and inverting (-) inputs. These potentials are developed by the power control board circuitry in the following manner.

When the impedances of the antenna circuitry (load) provide a good match to the power amplifier (low VSWR), and the heat sink temperature is below 80°C, a bias voltage produced by the dc reference bias circuitry is placed on the inverting input (pin 1 which is also called the reference input) of the differential amplifier.

When the transmitter is keyed, the forward (output) power from the final stages of the power amplifier is fed through the antenna switching network to the antenna circuit. This flow of power is sampled by the forward power sampling circuitry and places a bias, proportional to the forward power in the antenna switching network on the non-inverting input (pin 5) of the differential amplifier. The POWER SET potentiometer is then adjusted, changing the potential on the non-inverting input. As this voltage changes, relative to the reference input voltage, the output of the differential amplifier changes, in turn changing the control transistor collector voltage and therefore the output of the power amplifier.

Once the power has been set to the proper level, any change in the output power will be instantly corrected by the circuitry. If the power increases, the increase causes the differential amplifier output voltage to increase, decreasing the output from the dc amplifier which decreases the gain of the power amplifier until the output returns to the preset level. A decrease in transmitter power amplifier output causes the reverse action.

Any power reflected back from the antenna circuit is detected by the reverse power sampling circuit. Reverse power causes a bias in the antenna switching network which decreases the potential on the reference input of the differential amplifier. Therefore, increasing levels of reflected power will cause the transmitter power output to be decreased to a safe level.

Temperature increases detected by the temperature monitoring circuit will also decrease the reference level at the inverting input of the differential amplifier, reducing the output power as the heat sink temperature increases above a safe operating point for the power transistors. The higher the temperature, the more the decrease in power out. If the output has been reduced due to temperature, the VSWR circuit becomes more sensitive to reverse power, thus providing further protection for the rf power amplifier transistors.

(2) Circuit Description

Since the power control board has the capability to regulate the output of the transmitter power amplifier from a completely cut-off state to above the rated output power, a definite controlled output level is necessary whenever the transmitter is keyed. The desired controlled output level is determined by bias voltages present on the inverting and non-inverting inputs of the differential amplifier. Under normal operating conditions (normal heat sink temperature; 1:1 VSWR; 100% rated power out) the bias on the differential amplifier inputs are developed as described in the following paragraphs.

(a) Voltage Regulator and Main Divider Line

The A+ supply to the board is regulated by a series regulator circuit providing a nominal voltage of 8.0 volts. The Zener diode CR602 holds the base of the series pass transistor Q602 at a fixed potential. The series pass transistor operates as a variable resistor to hold the input to the reference circuitry constant. The divider consisting of the two resistors R611 and R612 and the diode CR607 provides the proper voltage tap points for the secondary voltage divider networks. All 36 pF capacitors in the board are used as rf bypasses.

(b) Reference Bias Circuit

The reference bias is developed (with normal heat sink temperature and a low VSWR) by the voltage divider made up of two resistors R604 and R612 and a diode CR606 between the regulated supply voltage and the switched A- source. Since A+ is applied to the board continuously and A- is only applied when the transmitter is keyed by the push-to-talk switch, the larger capacitor C613 connected between the inverting input and keyed A- provides a time constant which allows the inverting input bias to build up slowly when power is first applied. This prevents full power output from occurring until the leveling circuitry can react and reach a quiescent level.

(c) Forward Power Bias and Detection Circuit

The forward power reference voltage divider comprised of three resistors and a potentiometer R607 provides a stable potential that supplies a dc bias to the non-inverting input of the differential amplifier. With an approximately correct power output from the final stages of the power amplifier, a dc level proportional to that power is produced by the forward power detector circuit, which, in combination with the voltage developed by the voltage divider, produces a bias on the non-inverting input that can be adjusted by the POWER SET potentiometer.

The dc bias value will be determined by the power amplifier output and, with low reflected power balanced against the reference bias present on the inverting input of the differential amplifier. Once the bias has been set, and change in power output will change the bias on the non-inverting input causing the differential amplifier to compensate for the deviation.

(d) Drive Limit Circuit

The drive limit circuit, consisting of R608, R607 and CR603, is a secondary path of the power control board loop. This secondary loop acts as a clamp on the voltage of the controlled rf stage. When properly set, the circuit will have no effect on the normal power control functions. If for some reason the controlled loop tries to place excessive voltage on the controlled rf stage, such as when a power amplifier transistor failure occurs, diode CR603 conducts increasing the current into pin 5 reducing the collector voltage of the controlled stage. When the collector voltage decreases, CR603 turns off. The loop clamps at the drive limit point that was set. See the transmitter alignment procedure for correct setting of the drive limit control.

(e) No-Power-Output Protection Circuit

If less than 7 to 10 watts is detected at the input of the antenna switching unit, the no power output protection circuit turns off the controlled rf stage. Turn off occurs within a few milliseconds after the transmitter is keyed. The circuit protects the power amplifier devices against any malfunction which causes a no power output condition such as an unconnected power output cable to the antenna switching unit.

When the transmitter is keyed, capacitor C611 pulls the gate of the programable unijunction transistor (anode gate SCR) CR604 up to 8 volts which is above the 5.2 volts at its anode. The detected voltage from the forward power is divided by R620 and R621 and will keep the gate above 5.2 volts and CR604 off unless the forward power detected is less then 7 to 10 watts. If power does not come up to 7 to 10 watts before C611 charges to the cirtical voltage, CR604 will turn on. When CR604 turns on, it connects pin 1 of IC601 to A-. Grounding pin 1 turns off the controlled stage which turns off the transmitter.

(f) VSWR - Reverse Power Detection Circuit

With the power control board operating correctly with the proper amount of forward power and the correct biases; the detection of reflected power causes a decrease in the power amplifier output in the following manner.

The components of the reverse power detector circuit function the same as those in the forward power detector. The voltage divider R610 and R613 develops a bias voltage that is not quite enough to forward bias the diode CR605 that makes up one-half of a diode "OR" gate. When reflected power is detected, the resultant negative-going dc level lowers the dc bias level and the combination of the two forward bias the diode. The negative-going dc level on the inverting input increases the output voltage of the differential amplifier, decreasing the dc control output to protect the final stages of the power amplifier.

(g) Temperature Protection Circuit

When the heat sink temperature rises above approximately 80°C, the thermistor in parallel with the lower half of the VSWR voltage divider reaches a value of resistance which allows a more negative potential to be applied through the diode "OR" gate to the inverting input of the differential amplifier. The temperature protection decreases the level of the reference and therefore the power output of the power amplifier board.

(h) DC Level Output Amplification

The output of the differential amplifier is applied to the base of non-inverting transistor amplifier Q601 whose output supplies the output control current. As the forward power increases above the normal value, the output of the differential amplifier increases proportionally.

Since the dc level is increasing the base, the PNP transistor base-emitter voltage is less and the output control current decreases.

4. RECEIVER

Refer to the receiver schematic diagram in the DIAGRAMS section of this instruction manual. The following circuit theory covers the entire receiver except for the oscillator injection. The injection train which consists of an oscillator (channel elements) and three doubler circuits is fully covered in the INJECTION paragraphs of this section.

a. Receiver RF and IF

(1) RF Preselector

RF preselector selectivity prevents receiver degradation from the mixer image frequency and other high level off-channel signals. The rf preselector consists of six low loss, highly selective helical resonant cavities. The bandpass of the preselector is characterized by a flat acceptance bandwidth (preselector response within its bandpass does not vary) and a steep skirt response (attenuation of signals rapidly increases as their separation from the bandpass range increases).

Carrier signals received at the antenna are routed through the preselector cavities to the following mixer stage to be heterodyned with the injection frequency signal.

(2) Mixer

The mixer uses a field effect transistor with low noise level and high conversion gain. The circuit heterodynes the signal from the rf preselector with the injection signal from the multiplier to produce the intermediate frequency (i-f) of 11.7 MHz. Frequency relationships for the 450-512 MHz ranges are expressed as follows.

$$f_c = 24f_o + 11.7\ \text{MHz}$$

$$f_o = \frac{f_c - 11.7\ \text{MHz}}{24}$$

Where:

f_o = channel element frequency

f_c = rf carrier frequency

24 = channel element harmonic

11.7 MHz = mixer output frequency (i-f frequency)

(3) First Four-Pole Crystal Filter

This filter and the other four-pole crystal filter are the major factors in determining final receiver bandwidth and selectivity characteristics by greatly attenuating signals outside the predetermined receiver bandpass range.

The first four-pole filter consists of two dual-resonator, mode-coupled monolythic crystals and associated impedance matching circuitry. The output of mixer is coupled to the input of the filter by an adjustable matching network.

Refer to the SIMPLIFIED PIEZOELECTRIC COUPLING diagram. Each crystal blank produces mechanical vibrations at the crystal input when an electrical intermediate frequency signal is applied. These vibrations occur due to the inherent piezoelectric property in the crystal material and are propagated throughout the crystal. This same piezoelectric property converts the mechanical vibrations back to an electrical intermediate frequency signal at the output electrodes. The high "Q" of the crystals creates the narrow bandpass of the filter which results in excellent off-channel signal rejection.

The output of the first four-pole crystal filter is coupled to the first i-f amplifier through a fixed-tuned matching network.

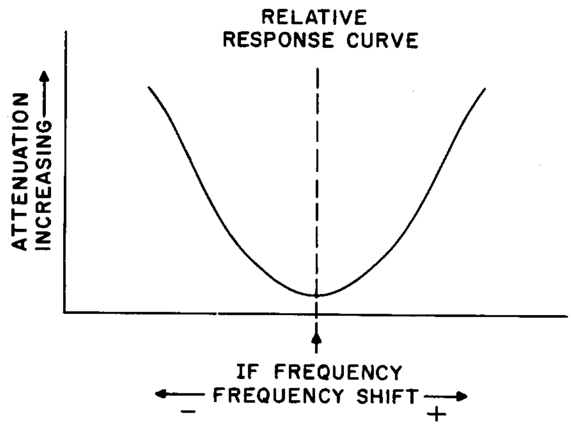
(4) First IF Amplifier

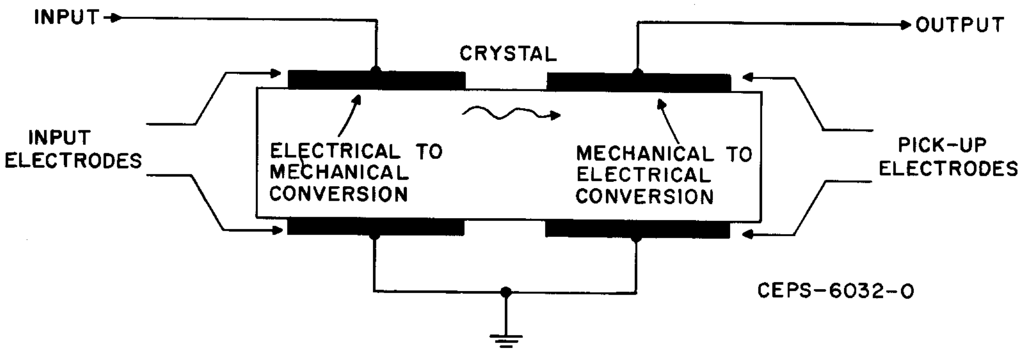
This circuit consists of an integrated circuit with associated discrete components to provide approximately 70 dB of gain to the i-f signal.

The IC contains three differential amplifier stages that are internally voltage regulated and temperature compensated. Isolation between the three stages is provided internally within the IC. The output of the IC is applied to the input of the second four-pole crystal filter .

(5) Second Four-Pole Crystal Filter

The crystals in this filter operate in a manner identical to that of the crystals in the first four-pole crystal filter described previously. Final receiver selectivity is established at this





Simplified Piezoelectric Coupling Diagram

filter. The output of this filter is coupled to the second i-f amplifier and limiter stage by a fixed-tuned matching network.

(6) Second IF Amplifier and Limiter

The second i-f amplifier and limiter consists of an integrated circuit with associated discrete components and performs two functions: (1) amplification and (2) limiting.

