SECTION 2
INSTALLATION

2.1 GENERAL

FCC License Required

It is illegal to operate a radio station in the United States without an FCC license. The FCC identifies a repeater as a mobile relay station and restricts their use to certain services. Check appropriate FCC rules and regulations to determine user eligibility. Licensing information and special forms can be obtained from the nearest FCC Field Engineering Office.

NOTE

Do not connect the repeater to AC power without a load connected to the transmitter because it may initially key for about 3 seconds.

115/230 VAC Operation

Unless otherwise specified, the repeater is set up at the factory for 115 VAC operation. If 230 VAC operation is desired, the power supply can be modified by some minor rewiring. Refer to the power supply wiring diagram on page 60 for details.

Pre-Installation Checks

Although each repeater is carefully aligned at the factory, shipment can upset some of the adjustments so pre-installation testing is recommended. Complete the tests listed in the "Performance Tests" section on page 31.

2.2 INSTALLATION

a. Install the antenna coaxial cable through the access holes in the front or back baseplates of the repeater cabinet. Connect the cable to the duplexer or to the transmitter and receiver, depending on the type of installation. Connect the power supply to AC power.

NOTE

Because most repeater installations require several hundred feet of coaxial cable, it is very important that the cable be a high quality product. Failure to do so may result in large power losses and poor repeater performance.

b. Set the controls on the cards as follows:

Call Guard Card - Set the ON-OFF switches on the PC board to "ON" if the respective Call Guard is used. Set the ENCODE switch on the front panel to "OFF".

Control Card - Set the REPEAT switch to "ON" and the ACCESS switch to "TONE".

Level Card - The CALL GUARD LEVEL control and the XMIT AUDIO LEVEL control are factory set or are adjusted during repeater alignment. Adjust the LOCAL AUDIO control for the desired audio output level and adjust the SQU ADJ control so the squelch breaks and the repeater keys when a signal is received.

SECTION 3
CIRCUIT DESCRIPTION

3.1 GENERAL

The Johnson 1000 is a completely solid state UHF, FM repeater operating on one channel in the 450-512 MHz frequency range. Power output is adjustable from 30-75 watts.

The receiver utilizes dual conversion and has intermediate frequencies of 10.7 MHz and 455 kHz. Selectivity is enhanced by various helical and crystal filters. The crystal frequency is multiplied 27 times, producing an injection signal at the first mixer that is 10.7 MHz below the receive frequency.

The exciter consists of four stages which multiply the crystal frequency a total of 24 times and other stages which amplify the crystal frequency to produce the power needed to drive the power amplifier. The power amplifier amplifies the exciter output to produce a 75 watt output from a nominal 10 watt input. A power control board maintains a constant power output over variations in temperature and voltage.

The repeater control circuitry is contained on the level adjust card, control card and Call Guard card (if used) located in the card rack. Power is supplied to the repeater by a rack mounted, 25 ampere, ferroresonent power supply.

3.2 RECEIVER

Refer to the block diagram on page 45 and to the schematic diagram on page 47 while following this circuit description.

3.2.1 Receiver 13 and 9 Volt Supply Voltages

The 13.8 volt supply to the receiver is on pins 19 and 35 of J200 and originates from pin 19 of J311 on the exciter. Power to the receiver is not switched so is applied whenever the power supply is turned on. 13.8 volts is applied to Q209 and Q210 and to a noise filter formed by L206 and C260 which removes low frequency noise. The DC supply is then fed to Q103 and Q215 and to the 9 volt regulator circuit formed by CR209 and R266. The 9 volt regulated supply is filtered by C240 and C251 and then fed to various parts of the receiver.

3.2.2 Helical Filters (L101-L105) and First Mixer (Q103)

From antenna jack J250, the received signal is fed to a five stage helical filter formed by L101, L102, L103, L104 and L105. Each helical is a high Q, parallel tuned circuit which passes a band of frequencies in the 450-512 MHz range. The helical adjusting screw varies the resonant frequency of the filter when it is adjusted in or out of the coil. Impedance matching between the helical filter assembly and the gate of Q103 is provided by L110 which is a factory selected value determined by frequency range. The injection signal, derived from the crystal oscillator, is injected at the source of Q103 and mixed with the received signal.