This stage is similar to the first i-f amplifier in that it has internal voltage regulation and temperature compensation. However, it employs four differential amplifier stages instead of three. The first two differential amplifier stages provide approximately 55 dB of gain to the i-f signal. The output of the second stage is used to provide metering (Meter 5). Its output is applied to the third differential amplifier stage which along with the fourth stage becomes over-driven to provide excellent symmetrical limiting characteristics.

Full limiting occurs with weak or strong signals or no signal (noise only).

The limited output of this IC provides a signal of constant amplitude to the discriminator. This is necessary since the discriminator would respond to a change in amplitude as well as to a change in frequency.

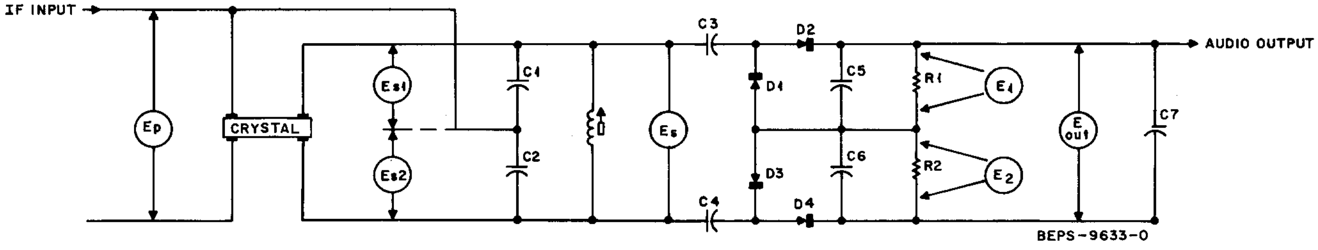
(7) Crystal Discriminator

The discriminator used is a phase discriminator. The operation is dependent upon a 90° phase shift which occurs at resonance between the input and output voltages of the dual-resonator crystal, (similar to a double-tuned, inductive coupled transformer).

Crystals inherently have a much more rapid change in phase shift than coils due to their high Q. Therefore, the steeper slope of a crystal discriminator will produce a much greater audio output voltage than a coil discriminator for given deviation in frequency.

Refer to the SIMPLIFIED DISCRIMINATOR CIRCUIT diagram. The component reference symbol letters do not correspond to the components shown on the schematic diagram but are used to simplify the discussion. The tuned circuit formed by L and series connected C_1 and C_2 is resonant at 11.7 MHz.

When the frequency of the applied primary voltage (E_P) is changed, the phase angle between E_P and E_S (secondary voltage) changes from that at resonance. This changes the relative magnitude of E_1 and E_2. The phase relationships are shown in the DISCRIMINATOR PHASE RELATIONSHIPS diagram.



Simplified Discriminator Circuit

Diodes D1 through D4 form a voltage doubling detector. The output voltages from the detector are developed across R1 and R2. The circuit is such that the output voltage (E_{OUT}) is equal to the difference between these two separate voltages. This means that when the frequency of the carrier, after conversion in the mixer, is exactly equal to the 11.7 MHz intermediate-frequency, no output will be obtained from the diodes because the voltage drops are equal and opposite (zero adjustment in the receiver alignment procedure). As the signal deviates from the intermediate frequency of 11.7 MHz, an output voltage will appear at E_{OUT}, as shown in the simplified discriminator circuit. The polarity of the voltage depends upon the magnitude of the voltages across R1 and R2. For the diode polarity shown, the discriminator output is positive below 11.7 MHz, where the phase angle changes and E_1 is greater than E_2, as shown in the phase relationships diagram. Above 11.7 MHz, the phase shift makes E_2 greater than E_1 and the output is negative.

b. Audio and Squelch

(1) Emitter Follower Circuit

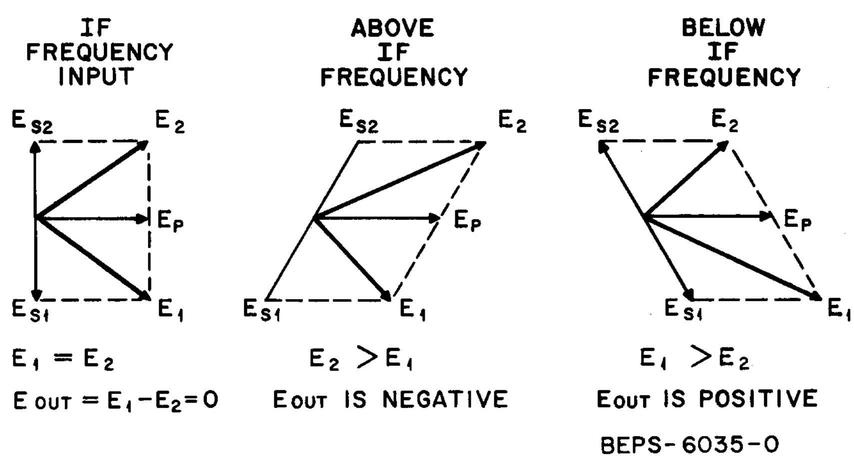
The emitter follower circuit provides a low impedance output which isolates the high impedance discriminator output from the following squelch and audio circuitry.

The output of the discriminator is capacitively coupled to the emitter follower input at IC201-1 and may consist of noise, audio signals, and/or PL tones. The output of the emitter follower at IC201-2 is routed to (1) external VOLUME and SQUELCH controls through coupling capacitor C203 and (2) a PL decoder in "Private-Line" tone-coded squelch radios.

(2) Audio Amplification Circuit

The signal from the VOLUME control is returned to the audio and squelch board at P903-5.

In "Private-Line" tone-coded squelch radios, jumper JU201 is removed to route audio to a PL filter on the PL decoder. Audio returned from this filter is free of PL tones, preventing the tone from being heard at the speaker. C204 and C205 prevent any dc potential from the audio channel from affecting the squelch shunt switch at that point.



Discriminator Phase Relationships

The preamplifier amplifies the low-level audio signal to provide the required drive to the differential amplifier. Negative feedback around the preamplifier is provided by C206 to attenuate audio signals above 3000 Hz. Further rolloff is provided by R205 and C233, and by R208 and C209. Capacitors C210 and C211 dc isolate the preamplifier output and the differential amplifier input from the squelch shunt switching.

The differential amplifier, output provides drive for the complementary amplifier. Resistors R216 and R217 form a bias network that biases the differential amplifier at exactly one-half of the supply voltage. Capacitor C212 eliminates the effect of any transient voltage that may be applied to the differential amplifier.

Final audio amplification on the audio and squelch board occurs in the complementary amplifier. Its output provides drive for the audio power amplifiers which are mounted on a separate board. Complementary amplifier emitter resistors R211 and R212 are external to the IC due to heat dissipation requirements.

Audio returned to the audio and squelch board from the audio power amplifier transistors is applied to the output transformer primary windings. This transformer consists of four windings -- two input primaries, an output secondary, and a feedback secondary. The output secondary winding couples audio power to an external 8-ohm speaker which can be driven with up to 10 watts at less than 5% distortion. Negative feedback from the output transformer winding through C208 and across R207 gives 6 dB per octave de-emphasis (roll-off) to the audio which has been pre-emphasized 6 dB per octave in the transmitter. Below 300 Hz, feedback from R209 and across C207 increases giving low frequency de-emphasis. Capacitor C235 supplies a light load to the audio power amplifier during certain situations such as the use of a headset. Capacitor C219 and C220 are rf bypass capacitors that shunt injection transients on the A+ and A- lines to ground.

Audio from T201 secondary is applied via intercabling to the control head. Jumpers JU1 and JU2 are used in conjunction with either the microphone or handset. If the handset is used, without receiver muting, JU2 is disconnected so that audio is heard in the handset as well as the speaker. If a speaker muting switch is used with the handset, JU1 and JU2 are both disconnected. The audio path is then through the hang-up box speaker mute switch so that audio is applied either to the speaker or handset (but not both).

(3) Noise Activated Squelch Circuit

(a) Squelch Input Circuit

The input signal from the SQUELCH control may consist of noise, audio message, and/or PL tones.

An input shaping network precedes IC202 that passes high frequencies and attenuates low frequencies. Use of high frequencies eliminates the effect of voice and PL tones and results in more sensitive threshold squelch action.

The first amplifier and limiter is driven into limit by its input signal and prevents audio from squelching (disabling) the audio channel on voice signals. Amplified, limited noise is then passed through a coupling network to the second amplifier. This coupling network is also a high pass filter which further attenuates voice and PL tone signals to the second amplifier.

The second amplifier amplifies the noise signal and applies it through an RC coupling network to the detector. C227 and R223 form another high pass filter that attenuates the low frequencies. Capacitor C228 is used to produce a peak-to-peak detector action from the noise detector, and thus, generate twice the output voltage of a peak detector. This capacitor does not affect frequency response.

(b) Detector and Switching Circuit

The detector output level is a function of received signal strength and the setting of the SQUELCH control. The detector develops the dc output voltage across filter capacitor C229. The lowest dc output voltage corresponds to a no signal input (maximum noise) condition. The output voltage increases as the received rf carrier signal level increases (noise decreases). The voltage may be used in PL radios to give an indication of on-channel usage even though the following noise squelch circuitry is inhibited. A voltage higher than approximately 2.8 volts dc indicates that the channel is being used, although not necessarily heard due to PL selection.

The primary function of the detector output, however, is the control of shunt switching. This is done as follows.

The detector output is applied to three squelch control circuits simultaneously:

- long "squelch-tail" circuit
- long "squelch-tail" defeat switch
- carrier squelch switching logic

With no received rf carrier signal (maximum noise condition), the long "squelch-tail" circuit and long "squelch-tail" defeat switch are "off" and the carrier squelch switching logic is "on". The audio channel is subsequently disabled unless the squelch control logic is overriden by other circuitry.

As the input signal level increases (noise decreases), the detector output voltage increases. A detector output voltage above 2.8 volts dc results in enabling of the long "squelch-tail" circuit. The long "squelch-tail" circuit produces a voltage at IC202-12 of 5.5 volts dc; this voltage causes the carrier squelch switching logic circuit to turn off and enable the audio channel. Capacitor C231 and resistor R224 provide a rapid rise, slow decay time constant to the voltage applied to the carrier squelch switching logic circuit. This permits a weak signal to immediately enable the audio channel, yet delays the audio channel shut-off if the signal is in a "flutter" condition. The voltage necessary to disable the carrier squelch switching logic is approximately 3.8 volts dc or greater.

A voltage greater than 5 volts dc at the detector output (rf carrier signal level that produces 20 dB quieting, or better), turns on the long "squelch tail" defeat switch. This disables the long "squelch-tail" circuit and the 150-millisecond delay function. Audio channel disabling now occurs immediately after the rf carrier disappears.

(c) Squelch Output Circuit

The squelch control logic circuit directly controls the shunt switching.

The output of the squelch control logic circuit depends upon the output of the preceding carrier squelch switching logic circuit and three additional input functions. With no additional inputs and the carrier squelch switching logic circuit "off", the squelch control logic circuit will turn off the shunt switches, allowing a message to be heard. If the carrier squelch switching logic is "on", the squelch control circuit will turn on the shunt switches, disabling the audio channel.

Two of the three additional functions that may affect squelch control logic output are associated with "Private-Line" tone-coded squelch operation. "PL" ON-OFF (IC202-14), which may be either shorted to ground or open, is connected to the hang-up box in PL operation. When an open is present at pin 14, (OFF), a received signal with or without a PL tone will be heard from the speaker. When at ground potential (ON), the output of the carrier squelch switching logic circuit is inhibited. When the proper PL tone is received, a positive 9.5 volts dc from the PL decoder to IC202-8 turns "off" the squelch control logic circuit. This turns off the squelch shunt switches and allows a message to be heard.

The third additional function (mute) takes priority over all other squelch functions and mutes the audio channel via the squelch shunt switches when the radio set is in the transmit mode. While the transmitter is keyed, 9.6 volts dc is applied to P903-7 and coupled to IC202-11 to turn on the squelch shunt switches and disable the audio channel.

The squelch control logic output at IC202-10 supplies a digital output voltage to permit an indication that the receiver is unsquelched (audio channel enabled).

Audio disabling is performed by shunting two points of the audio circuit through a low impedance path to ground. When the two solid-state shunt switches are turned on, signals developed across resistors R225 and R226 are shunted to ground. This prevents any signals from being heard from the speaker. Conversely, when the shunt switches are "off", a message may be heard from the speaker. Both shunt switches are simultaneously either "on" or "off", and provide a total of 90 dB of attenuation to any signal in the audio channel when "on".

c. "Private-Line" Decoder

(1) General

(a) "PL" Tone Present

With PL tone present on the input signal to the decoder, the PL filter passes low frequency

PL tones and attenuates voice and noise signals above 300 Hz. The noise switch shorts out high frequency noise signals. The tone from the PL filter is amplified by the PL amplifier and limited to a fixed level by the amplifier/clipper. The tone is applied to the "Vibrasponder" resonant reed which vibrates when the tone is the same frequency as the reed's resonant frequency. When the reed is vibrating, the device acts as a transformer and couples the tone from primary to secondary. The tone is amplified in the next stage and applied to a detector. When tone is present, the detector develops a dc output which activates the output switch. When the output switch is activated, 9.5 volts is present at its output to enable the audio circuits. The output also activates the noise switch.

The separate audio filter which is located on the PL decoder board is a high pass filter which allows voice signals above 300 Hz to pass but blocks PL tones. This filter is connected in series with the audio signal path in "Private-Line" radios to prevent the PL tone from being heard in the speaker.

(b) "PL" Tone Absent

When no PL tone is present, or a tone other than that required to activate the reed is present, no signal is coupled through the "Vibrasponder" resonant reed. No detector output is developed, thus the output switch is off. The output voltage is 0 volts at this time which inhibits the squelch circuit to prevent an audio output to the speaker. The noise switch is off at this time which allows high frequency noise to bypass the PL filter. The presence of high frequency noise desensitizes the amplifiers and acts as an "anti-falsing" feature to prevent a random low-frequency noise signal from activating the resonant reed.

(2) Decoder Input Circuits

The receiver discriminator output signal is routed through an emitter follower stage on the receiver audio & squelch board. The emitter follower output is applied as the input to the PL decoder. The signal consists of noise only when no carrier signal is being received. With a carrier signal input to the receiver, the noise is reduced and voice audio or voice audio and PL tone added.

These input signals are routed through the low pass filter and noise gate circuit. A receiver input signal that is modulated ±0.5 kHz with PL tone produces a nominal 60 millivolts rms signal at the input to the decoder. The low pass filter consisting of L801, C802, C803 and C805 attenuates sharply all signals above 300 Hz. Thus, voice and noise signals above 300 Hz are blocked, but PL tones are passed. High pass filter C801, R803, and C807 presents a parallel path for high frequency noise whenever the decoder is not activated. This condition is desirable so that low frequency noise (only) will not falsely activate the decoder. When the proper tone has been received and the decoder is activated, noise switch Q807 acts as a short and grounds all high frequency signals before they reach amplifier Q801.

(3) Input Amplifier Circuits

Amplifier Q801 amplifies noise and PL tone signals which are coupled to amplifier/clipper Q802. Diode CR801 and the base emitter junction of Q802 limit both the positive and negative swing of the signal to a maximum amplitude. The amplified output of Q802 provides a constant amount of drive even though the amount of PL tone deviation from various transmitters is not constant. It also limits the noise signals to prevent oversensitivity to noise signals which could falsely operate the "Vibrasponder" resonant reed. "Vibrasponder" driver Q803 operates as an emitter follower to provide current drive to the low impedance "Vibrasponder" resonant reed.

(4) "Vibrasponder" Resonant Reed

The "Vibrasponder" resonant reed is the frequency determining device of the decoder. When the input tone from the "Vibrasponder" driver is the same frequency as the reed's resonant frequency, the reed vibrates. At resonance, the reed acts as a high Q transformer coupling energy from the primary to the secondary winding. At all other frequencies, the reed will not vibrate and no energy is coupled to the secondary winding. The reed is a precision built device consisting of a tuned cantilever reed of special steel mounted on a rugged base with a coil and permanent magnets. The entire assembly is spring-mounted and hermetically sealed in a metal housing to insure long life at peak performance under all types of conditions. Its design eliminates the need for servicing throughout its useful life. The plug-in unit is easily removed and replaced.

The reed is sensitive to within 1 Hz of its resonant frequency. Specific tones in the 67 to 210 Hz range are used.

(5) Output Circuit

When the proper PL tone is applied to the reed, it develops a sinusoidal wave output at its resonant frequency. This sinusoidal wave is amplified by Q804. Negative feedback through C810 maintains the sinusoidal waveform. The amplified signal is coupled to detector Q805 which converts the signal to a dc potential. Q805 is cut off with its collector voltage of 9.6 volts until the tone is applied. With tone applied, the positive most portion of the sinusoidal wave is clamped at approximately .6 volt. The positive swing of each cycle causes momentary conduction of Q805 and the collector voltage drops to near zero volts. C813 charges during the conduction period and discharges through R820 and R821 to develop a filtered dc potential which forward biases output switch Q806. With Q806 activated, 9.6 volts is gated to the output which unsquelches the receiver. Noise switch Q807 is also activated which places a short across the noise gate as explained in paragraph (b).

(6) Audio Filter

Audio and PL tone from the VOLUME control are routed through an audio filter consisting of C814-C817 and L802 and L803. The filter is electrically separate from the decoder but physically mounted on the same board. This filter is high-pass type which blocks the PL tone and passes the audio to the audio & squelch board.

5. ANTENNA NETWORK

Refer to the following SIMPLIFIED ANTENNA NETWORK diagram. The antenna network provides the following functions.

--Connects the transmitter final power amplifier stage to the radio antenna connector at all times.

--Provides the transmitter final power output stage with a low VSWR 50-ohm load during transmit independent of the load presented to the radio antenna connector.

--Attenuates all transmitter carrier hormonics to a level of at least -85 dB below the carrier.

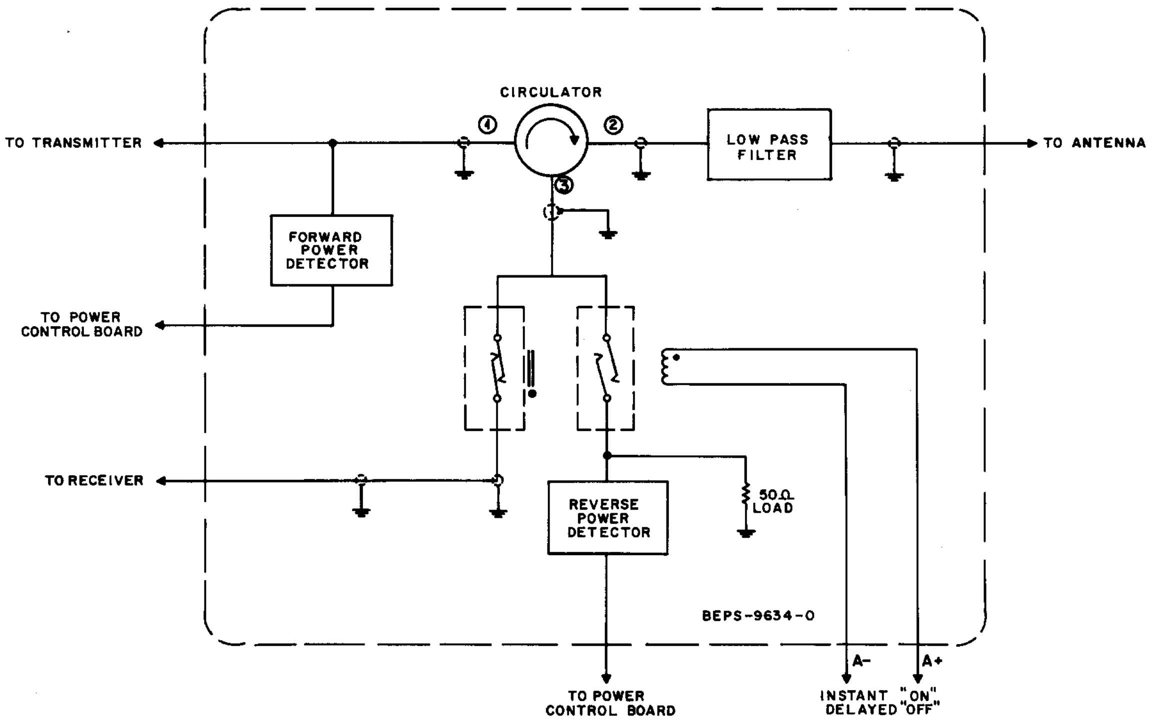
--Connects the receiver to the radio antenna connector during receive operation.

--Provides dc voltages proportional to forward and reverse power appearing at the antenna connector.

a. Circulator

The circulator is a 3-Port device which takes advantage of the unique magnetic properties of yttrium iron garnet (YIG). By subjecting a transmission line circuit sandwiched between two YIG discs to a critical value of static magnetic field, a device can be made which is non-reciprocal in nature. That is, a signal entering port 1 of the circulator leaves at port 2 and a signal entering port 2 leaves at port 3. In general a signal entering any port will leave at an adjacent port (in the direction of the arrow). This characteristic is used to advantage in the antenna switching network. The transmitter is always connected to the circulator at port 1 and the antenna is always connected to port 2 of the circulator. During transmit, port 3 is connected to a 50-ohm, 50-watt load through a reed switch. This circuit arrangement provides the transmitter power amplifier output stage with a low VSWR 50-ohm load independent of the condition of the load connected to the antenna connector. Whenever a mismatched load appears at the antenna connector, the reflected power from the mismatched load enters port 2 of the circulator and is routed to port 3 and to the 50 ohm load inside the unit.

During receive, the reed switch to the 50-ohm load is open and the receiver is connected to port 3 of the circulator. The received signal enters the antenna connector, through the low pass filter and into port 2 and is routed through the circulator and out port 3. The signal is then connected to the receiver via the reed switch.



Simplified Antenna Network

b. Power Detectors

To provide an input to the power control board indicating the power level out of the transmitter, a peak voltage detector is coupled through a capacitive divider to the coaxial line at the transmitter input port of the circulator. This detector provides a dc output voltage proportional to the square root of the power entering port 1 of the circulator.

A peak voltage detector is also used to sense the peak voltage across the 50-ohm load in the unit. Under most normal operating conditions, the power disipation in the load is only a few watts. However, under extreme conditions of antenna mismatch and a high power radio, the reflected power could approach the power disipation (50 watts) capability of the load. To protect the load against such a condition, the rf voltage across the load is sensed and a dc voltage proportional to the rf voltage is fed back to the power control board. When the rf voltage across the load starts to increase beyond the normal safe range, the power control decreases the power output of the transmitter to maintain a safe dissipation in the 50 ohm load.

c. 50-Ohm Load

The 50-ohm load is required to have a low VSWR in the UHF band. It should be able to absorb the maximum reflected power from the antenna while monitoring this VSWR. To accomplish this, the load is constructed using thick-film techniques and is mounted on a beryllia block to achieve good thermal conduction of the dissipated power to the heat sink.

6. DC SWITCHING, REGULATION, AND FILTERING

The control board (center-interface board) provides dc switching, regulation and filtering for the radio set. Specifically the functions are

- Power distribution and filtering.
- A 9.6-volt regulator.
- Push-to-talk switching and sequencing.
- Reverse polarity protection.
- Interconnection between circuits of the radio set.
- Frequency selection routing for four-frequency radios.
- Interconnections for options (Time-Out Timer, etc.).
- Metering

Receptacles on the control board mate with pins on the transmitter and receiver circuit boards to distribute desired functions from outside the radio and from board to board inside the radio. The double sided board routes the signals and eliminates the need for most wires. The few wires used, are terminated in removable female pin tip connectors to mate with pins in the circuit board. Additional pins in the board are provided for connecting accessory items such as a positive ground converter. The 37-pin connector at the end of the circuit board mates with the cable to the control head and battery. A control socket allows a Motorola portable test set with a TEK-37 Adapter Cable to control the radio set for testing. For the following circuit operation, refer to the control board schematic diagram in the DIAGRAMS section of this manual.

a. Power Distribution and Filtering

Vehicle battery voltage is applied at various pins of P901. Due to the high current requirements of the power amplifier, A+ and A- for the power amplifier are brought in at P901-A and -B which are large diameter pins that mate with plug-on cables from the power amplifier. A+ is also applied at J901-22 and filtered by L901 and C901. The "filtered A+" is routed to the exciter and the audio & squelch circuit boards and made available to reed switch K901, which is closed when the push-to-talk function is activated. A- is supplied to J901-11 as reference voltage to the exciter, audio & squelch board and reed switch K902.