3.2.3 Oscillator/Tripler (Q211), First Tripler (Q213) and Second Tripler (Q101)

Q211 is a modified Colpitts oscillator that is temperature compensated to keep the crystal frequency within 5 parts per million (± 0.0005%) from -30°C to +60°C. The crystal frequency is determined by the following formula:

$$\frac{\text{Receive Frequency} - 10.7\text{ MHz}}{27}$$

The effective capacitance of the oscillator is controlled by a passive temperature compensation network formed by RT201 and C291. When the temperature changes, the capacitance of RT201 changes to keep the oscillator on frequency. C291 adjusts the range of RT201 and is factory selected and shipped with the crystal. The value of C291 in picrofarads is stamped on the side of the crystal. This capacitor must be moved with the crystal if the crystal is shifted to another channel or transceiver. C269 is used to set the transceiver exactly on frequency and C271 is a range selection capacitor for C269. Base bias for the transistor is provided by voltage divider network R273/R275 and positive feedback to keep the oscillator running is provided by C273 and C274. Capacitors C274 and C289 bypass AC from emitter resistors R277 and R291.

The output of oscillator Q211 is tuned to the third harmonic of the oscillator frequency so this stage also functions as a tripler. The output is tuned by two parallel resonant circuits formed by C277/T208 and C280/T209 and the signal is coupled from one filter to the other by C278. Capacitor C279 bypasses RF from the DC line and R282 is a current limiting resistor.

The filter output is coupled by C281 to second multipler Q213 which is also a tripler stage. The impedance of the filter is matched to the input of Q213 by C282 and the output of Q213 is tuned to three times the input frequency by C284 and T210. L209 and C285 block RF from the DC line and C286 and C110 match the impedance of the filter to that of Q101. A sample of the RF signal is coupled by C287 to CR212 and rectified to produce a DC voltage at TP204. This test point is used for tuning T208, T209 and T210.

The output of second tripler Q101 is tuned to three times the input frequency by L109 which is in parallel with the transistor capacitance. The signal is coupled by C114 to a three stage helical filter which removes harmonics before mixing occurs at Q103. The injection signal is 27 times the crystal frequency and 10.7 MHz below the receive frequency to produce a first IF of 10.7 MHz on the output of the first mixer.

3.2.4 Crystal Filter (Z202), 10.7 MHz Amplifier (Q215) and Crystal Filter (Z201)

The 10.7 MHz output from the first mixer is filtered by C111 and L202 which form a low pass filter to remove harmonics from the signal. The output of Q103 is tuned for 10.7 MHz by T111 and C229 and then coupled by C201 to crystal filter Z202. RF is blocked from the DC line by L212 and L213 and bypassed by C296, C297 and C299. The input impedance of Z202 is matched to the output impedance of Q103 by C219, C201, C220 and L211. The output impedance of Z202 is matched to T201 by C202 and R201. Z202 is a two-pole crystal filter that is used to increase receiver selectivity. It has a center frequency of 10.7 MHz and a bandwidth of 15 kHz.

From the filter, the signal is fed to transformer T201 which is tuned to 10.7 MHz. C202 and R201 match the impedance of Z202 to that of T201. The signal is coupled by C298 from T201 to IF amplifier Q215 which is used to regain crystal filter losses. The output of Q215 is tuned by C204 and L204 and fed through R295 to Z201. Z201 is a four-pole crystal filter with the same bandwidth and center frequency as Z202. R295 on the input of Z201 and L205 and voltage divider C206/C207 on the output of Z201 are used for impedance matching.

3.2.5 Second Oscillator (Q213), Second Mixer (Q202), First IF Amplifier (Q203) and Second IF Amplifier (Q204)

Second oscillator Q214 is a modified Colpitts oscillator operating on the fundamental frequency of the crystal. Bias is established by voltage divider network R263/R229 and positive feedback to maintain oscillation is provided by C263 and C264. C262 is used to pull the oscillator on frequency and RF bypass from the DC line is provided by C261 and C266. The injection signal is coupled by C209 from the emitter of Q214 to the output of Z201 where it is mixed with the 10.7 MHz first IF signal. These signals are then coupled by C206 to second mixer Q202.

The output of Q202 is tuned to 455 kHz (11.155 MHz -10.7 MHz) by a parallel tuned circuit formed by C214 and the primary of T202. R208 across the tank circuit is used to lower the circuit "Q" and transistor bias is provided by voltage divider network R203/R206. The 455 kHz signal is coupled through T202 and coupling capacitor C215 to first IF amplifier Q203. The output of Q203 is tuned by a tank circuit similar to that used in the previous stage. After amplification by Q203, the signal is fed to second IF amplifier Q204 which is identical in configuration to first IF amplifier Q203. A sample of the RF signal from T204 is coupled by C225 to CR201 and rectified to produce a DC voltage at TP203. This test point is used for aligning the IF section.

3.2.6 Limiter/Discriminator (U201), Audio Preamplifier (U202A) and Call Guard Filter (U202B)

Integrated circuit U201 contains IF amplifier, limiter, detector and audio preamplifier stages. A quadrature-type detector is used to recover the audio from the frequency modulated signal. A phase shift network on pins 8, 9 and 10 shifts the phase of a reference signal 90° at an input frequency of 455 kHz. When deviation occurs and the input frequency varies from 455 kHz, the phase shift varies accordingly at an audio rate. For example, a frequency deviation of + 5 kHz may produce a phase shift of 120° instead of 90°. The quadrature detector, which has no output at 90°, converts this phase shift into an audio signal. The signal is then amplified by preamplifier stages following the detector stage. L211 is used to tune the phase angle to produce maximum undistorted output from U201.

The detected audio signal from U201 is coupled by C235 to a 6 dB per octave de-emphasis network consisting of C230, R233, C255, R234, C237 and R232. This network removes the pre-emphasis from the audio signal that was put in when the signal was transmitted. From the de-emphasis network the signal is fed to U202A which is an operational amplifier. The amplification of the stage is controlled by feedback through R231 and C247 together with the resistance of R233, R234 and R232 (C247 is used to roll off the amplification of frequencies over 3000 Hz). From U202A, the signal is fed to Call Guard filter U202B and to pin 20 of J200. From pin 20 the signal is fed to Call Guard audio switch U701B on the level adjust card.

Call Guard filter U202B removes the Call Guard tone from the receive audio. The filtering is done by C252, R244, C253, C254 and R246 in combination with U202B. The output is coupled by C246 to volume potentiometer R710 and transmit audio potentiometer R714 on the level adjust card.

3.2.7 Audio Amplifier (Q206), Driver (Q207) and Output Stages (Q209, Q210)

From the volume control, the audio signal is coupled by C250 to Q206. The audio signal is amplified by Q206 and then directly coupled to Q207 which is in series with the primary of transformer T206. Q206 bias voltage is developed across R262 and applied through R252. Negative feedback to decrease distortion is provided by C259. B+ to Q206 and base bias for Q207 is fed from the 9 volt regulated line through R248, R200 and R251. When the receiver is squelched, this supply is removed by Q208 which turns on and grounds the junction of R248 and R200.

When an audio signal is applied to the base of Q207, the current through the primary of T206 changes at an audio rate, inducing an audio voltage in the secondary. The output of T206 is on opposite ends of the secondary winding to produce 180° out of phase input signals to a push-pull amplifier formed by Q209 and Q210. To prevent crossover distortion, the transistors are biased slightly on (with no signal input) by R253, R254, R255 and R256. CR207 isolates the receive 13 volt line from Q209 and Q210 in the transmit mode and DC bias stability is provided by R261 and R257. The speaker is connected from the negative side of C257 to ground. When Q210 conducts, C257 charges through the speaker coil and when Q209 conducts, C257 discharges in the opposite direction through the speaker coil. An RC network formed by C256 and R260 is used to dampen oscillations caused by the inductive effects of the speaker coil and also to provide a load when no speaker is attached.

3.2.8 Squelch Amplifier (U202C), Squelch Filter (U202D) and Squelch Gate (Q208)

The squelch circuit is controlled by the amount of noise present in the limiter/discriminator output. When no on-frequency signal is being received, inherent receiver noise is amplified and is present at a high level in the limiter/discriminator output. When an on-frequency signal is received, the signal is present at a higher level than the noise in the receiver resulting in a decrease in the noise output from the limiter/discriminator as the received signal gets stronger. The limiter circuit preceding the discriminator removes noise pulses as the received signal strength increases to also produce a decrease in noise. So the noise level in the output from U201 is inversely proportional to received signal strength.