Reverse polarity protection diode CR909 connects between A+ and A-. The diode is reverse biased when the input power is of the proper polarity and has no effect. If reverse polarity is applied, the diode short circuits and blows the fuse to protect the circuits in the radio set.

In negative ground installations, "battery (+)" is applied to P901-3 and filtered by L902 and C902. For positive ground operation, there is no input at pin 3; instead "battery (-)" is applied at P901-18 and routed to a positive ground converter. The (+) output of the converter is applied to the junction of L902 and C902. With either type of operation, a "filtered B+" voltage is available at this point for distribution to the receiver and the 9.6-volt regulator.

The circuit-board mounted control socket allows a portable test set to be connected for various tests. The speaker audio can be monitored between pins 1 and 2, and microphone audio or microphone dc at pin 7. Pin 5 monitors push-to-talk keying. If the push-to-talk function is not present, pin 5 will be at the battery voltage. Pin 3 is omitted, +9.6 V is present on pin 4 (not directly measurable on test set), and pin 6 is ground reference.

b. 9.6-Volt Regulator Circuit

Filtered A+ is applied to a 9.6-volt regulator circuit which provides regulation within ±100 millivolts for input voltages from 10.5 to over 16 volts. Automatic shutdown occurs if the output becomes overloaded or shorted.

The regulated output voltage is developed across Zener diode CR911, diode CR912 and the resistors in the base of output voltage sensor Q903. Since the voltage across the Zener diode is constant, almost the entire variation is applied to the base of Q903. It amplifies and inverts the variation, developing a negative feedback which is applied to the base of driver Q902. Driver Q902, in turn, controls the base current drive to series regulator Q901. Total load current flows through Q901 which acts as a controlled series resistance in response to drive from Q902. The complete negative feedback path causes the resistance of Q901 to counteract output voltage variations.

Drive to Q901 is relatively independent of input voltage since drive to Q903 is derived from the regulated output. Therefore, its collector current and the drive to Q902 are also derived from the regulated output.

Diode CR910 protects the circuit from extreme overload such as a short. If the 9.6-volt output is shorted or overloaded, it drops toward zero. Q903 would tend to cut off. However, when the output voltage drops .6 volt below the voltage at the collector of Q903, diode CR910 conducts. This occurs if the output current exceeds 450 milliamps (normal load current is approximately 250 milliamps, plus the current for any optional accessory items operating from 9.6 volts). This action limits the amount of forward bias on Q902, and the emitter resistor limits maximum collector current of Q902. Since collector current of Q902 is the base drive current for Q901, it is limited to this same low value and Q901 shuts down.

The output voltage of the regulator is a nominal 9.6 volts. Some radios may be as low as 9.1 volts and others may be as high as 9.9 volts. However, the regulation for a given radio is ±100 millivolts from the regulated value over the entire range of input voltage, load, and temperature.

The output of the regulator develops the "9.6 volts continuous" which is applied to reed switch K902 and to some receiver and PL encoder circuits. In the receive mode, "switch 9.6 volts" is applied to certain receiver circuits. In the transmit mode, the "switched 9.6 volts" is removed and the "keyed 9.6 volts" is applied to the exciter board.

c. Push-to-Talk Switching and Sequencing Circuit (Refer to P-T-T Sequencing Diagram)

The push-to-talk switching and sequencing circuits control the application of dc power to the transmitter and control the sequencing so the receiver is disconnected from the circulator before the transmitter rf output is applied and the 50 ohm load is connected to the circulator in the antenna network. Sequencing during transmitter turn-off assures that rf power output is ended before the receiver is switched back to the circulator.

(1) Transmitter Turn-On

The following sequence of actions occurs to turn on the transmitter:

--Transmitter keying is initiated by closing the push-to-talk switch on the microphone.

--Closing the push-to-talk switch grounds one side of the 1st P-T-T reed Switch K901 coil. The other side is connected to "battery hot" and the reed switch energizes, closing the contacts. The switch operates equally well from negative ground or positive ground electrical systems.

--"Keyed A+" from K901 is routed through the exciter (and the PL encoder in "Private-Line" radios) to the second P-T-T reed switch K902.

--Initially, current flows through both coils of K902, producing opposite and cancelling magnetic fields. The reed switch does not energize at this time.

--"Keyed A+" is routed through diode CR913 to the antenna switch. The antenna switch energizes and removes the receiver from the circulator and connects the 50 ohm load.

--After approximately 10 milliseconds delay, C904 becomes charged and current through coil 2 of K902 decreases to the point where full magnetic cancellation no longer occurs. K902 energizes and applies "keyed A-" and "keyed 9.6 volts" to the exciter which allows rf output to be developed. At the same time "switched 9.6 volts" is removed from the receiver.

(2) Transmitter Turn-Off

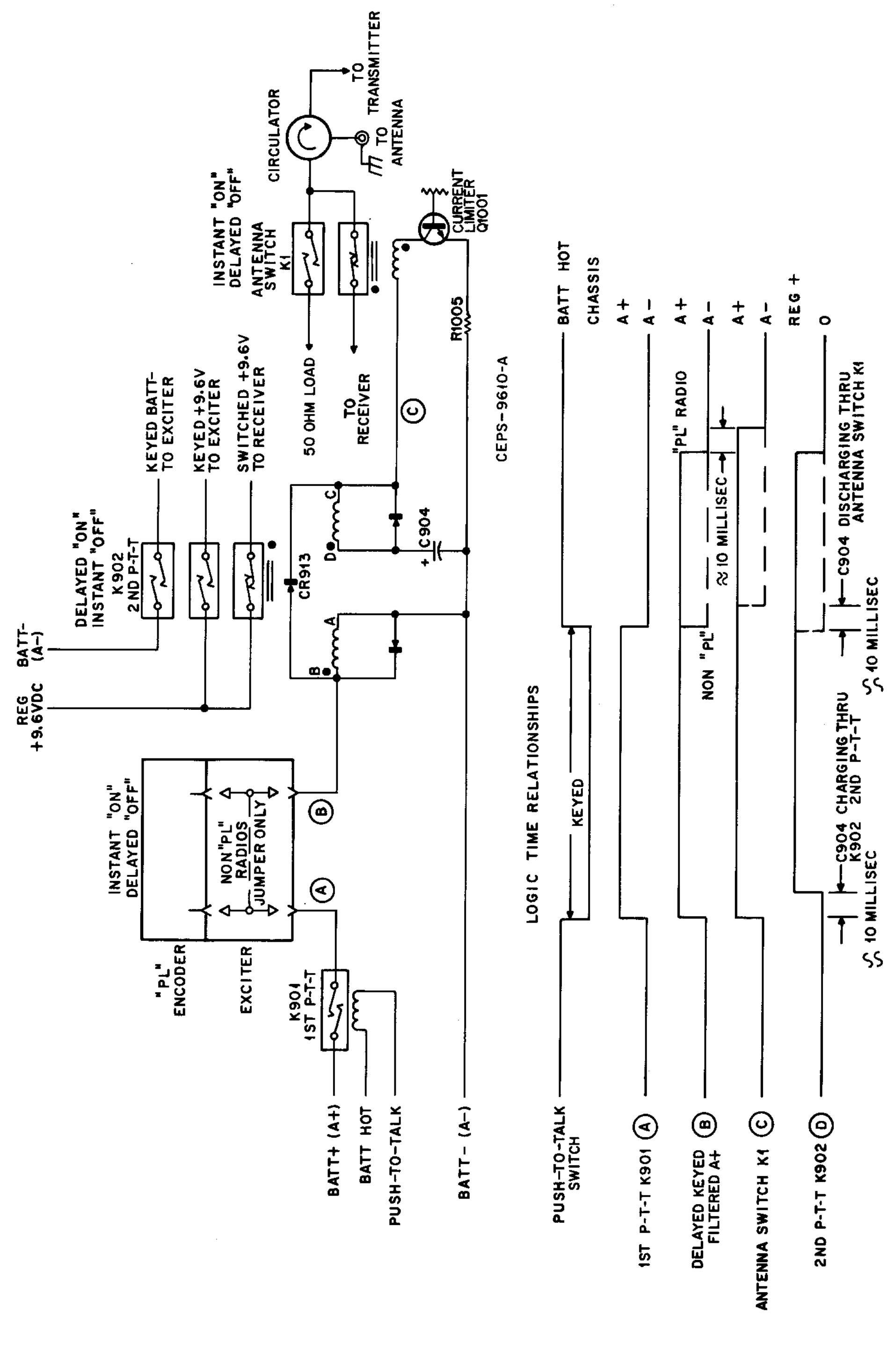
When the push-to-talk switch on the microphone is released, the following sequence of actions occurs:

--K901 de-energizes immediately.

--In "Private-Line" radios, "Keyed A+" continues for approximately 150 milliseconds after unkeying. This delay is produced by the PL encoder. In non-"Private-Line" radios, "keyed A+" is removed as soon as K901 de-energizes.

--K902 de-energizes immediately upon loss of "keyed A+", removing power from the transmitter.

--C904 discharges through the antenna switch coil. Sufficient current is available to produce approximately 10 milliseconds delay before the antenna reed switch de-energizes. This allows transmitter rf power output to go to zero before the receiver is connected back to the circulator.



P-T-T Sequencing Diagram

7. FREQUENCY SELECTION

a. General

The UHF "Micor" Radio Set is capable of operation on any one of from one to twelve channels. A channel is defined as one transmit frequency and one receive frequency that are selected as a transmit-receive frequency pairing for each available radio set channel. The transmit frequency may be the same as the receive frequency for a particular channel or the transmit and receive frequencies may be different. Through the use of an offset oscillator in the transmitter in conjunction with a receiver injection signal to derive the transmitter frequency, the need for channel elements in the transmitter is eliminated. In radio sets equipped with two offset oscillators, it is possible to transmit on two different frequencies for each channel element in the receiver, up to a maximum of twelve transmit frequencies. The appropriate offset oscillator for each channel is programmed with jumpers as described in the instructions in the following paragraphs.

Frequency selection in some multi-channel radio sets is accomplished through the use of a diode matrix on the control (interconnect) board (channels F1 through F4) and a separate diode matrix board (channels F5 through F12). On other multi-channel radio sets frequency selection is accomplished by using an optional four or twelve-channel universal switching board. The frequency selection system used in a particular radio set is chosen before manufacture, depending on the required transmit and receive frequency pairing for each channel. The following paragraph states the guidelines used for offset oscillator frequency determination and thus, the method of frequency selection used in the radio set.

b. Guidelines To Offset Oscillator Frequency Selection

These guidelines are used by the factory to determine the best offset oscillator frequency to be used in a particular radio set. The guidelines are provided for those cases where the serviceman may have to change the offset oscillator frequency, or change the transmitter from standard to wide-spaced operation in the field. Note that when a radio set is changed from standard to wide-spaced transmitter operation, the standard transmitter assemblies (exciter and low level amplifier) will have to be replaced with wide-spaced assemblies.

Step 1. Refer to the Table 1. Channel Selection Pairing Example #1 and make a similar table using your own transmit-receive frequency pairings.

Step 2. Subtract the receive frequency (F_R) from the transmit frequency (F_T) to obtain the offset spacing for each channel.

Table 1. Channel Selection Frequency Pairing Example #1

Control Head Switch Position	Transmit Frequency in MHz (F_T)	Receive Frequency in MHz (F_R)	* Offset Spacing in MHz (F_T-F_R)
F1	406.500	406.500	0.000
F2	406.500	406.000	+ 0.500
F3	406.000	407.000	- 1.000
F4	409.000	407.000	+ 2.000
F5	408.500	406.500	+ 2.000
F6	408.000	406.000	+ 2.000

*Offset spacing (F_T - F_R) may be a negative number.

Table 2. Allowable Offset Spacings

Radio Set Frequency Range in MHz	Usable Offset Oscillator Frequency in MHz	Allowable Offset Spacing in MHz (F_T-F_R)
406-420	* 8.7 to 20.7	- 3 to + 9
450-470	** 11.7 or 16.7	0 or + 5
470-512	** 11.7 or 14.7	0 or + 3

* This offset oscillator frequency is defined as the "plug-in" oscillator frequency.

** If a wide-spaced transmitter is used, one offset oscillator frequency will always be 11.7 MHz which corresponds to an offset spacing of 0 MHz. The other offset oscillator frequency will be either 14.7 MHz or 16.7 MHz or the "plug-in" oscillator frequency.

Step 3. Compare the offset spacing frequencies obtained in your table with the allowable offset spacing shown in Table 2., above. If more than two offset spacings (F_T-F_R) are present, excluding 0 MHz, then a four or twelve-channel universal switching board is required. Otherwise, a four or twelve channel diode matrix board is used. If the most common offset spacing other than 0 MHz, is not +5 MHz for 450-470 MHz radio sets, or is not +3 MHz for 470-512 MHz radio sets, the offset spacing is not allowable and may not be used in the radio set.

In the example shown, the radio set frequency is in the 406-420 MHz range and uses the "plug-in" oscillator frequency. In this frequency range, the most advantageous offset oscillator frequency choice is that frequency which corresponds to the most common offset spacing other than 0 MHz. Reviewing Table 1, shows that the most common offset spacing other than 0 MHz is +2.000 MHz. The required offset oscillator frequency is calculated using the following formula.

$$F_{OFF} = (F_T - F_R) + 11.7 \text{ MHz}$$

Where: F_{OFF} = Offset Oscillator Frequency in MHz.

For an offset spacing of +2.000 MHz, the offset oscillator frequency would be

13.7 MHz; (408-406 MHz) + 11.7 MHz.

c. Radio Sets Using Diode Matrix Board

(1) Circuit Description

Refer to the universal switching board and diode matrix board schematic diagram in DIAGRAMS section of this instruction manual. Selection of transmit-receive frequency pairs for channels one through four is accomplished with the F1 through F4 diode matrix on the main control (interconnection) board. Selection of frequency pairs for channels five through twelve is accomplished by the addition of a diode matrix board to the receiver. In radio sets equipped with two offset oscillators, it is possible to transmit on one of two different frequencies for each channel element for a maximum of twelve transmit frequencies. The selection of the transmit-receive frequency pairs for each channel as well as the selection of the standard or wide-spaced offset oscillator for the transmit frequency is made by programming the diode matrices with jumpers.

The offset oscillator select jumpers are jumpers JU901 through JU904 on the main control board, for channels F1 through F4, and jumpers JU1205 through JU1212 on the diode matrix board for channels F5 through F12. If the offset oscillator select jumper is not cut for a given channel, the transmit frequency will be higher than the receive frequency. In 450-470 MHz radio sets, the difference is +5 MHz and in 470-512 MHz radio sets, the difference is +3 MHz. If the offset oscillator select jumper is cut for a given channel, the transmit frequency will be the same as the receive frequency.

When two or more channels have the same receive frequency but different transmit frequencies, jumpers are added to select the same channel element in the receiver for each of the common control head channel selector switch positions. The jumpers are used to connect the anodes of the corresponding channel element

Table 3. Channel Selection Frequency Pairing Example #2

Control Head Switch Position	Transmit Frequency in MHz (F_T)	Receive Frequency in MHz (F_R)	Offset Spacing in MHz (F_T-F_R)
F1	456.900	451.900	+ 5.000
F2	457.000	452.000	+ 5.000
F3	452.000	452.000	0.000
F4	451.900	451.900	0.000

switching diodes for selection of the common channel element. For four-channel radio sets and for channels F1 through F4 of twelve-channel radio sets, the diodes are CR905 through CR908. The diodes are located on the main control board. For channels F5 through F12 of twelve-channel radio sets, the diodes are CR1201 through CR1208. The diodes are located on the diode matrix board. The radio sets may be operated with less than their full four or twelve-channel capabilities. In which case, jumpers are added to select the last operational pair of transmit-receive frequencies for all extra positions of the control head channel selector switch.

(2) <u>How To Program Four-Channel Radio Set</u>

To determine how to program the control board diode matrix for four-channel radio sets, proceed as follows:

Step 1. Refer to Table 3. Channel Selection Frequency Pairing Example #2 and make similar table using your own transmit receive frequency pairing.

Step 2. Subtract the receive frequency (F_R) from the transmit frequency (F_T) to obtain the offset spacing for each channel. For 450-470 MHz radio sets, the allowable offset spacing can be 0 MHz or +5 MHz, or both. For 470-512 MHz radio sets, the allowable offset spacing can be 0 MHz or +3 MHz, or both. For any other offset spacing, the transmit-receive frequency pair is <u>not</u> allowable and can not be used in the radio set.

Step 3. Program the offset oscillator select jumpers as follows. For those channels where the offset spacing is 0 MHz, cut the corresponding wide-spaced select jumpers. This prevents the wide-spaced offset oscillator from being selected. In this example, cut JU903 and JU904 on the main control board. For those channels where the offset spacing is either +3 MHz or +5 MHz (only one offset spacing may be used), make sure that the wide-spaced select jumper(s) is present. In this example, JU901 and JU902 should be present on the main control board.

Step 4. Insert channel elements into their proper positions. In this example, insert the 451.900 MHz and the 452.000 MHz channel elements into positions F1 and F2, respectively on the receiver rf and if board. Note that when two channels share the same receive frequency, the channel element should be installed into the lowest receive frequency position.

Step 5. Program the receive frequency select jumpers on the main control board for those channels which share common receive frequencies. In this example, R1 and R4 share one receive frequency and R2 and R3 share another receive frequency. Connect a jumper between the anodes of CR905 and CR908 and another jumper between the anodes of CR906 and CR907.

Step 6. For four-channel radio sets which are to be operated with less than four channels, jumpers must be added so that the last set of operational frequencies is also selected by all extra positions of the control head channel selector switch. For example, a radio set ordered for two-channel operation would require jumpers between the anodes of CR906, CR907 and CR908. In addition, JU903 and JU904 must be programmed the same as JU902.

Step 7. Insure that you have programmed the diode matrix properly by tracing the channel element select path for each transmit and receive frequency, from the control board channel select pins through to the respective channel element. Each of the eight circuits should lead to one and only one channel element.

Table 4. Channel Selection Frequency Pairing Example #3

Control Head Switch Position	Transmit Frequency in MHz (F_T)	Receive Frequency in MHz (F_R)	Offset Spacing in MHz (F_T-F_R)
F1	456.000	451.000	+ 5.000
F2	455.950	450.950	+ 5.000
F3	455.900	450.900	+ 5.000
F4	450.900	450.900	0.000
F5	451.000	451.000	0.000
F6	450.850	450.850	0.000
F7	455.800	450.800	+ 5.000
F8	450.800	450.800	0.000
F9	455.850	450.850	+ 5.000
F10	450.950	450.950	0.000
F11	450.750	450.750	0.000
F12	455.750	450.750	+ 5.000

(3) How To Program Twelve-Channel Radio Set

The programming methods used with twelve-channel radio sets is much the same as that used with four-channel radio sets. It is suggested that the reader familiarize himself with those methods before proceeding with this example. Note that the diode matrix for channels F5-F12 is contained on a separate circuit board.

Step 1. Refer to Table 4. Channel Selection Frequency Pairing Example #3 and make a similar table using your own transmit-receive frequency pairing.

Step 2. Subtract the receive frequency (F_R) from the transmit frequency (F_T) to obtain the offset spacing for each channel. Note that only an exact offset spacing of 0 MHz or +5 MHz or both may be used in 450-470 MHz radio sets. Only an exact offset spacing of 0 MHz or +3 MHz or both may be used in 470-512 MHz radio sets.

Step 3. Program the offset oscillator select jumpers as follows. In this example cut jumpers JU904 (F4), JU1205 (F5), JU1206 (F6), JU1208 (F8), JU1210 (F10) and JU1211 (F11).

Step 4. Insert channel elements into their proper positions. In this example, the channel elements are installed as shown in Table 5., below.

Table 5. Channel Element Placement

Channel Element Frequency in MHz	Position on Receiver RF & IF Board
451.000	F1
450.950	F2
450.900	F3
459.850	F6
450.800	F7
450.750	F11

Step 5. Program the receive frequency select jumpers on the F5-F12 diode matrix board. In this example, add jumpers as shown in Table 6., below.

Table 6. Receive Frequency Programming

Common Receive Frequency in MHz	Control Head Switch Position	Add Jumper Between J106 Points
451.000	F1 & F5	1 & 5
450.950	F2 & F10	2 & 10
450.900	F3 & F4	3 & 4
450.850	F6 & F9	6 & 9
450.800	F7 & F8	7 & 8
450.750	F11 & F12	11 & 12

Step 6. For twelve-channel radio sets which are to be operated with less than twelve channels, jumpers must be installed so that the last set of operational frequencies is also selected by all extra positions of the control head channel selector switch. For example, a radio set ordered for eight-channel operation would require jumpers between J106-8, -9, -10, -11 and -12. In addition, JU1209 through JU1212 would have to be programmed the same as JU1208.

(4) One-Channel Radio Set

One-channel radio sets do not require jumper programming. The channel element is always installed in the F1 position on the receiver rf and if board. Jumper JU909 is connected between the cathode of CR905 and chassis ground on the main control board as shown on the control board circuit board detail. The channel element is activated whenever power is applied to the radio set.

d. Radio Sets Using Universal Switching Board

(1) Circuit Description

Refer to the universal switching board and diode matrix schematic diagram in the DIAGRAMS section of this instruction manual. The universal switching board allows independent transmit-receive frequency pair programming for each position of the control head channel selector switch. The board uses a diode matrix which enables a programmable transistor matrix to effect independent frequency selection.

Transistors Q1201 through Q1224 form the transistor matrix. The even-numbered transistors select the receive frequency. Their collectors are connected to circuit board eyelets R1 through R12. The odd-numbered transistors select the transmit frequency. Their collectors are connected to circuit board eyelets T1 through T12. One transistor from the transmit-select group is paired with one transistor from the receive-select group. The emitters of the transistors in the pair are connected to a diode in the diode matrix.

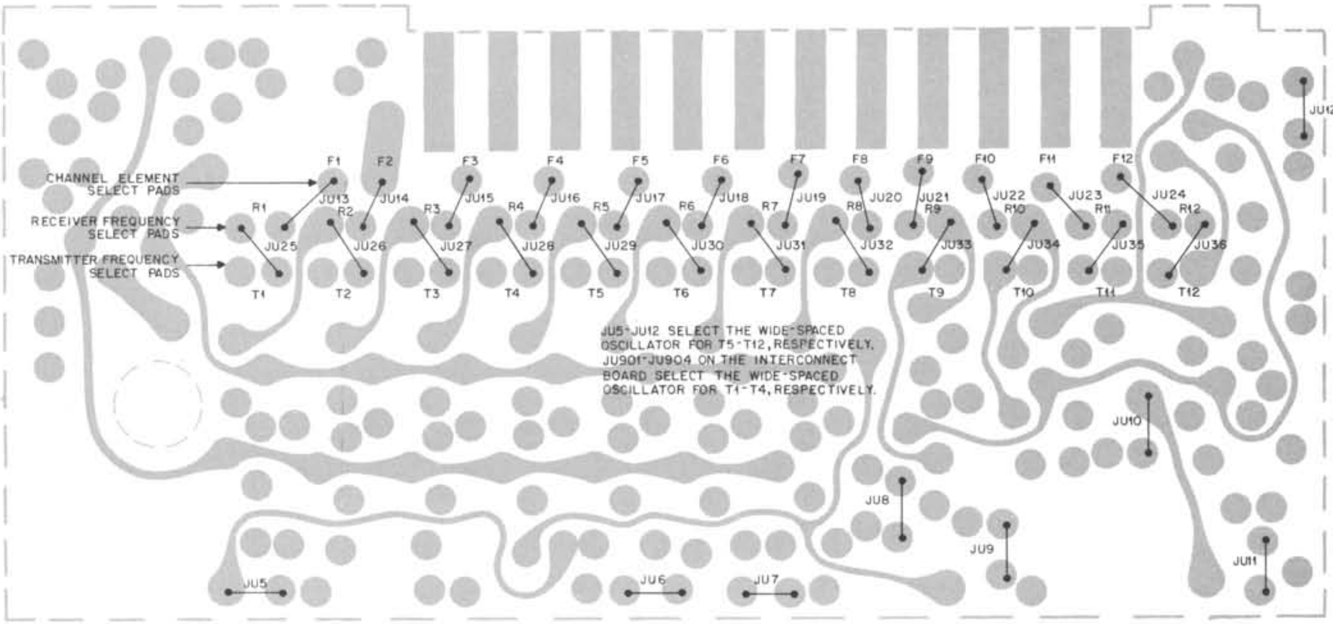
When the radio set is in the receive condition, only one transistor on the board is turned-on. It is selected through the diode matrix by the control head channel select switched ground and the bias developed across R1204. The bias across R1204 is developed from the continuous +9.6 volt line, through R1203 and CR1217.