The signal and/or noise output from U201 is fed to U202C and amplified by an amount set by the ratio of R239 to R240. The input level to squelch filter U202D is established by voltage divider R237/R238. The purpose of the squelch filter is to remove all frequencies below 3000 Hz so only high frequency noise is passed. This filtering is done by C238, C241, C242 R235 and R249 in conjunction with operational amplifier U202D. From U202D the noise signal is fed to a rectifier/voltage doubler circuit consisting of C244, CR203, CR204 and C248 which converts the noise pulses to a DC level.

The output across C248 is applied to a voltage divider formed by R250, CR206 and the squelch control. The squelch control adjusts the DC level felt on the base of squelch gate Q208. When the rectified noise level on the base of Q208 becomes high enough, Q208 turns on and the potential at the junction of R248 and R200 drops near ground. This removes the B+ supply from Q206 and mutes the speaker audio. So when no signal is being received, there is high noise output from U201 resulting in an increase in the DC level at the base of Q208. This causes Q208 to turn on and squelch the receiver. When a signal is received, the noise level drops causing Q208 to turn off. B+ is then applied to Q206 resulting in audio from the speaker. By increasing the resistance of the squelch control, more rectified noise is felt on the base of Q208 requiring a stronger received signal (that produces less noise) to turn off Q208.

To prevent intermittent squelching when receiving a weak, fading signal, a hysteresis circuit formed by R242 and CR208 is used. CR208 is forward biased only in the unsquelched mode, providing a shunt through R242 and C236 to ground for some of the noise signal. This effectively reduces the sensitivity of the squelch circuit to noise resulting in a greater noise change required to change from an unsquelched to a squelched condition than vice versa. C245 is used to prevent Q208 from changing states during brief fading of the received signal and C243 provides negative feedback of noise pulses.

3.3 EXCITER

Refer to the block diagram on page 45 and to the schematic diagram on page 48 while following this circuit description.

3.3.1 Exciter 13 and 9 Volt Supply Voltages

The 13.8 volt supply to Q378 on the exciter board and Q401 and the 9 volt regulator on the power control board is taken directly from power plug P1. Various RF signals are filtered from the DC supply by C1, C2, C3 and C90. P1 is connected to pin 19 of J311 and is jumpered to pin 35 by the repeater wire harness. The 13.8 volt supply on pin 35 is applied to a filter formed by L1 and C4 which removes low frequency noise. The 13.8 volt supply is then applied to transmit switch Q348 and to receive switch Q349 which is not used in the repeater. Pin 10 of J311 is connected to Q708 on the level adjust card and Q606 on the control card. When the output of either transistor goes low, Q348 is turned on. Power is then applied to various circuits causing the transmitter to key up. The 9 volt regulator circuit formed by CR301 and R303 supplies a regulated voltage to the TCXO and to the transmit audio circuitry.

3.3.2 First Audio Amp, Compressor, Second Audio Amp and Splatter Filter (U301)

The transmit audio processing is done by U301, a quad operational amplifier which amplifies, limits and filters the audio signal. The audio from Q706 on the level adjust card is coupled by C305 to pin 12 of U301. This stage provides impedance matching and amplification as determined by the ratio of R310 to R309. C306 in series with R309 is a bypass capacitor and R311 and C307 form a 6 dB per octave pre-emphasis network.

From the pre-emphasis network, the signal is then fed to limiter U301B which sets the maximum deviation of the transmitter. With a normal signal input level, no limiting occurs and the amplification of the stage is determined by the ratio of R312 to the impedance of C307 and R311. A diode bridge limiter formed by CR303-CR306 is in the feedback circuit of U301B and the level at which limiting occurs is determined by the bridge bias. The bridge bias is determined by R312, R313, R314 and R315.

With a positive output pulse on pin 1, current through CR305 and R314 increases and current through CR303 and R313 decreases a like amount. Since CR304 and CR306 are in parallel with CR303 and CR305, the output level of the bridge follows the input level to the bridge as long as limiting does not occur. When limiting of a positive pulse occurs, CR303 and CR306 reverse bias and CR304 and CR305 remain forward biased. The output circuit then consists of R312, R315 (effectively in parallel), CR304 and R313. Since R313 is connected to 9 volts, these components form a voltage divider with the output taken across R312 and R315.