When the radio set is transmitting, only two of the universal switching board transistors are turned-on. One of the two is always Q1225. The other will be the transistor in the transmit select group that is paired with the previously selected receive transistor. The transmit select transistor bias is developed across R1202.

When keyed +9.6 V is applied to the base of Q1225 through R1201, Q1225 saturates. This causes base bias for the transmit select transistors to be developed across R1202. With Q1225 in saturation, no current can flow through CR1217 and no bias is developed across R1204. All of the receive select transistors are therefore turned-off.

The channel element ground leads are connected through J106 to circuit board eyelets F1 through F12. If a jumper is connected from an "F" eyelet to a "T" or "R" eyelet, the channel element connected to that "F" eyelet will be activated whenever that particular "T" or "R" point is selected.

If the universal switching board is being field installed into the radio set, remove CR905 through CR908 from the main control board.



NOTES:
1. BOARD VIEWED FROM COMPONENT SIDE.
2. FOR CLARITY, ONLY JUMPERS ARE SHOWN.

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Universal Switching Board With Programming Jumpers Intact

Equivalent diodes are contained on the universal switching board in a similar circuit configuration.

The following procedure explains how to set up a radio set for a given group of transmit-receive frequency pairs.

(2) Programming Concept

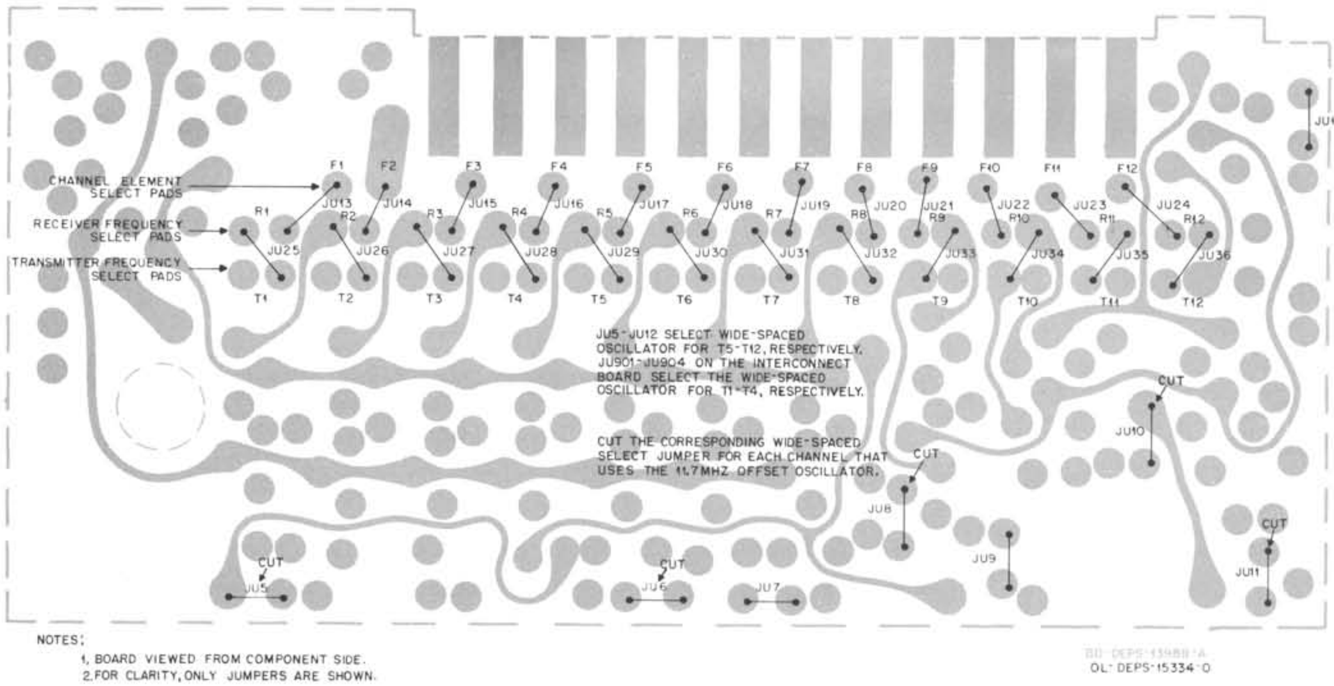
The universal switching board is supplied with all 36 programming jumpers present. Refer to the Universal Switching Board With Programming Jumpers Intact Diagram. The programming jumpers are either cut, left intact or relocated as outlined in the example described in the following paragraphs. The programming jumpers are used to interconnect three sets of twelve pads (designated the F, R and T pads). Each set of pads is numbered from one through twelve as shown in the diagram. The F pads are interconnected to corresponding channel elements on the receiver RF and IF board. Proper placement of the programming jumpers from the F pads (channel elements) to the appropriate R pads (receive frequency) and then to the T pads (transmit frequency) results in the desired receive-transmit frequency selection for the corresponding radio channel. Each F pad has one eyelet and therefore will accept only one jumper for channel element selection. Each R pad and T pad have two eyelets and therefore will accept two jumpers for frequency selection. In addition, the universal switching board includes wide-spaced exciter select jumpers, JU5 through JU12, which permit selection of the second offset oscillator frequency for channels F5 through F12, respectively.

(3) How To Program The Radio Set

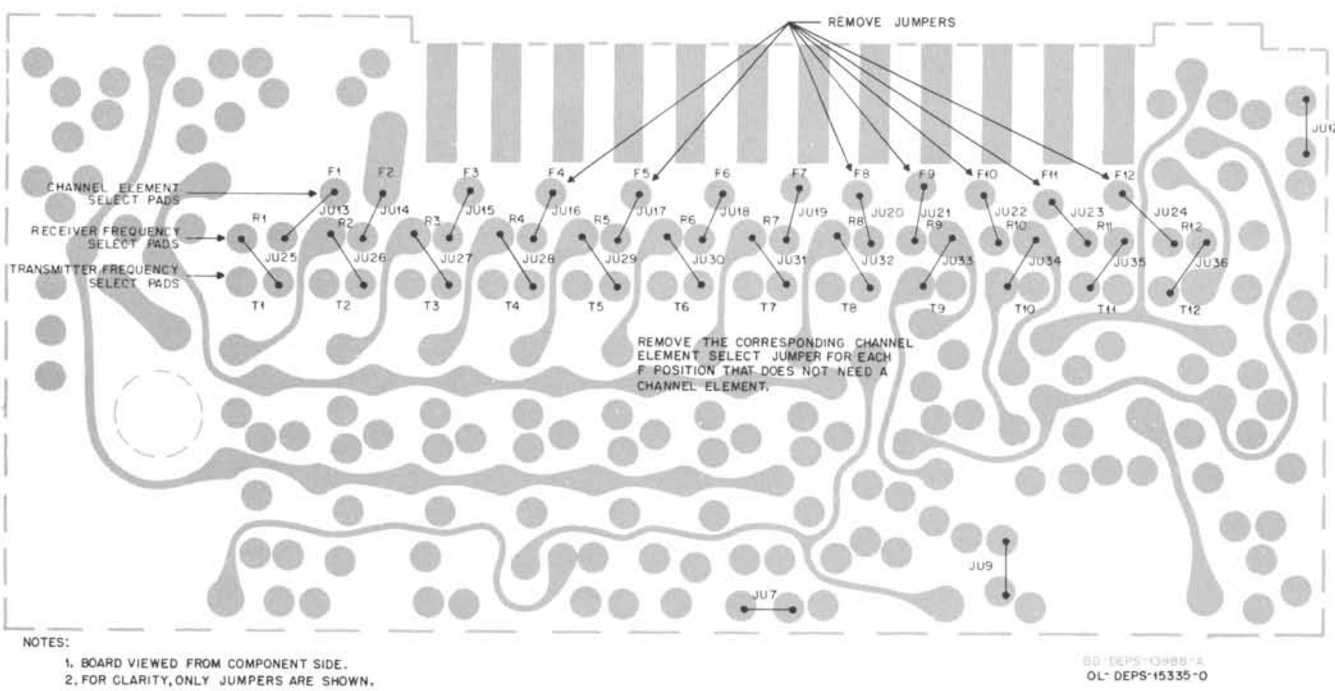
To determine how to program the universal switching board for your radio set, proceed as follows:

Step 1. Refer to Table 7. Channel Selection Frequency Pairing Example #4 and make a similar table using your own transmit-receive frequency pairing. The example shown is for the twelve-channel radio set. The four-channel radio set would be programmed in a similar manner.

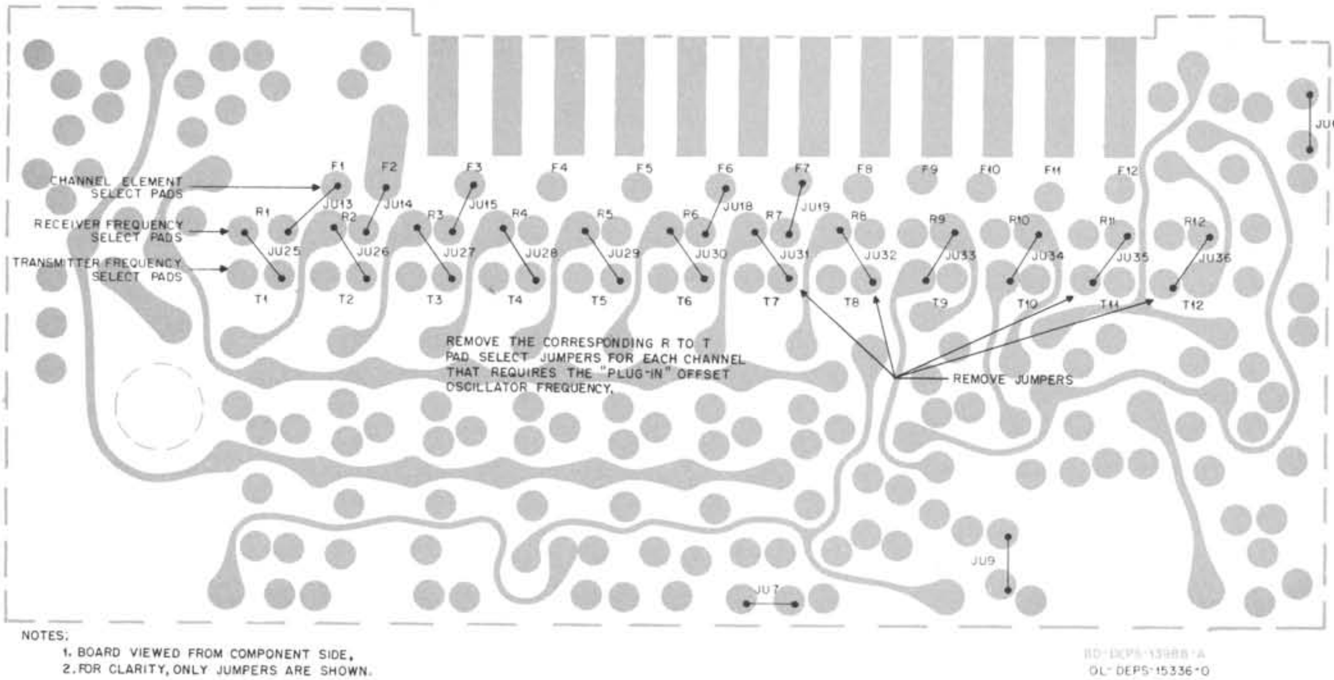
Step 2. Subtract the receive frequency (F_R) from the transmit frequency (F_T) to obtain the offset spacing for each channel.



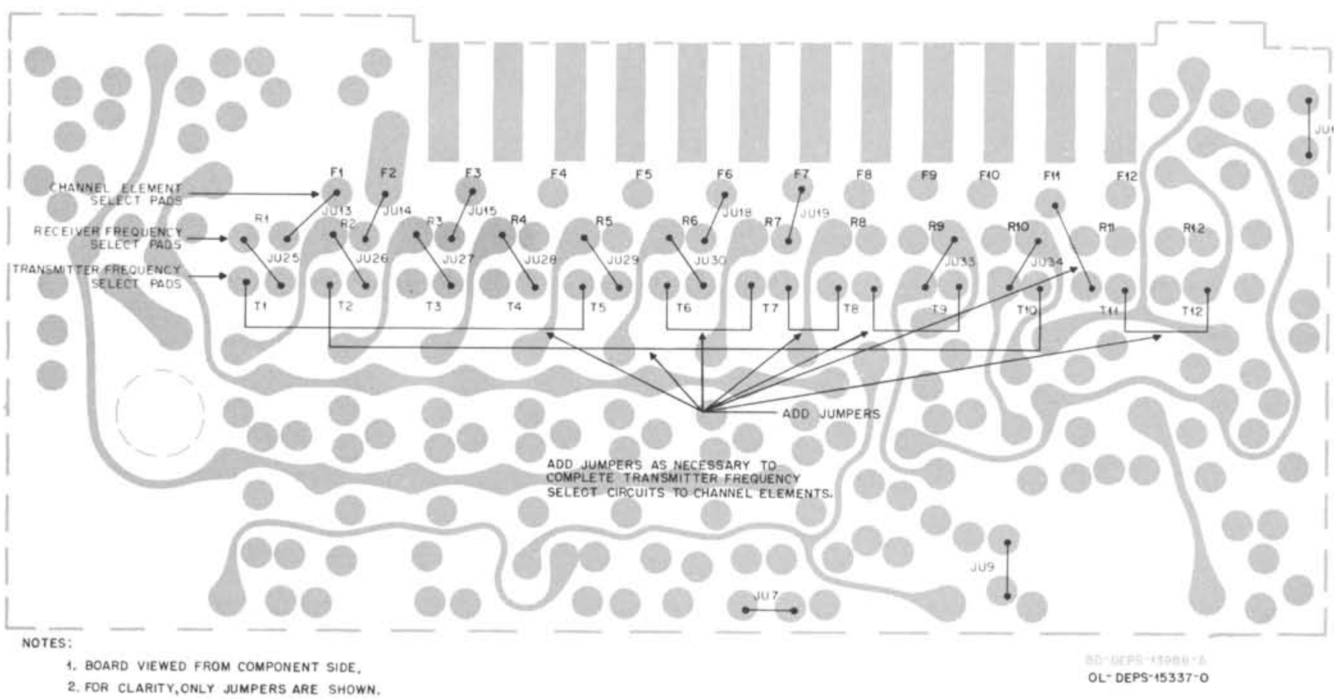
Universal Switch Board
Programming Step 3.



Universal Switching Board
Programming Step 6.



Universal Switching Board
Programming Step 7.



Universal Switching Board
Programming Step 8.

Table 7. Channel Selection Frequency Pairing Example #4

Control Head Switch Position	Transmit Frequency in MHz (F_T)	Receive Frequency in MHz (F_R)	* Offset Spacing in MHz (F_T-F_R)
F1	456.000	451.000	+ 5.000
F2	455.950	450.950	+ 5.000
F3	455.900	450.900	+ 5.000
F4	450.900	450.900	0.000
F5	451.000	451.000	0.000
F6	450.850	450.850	0.000
F7	455.850	450.800	+ 5.050
F8	450.850	450.800	+ 5.050
F9	455.850	450.850	+ 5.000
F10	450.950	450.950	0.000
F11	450.750	450.950	- 0.200
F12	455.750	450.950	+ 4.800

* Offset spacing (F_T-F_R) may be a negative number.

Step 3. Compare the offset spacing frequencies obtained in your table. For those channels whose offset spacing is 0.000 MHz ±1 MHz, the 11.7MHz offset oscillator is used. The corresponding wide-spaced exciter jumpers are cut to prevent selection of the wide-spaced oscillator. These jumpers are JU901 through JU904, for channels F1 through F4 which are located on the main control board, and jumpers JU5 through JU12, for channels F5 through F12 which are located on the universal switching board. In this example, cut jumpers JU904, JU5, JU6, JU8, JU10 and JU11. Refer to the programming detail diagram.

Step 4. Determine the most common allowable spacing other than 0 MHz. These channels will use an offset oscillator frequency that is not 11.7 MHz. In this example, the most common offset spacing other than 0 MHz is +5 MHz. This corresponds to an offset oscillator frequency of 16.7 MHz which is calculated using the following formula:

$$F_{OFF} = (F_T - F_R) + 11.7 \text{ MHz}$$

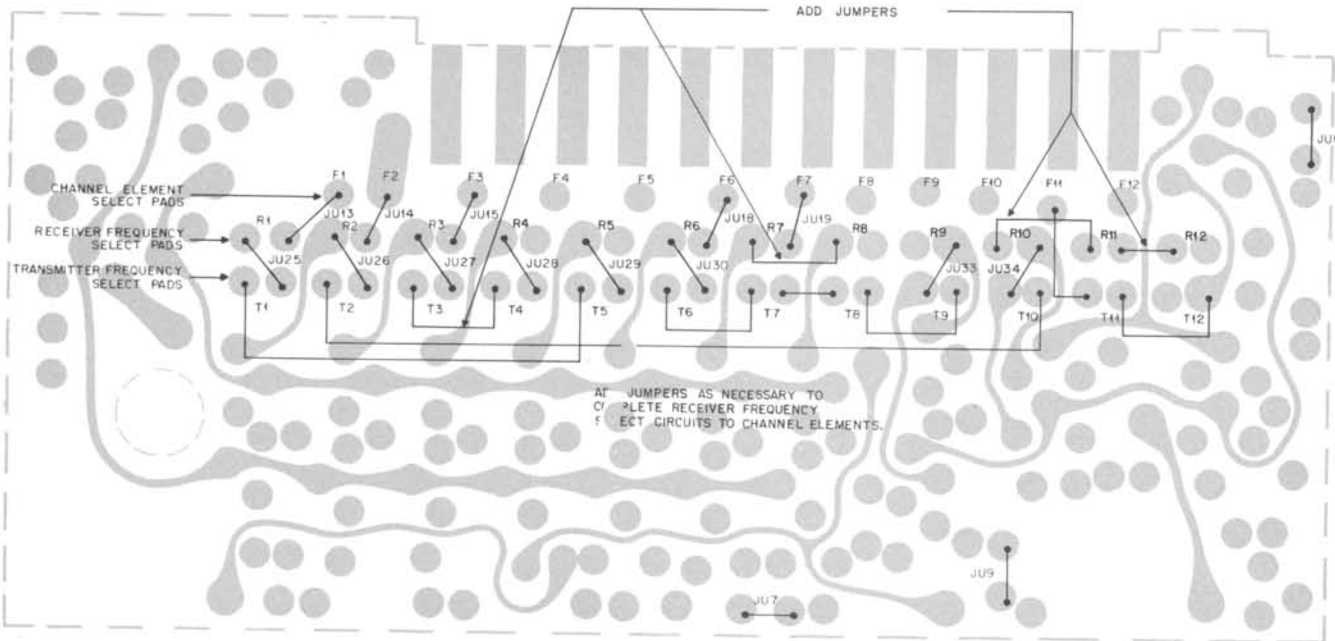
Where: F_{OFF} = Offset Oscillator Frequency in MHz.

In those cases where additional frequencies are being added to the radio set in the field, check the exciter board to see what offset oscillator crystal frequencies are present. If the universal switching board has been factory installed, the offset oscillator frequencies supplied with the radio set may not be the same as those determined by this procedure. If that is the case, the existing offset oscillator frequencies may be used, or new crystals may be ordered to change the offset oscillator frequencies to those determined by this procedure. If it is desireable to use an existing offset oscillator frequency, (1) ignore the instructions given for selecting the "plug-in" oscillator frequency, (2) use the offset spacing (F_T-F_R) presently being used in your radio set in place of the most common spacing when programming the jumpers, and (3) program the jumpers following the procedure given in these instructions.

Step 5. Insert channel elements into their proper positions. One channel element is required for each different receive frequency plus any transmit-only frequencies as determined in these instructions. In this example, there are five different receive frequencies. The channel elements for these frequencies are installed into positions on the receiver rf and if board as shown in Table 8., below. Note that when two or more channels share the same receive frequency, the channel element is installed into the lowest receive frequency position.

Table 8. Channel Element Placement

Channel Element Frequency in MHz	Position On Receiver RF & IF Board
451.000	F1
450.950	F2
450.900	F3
NONE	F4
NONE	F5
450.850	F6
450.800	F7
NONE	F8
NONE	F9
NONE	F10
NONE	F11
NONE	F12



NOTES:

1. BOARD VIEWED FROM COMPONENT SIDE.
2. FOR CLARITY, ONLY JUMPERS ARE SHOWN.

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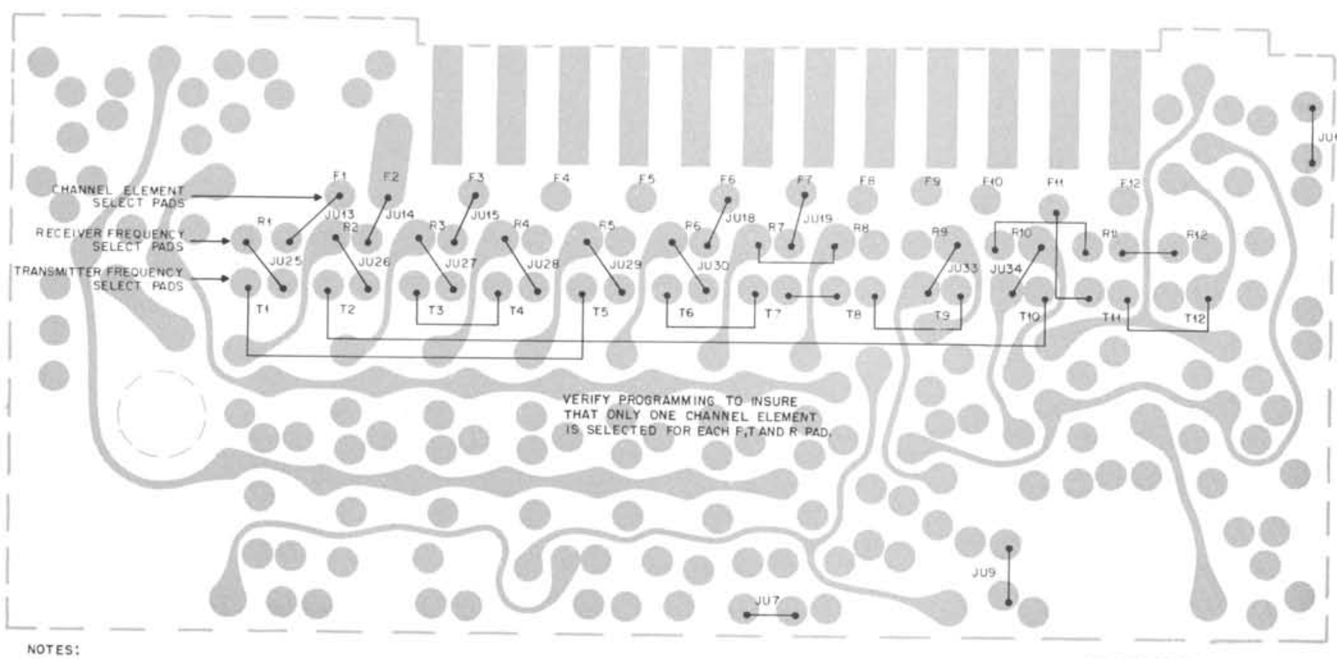
Universal Switching Board
Programming Step 11.



NOTES:

1. BOARD VIEWED FROM COMPONENT SIDE.
2. FOR CLARITY, ONLY JUMPERS ARE SHOWN.

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Universal Switching Board
Properly Programmed Per Example.

Step 6. Remote the channel element select jumpers (JU13 through JU24) for those channels which do not require channel elements. Note that the jumpers must be completely removed from the board as the eyelets must be able to accept other jumpers, if the programming instructions so dictate. In this example, positions F4, F5, F8, F9, F10, F11 and F12 do not mount channel elements. Therefore, the corresponding select jumpers are removed as shown in the programming detail diagram.

Step 7. Program the R to T pad jumpers (JU25 through JU36) to select the "plug-in" offset oscillator frequency for those channels that do not use the common offset spacing (F_T-F_R) of 0 MHz or +5 MHz. In this example, those channels are F7, F8, F11 and F12. Remove the corresponding select jumpers as shown in the programming detail diagram.

Step 8. If a T to R pad jumper or an R to F pad jumper is missing, connect the T pad to the first preceeding T pad that is related to it by an offset spacing of 0 MHz or the most common allowable spacing other than 0 MHz. Refer to the programming details for steps 7 and 8. The first jumper that is missing in this example is R4 to F4. Start with the T4 pad and search for a preceeding T frequency related to T4 by 0 MHz or +5 MHz. T3 is +5 MHz above T4, therefore jumper T4 to T3. Continue this procedure for each frequency where the T to R or R to F jumper is missing. If there is not any preceeding T frequency that is related to the T pad in question, go to the next higher open T pad and continue the search. Table 9 outlines the remaining steps for this programming procedure.

Step 9. If the radio set requires a transmit-only channel element, perform the following procedure. Otherwise, proceed to Step 10. In order to determine the channel element frequency, use the following formula.

$$F_R = F_T - F_{OSC} + 11.7 \text{ MHz}$$

Where: F_R = Receive frequency stamped on channel element

F_T = Desired transmit frequency

F_{OSC} = Required offset oscillator frequency

In this example, the transmit only channel element for T11 would have to be ordered for a receive frequency of 450.750 MHz (450.750 MHz - 11.7 MHz +11.7 MHz).

The channel element is installed on the receiver rf and i-f board in the nearest open F position corresponding to the transmit-only channel position. In this example, the channel element is installed in the F11 position. T11 is jumpered to F11 to complete the channel element select path.

Step 10. Insure that you have programmed the diode matrix properly by tracing the T pads to the channel element select F pads. Each T pad should lead to one and only one channel element. For example, T10 is jumpered to T2; T2 is jumpered to R2, and R2 is jumpered to F2. Therefore, T10 is traceable to only the channel element in position F2.

Table 9. "Plug-in" Offset Oscillator Programming

Missing Jumper	Related T Frequencies	Relationship in MHz	Add Jumper Between
R5-F5	T5-T1	-5	T5-T1
T7-R7	T7-T6	+5	T7-T6
T8-R8; R8-F8	T8-T7	-5	T8-T7
R9-F9	T9-T8	-5	T9-T8
R10-F10	T10-T2	-5	T10-T2
T11-R11; R11-F11	*	NONE	SEE TEXT
T12-R12; R12-F12	T12-T11	+5	T12-T11

* T11 is not related to any other transmit frequency. This is a special case and requires a transmit-only channel element to develop the necessary transmit frequency.

Step 11. Program any R pads that are not connected to an F or T pad. These should be jumpered to the next preceeding R pad having the same frequency. If there is not an open eyelet in the preceeding R pad, then trace from that R pad to the open T pad and jumper from T to R. Refer to the programming detail for step 11. Check the board to determine if there are any T or R pads with both eyelets open. There should be none. Check the programming to make sure that all T and R pads trace back to one and only one F pad. Refer to the programming detail which shows the board completely programmed per this example.

8. ACCESSORIES

The control head and cables are described in separate sections of this instruction manual. A description of the "private-line" circuitry is included with the transmitter and receiver. The receiver pre-amplifier, time-out-timer and positive ground converter are described.

9. RECEIVER PREAMPLIFIER

The preamplifier is a single stage grounded gate FET (field effect transistor) rf amplifier which connects between the antenna switch and receiver rf deck. It improves receiver sensitivity 6 dB from the specified receiver 20 dB quieting sensitivity of .5 microvolt.

The signal from the antenna is coupled directly into the input tuned-line of the preamplifier. This tuned-line passes the desired signal and matches the relatively low FET input impedance to the 50-ohm input line. The signal is capacitively coupled to the source terminal of the FET where it is amplified and then capacitively coupled to the output tuned-line. The output tuned-line is a high Q tank circuit. It passes the desired signal and matches the relatively high FET output impedance to the 50-ohm output line.

10. TIME-OUT TIMER

a. Timing and Switching Circuit

When the transmitter is keyed, forward bias is applied to the base of the N-P-N inverter transistor Q1 and turns it on. The collector voltage of Q1 decreases and the N-P-N timer reset transistor turns off. This allows C1 to begin charging through R5, increasing the anode voltage of the programmable unijunction transistor Q3.

A programmable unijunction transistor is a diode that will not conduct in the forward direction until the voltage on the anode exceeds the voltage applied to the gate by 0.6 volt. When that point is reached, the programmable unijunction transistor conducts until capacitor C1, is completely discharged. It takes about one minute for the charge on C1 to exceed by 0.6 V, the gate voltage determined by the divider resistors R6 and R7.

The conduction of Q3 fires the time-out switch SCR1 causing it to conduct and groung the transmitter modulator through CR1. The time-out switch will continue to conduct as long as the keyed 9.6 volts is present.

b. Alert Tone Circuit

When SCR1 conducts, forward bias is applied to the base of the P-N-P alert tone switch transistor Q4, turning it on. The unijuction alert tone oscillator Q5 produces a tone whose frequency is determined by R12 and C5.

The unijunction transistor Q5 has three leads; emitter, base 1 and base 2. When C5 charges to approximately 60% of the voltage from base 2 to base 1, the emitter begins to conduct, and capacitor C5 is discharged across R14. When the capacitor is discharged, current flow stops and charging begins again through R12. Thus a pulse appears across R14 at a 1 kHz rate.

The N-P-N isolation switch Q6 turns on passing the alert tone to the audio/squelch board. When the alert oscillator is not in operation, Q6 presents an open circuit to the audio circuit.

The time-out timer resets itself whenever the transmitter is unkeyed. If the time-out switch has not been turned on when the transmitter is unkeyed the charge accummulated on C1 is discharged through R4 and Q2 to ground. If the alert tone is already on, it is shut off as soon as the transmitter is unkeyed, because the keyed 9.6v which supplies power to the switches, oscillator, and the time-out switch is removed. Any charge on C1 will be discharged by the timer reset and ensure the full time interval on the next transmission.

11. POSITIVE GROUND CONVERTER

a. General

The positive ground converter operates from a negative 12-volt battery input with reference to radio chassis potential. It converts that input to a positive 12-volt output with reference to the chassis. This is accomplished by a chopper which develops an approximate 7 kHz alternating voltage, then rectifies the alternating voltage to produce a positive dc output. A short-circuit protector prevents excessive current if the output voltage becomes shorted.

b. Chopper

The chopper is a free running multivibrator which operates at approximately 7 kHz. The circuit consists of transistors Q1 and Q2, saturable core toroid transformer T1 and associated components. The negative polarity of the input voltage is applied to the emitters of Q1 and Q2; the positive polarity is applied to the collectors through transformer T1. The starting voltage is applied to both transistors, but slight imbalance will cause one transistor to conduct before the other. Assume Q1 conducts first. The resulting increase in Q1 collector current through the primary of the transformer induces a voltage in the feedback winding of the correct polarity to cause Q1 to be driven to saturation and Q2 to be driven to cutoff. As the transformer saturates, causing no change in flux density, the drive to the base of Q1 is reduced and its collector current begins to decrease. This causes a change in flux density in the opposite direction that drives Q1 into cutoff and Q2 into saturation. The action repeats with Q1 and Q2 alternately conducting, thus developing an alternating voltage across the secondary (output) winding of transformer T1.

Diode CR2 and resistors R1 and R2 form the starting and running bias circuit. Diode CR2 is reverse biased when power is first applied, thus the full supply voltage is applied through R2 and the feedback winding of T1 to the bases of Q1 and Q2 as forward bias. Once started, the feedback voltage forward biases CR2, and R1 and R2 form a voltage divider to establish a lower running bias. Capacitor C3 provides a path for the 7 kHz alternating voltage to decrease the switching time of the chopper.

c. Input Filter

Input filter C1, C2 and L1 filter out transients that may be present on the input and prevents coupling of the 7 kHz alternating voltage into the input circuit. Diode CR1 is a reverse polarity protection device for the converter. No input current flows if opposite polarity power is applied, and the transistors are protected.

When a radio with a positive ground converter is used with a negative ground electrical system, the negative ground cable routes battery voltage to different pins of the radio set connector. The negative ground cable provides positive voltage (BATT+) directly to the control board input filter instead of negative voltage (BATT-) to the positive ground converter input. This leaves the converter inactive; however, positive voltage (B+) is provided at the output of the control board filter. This point in the circuit is normally supplied with B+ voltage by the converter output when the converter is used with the positive ground cable. Therefore, the radio can be used interchangeably with positive or negative ground electrical systems; no adjustments inside the radio set are required.

d. Rectifier

Diodes CR3 and CR4 form a full wave rectifier which converts the 7 kHz alternating voltage from transformer T1 into a positive dc voltage. Capacitive filtering by C4 removes the ac ripple. The dc output voltage of the rectifier varies directly with the input voltage; that is, the output voltage of the converter increases when the input voltage increases, and vice versa.

e. Short Circuit Protector

The short-circuit protector consist of transistors Q3 and Q4 and associated components which operate as an electronic switch. During normal operation the switch is "on" and allows the rectifier output to be applied to the load. In a short-circuited or overloaded condition the switch turns "off" and blocks the rectifier output from the load. Thus the circuit protects the converter from damage by excessive current.

The circuit uses Q4 as a short-circuit detector to control the drive to the base of saturated switching transistor Q3. Resistors R3 and R4 form a voltage divider which establishes the voltage at the emitter of Q4. Resistors R6 and R7 form another voltage divider which establishes the voltage at the base of Q4. The emitter voltage reference is determined by the input voltage to the circuit and the base voltage reference is determined by the output voltage. In normal operation, Q4 is forward biased to provide base current to Q3. This current is sufficient to drive Q3 into saturation causing it to appear as a closed switch. The output voltage in that condition is virtually the same as the input voltage. Any variations in voltage causes both reference points to increase or decrease at the same ratio and the forward bias is maintained.

A short or overload in the output circuit causes the voltage at the base of Q4 to drop. If the overload is great enough to cause the base-to-emitter voltage of Q4 to drop below 0.6 volt, Q4 turns off and removes base drive current from Q3. In turn, Q3 also turns off and appears as an open switch. The only current available in this condition is through resistor R5, which limits the output current to about 10% of normal.

Resistor R5 also functions as the turn-on resistor for the protection circuit after the overload is removed, and as the starting resistor each time power is initially applied to the circuit. When Q3 is in the "off" condition, resistors R5, R6 and R7 form a voltage divider that provides forward bias to Q4. This circuit initially switches Q3 "on" or switches Q3 back "on" after an overload condition is removed.

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