During limiting, the bridge opens up so the gain of U301B is controlled by CR315-CR318 rather than R312. The output on pin 1 is free to vary while the output of the bridge remains at the clipped level. Diodes CR317 and CR318 conduct with very large input signals to provide an additional feedback path to prevent the amplifier from saturating. CR315 and CR316 are used to drain off excess bias from the input of the amplifier. CR315-CR318 are included to minimize distortion during abnormal signal conditions and do not affect normal limiter operation.

The limiter output is then applied to the second audio amplifier stage on pin 6. The gain of the stage is established by the ratio of R317 to R315. Feedback to provide attenuation of high frequencies is provided by C310. The output is fed to pin 9 of the splatter filter stage which filters out high frequencies to prevent adjacent channel interference. R318, R319, R320, C311 and C312 together with U301D filter out signals above approximately 3000 Hz. The output is then fed through R322 to the transmit oscillator where the crystal frequency is frequency modulated.

3.3.3 2.5 PPM TCXO (Q701, Q702)

The 2.5 PPM TCXO (temperature compensated crystal oscillator) is a separate PC board assembly mounted on the accessory rails over the transmitter board. The TCXO is not field serviceable because a factory recalibration must be performed whenever a component is changed. A new component may have slightly different characteristics and cause the oscillator frequency to go out of tolerance.

A modified Colpitts oscillator is used that is temperature compensated to keep the transmit frequency within 2.5 parts per million (0.00025%) from -30°C to +60°C. The oscillator operates on the fundamental frequency of the crystal and the crystal frequency can be determined by the following formula:

$$\text{Crystal Frequency} = \frac{\text{Transmit Frequency}}{24}$$

The effective capacitance of the oscillator is varied by a passive temperature compensation network which controls the voltage across varactor diode CR701. The oscillator is set exactly on frequency by C705 and buffering between Q701 and the output is provided by Q702.

The transmit audio is fed through R702 and applied across CR701. The capacitance of CR701 varies at an audio rate, producing a change in the crystal frequency. The amount of deviation is determined by the amplitude of the audio signal which is controlled by R702.

3.3.4 Tripler (Q320), First Doubler (Q345), Second Doubler (Q346), First Driver (Q347) and Third Doubler (Q375)

The output of Q702 is coupled by C300 to Q320 which functions as a tripler. The output is tuned to three times the crystal frequency by L322 and C331. For additional filtering, the signal is then coupled by C330 to another tuned circuit formed by L323 and C332. C333 couples the signal to a third filter stage formed by L345, C334 and C336. C334 and C336 function as a voltage divider for impedance matching to Q345. A sample of the signal is coupled by C335 to rectifier CR312 to produce a DC voltage at TP301. This test point is used for tuning L322, L323 and L345.

Base bias for first doubler Q345 is provided by voltage divider R351 and R352. The doubler output is tuned to six times the crystal frequency by T346 and C341 and AC bypass is provided by C342 and C355. The signal is then coupled by C339 to another filter formed by L347, C340 and C344. C340 and C344 function as an AC voltage divider for impedance matching with the next stage.

The output of second doubler Q346 is tuned to twelve times the crystal frequency by T348 and C349. The signal is then coupled by C348 to L348 and C351 for additional filtering and then by C352 to L349 and C353 for still more filtering.

First driver Q347 is used to regain filter losses and to provide an amplified signal for the following stages. The output of Q347 is tuned by C357 and L350 and impedance matching to the next stage is provided by C358 and L351.

The output of third doubler Q375 is tuned to twenty-four times the crystal frequency by L352, C362 and C366. C362 and C366 also match the output of Q375 to L353/L354 which form a transformer. An AC ground is provided to L352 by C363, C364 and C365 and negative feedback to prevent self oscillation of Q375 is furnished by C361 and R366.

The output of the transformer is matched to the bandpass filter by C367 and C368. The bandpass filter is made up of a low pass and a high pass section so only the frequencies from about 450-512 MHz are passed. The high pass section is made up of L355, R372, C369, C370, C371 and two 10 nH coils formed on the PC board. The low pass section is made up of C372, C373 and two 15 nH coils formed on the PC board.

3.3.5 First Amplifier (Q376), Second Amplifier (Q377) and Predriver (Q378)

From the bandpass filter, the signal is fed via microstrip to first amplifier Q376 (microstrip is designated on the schematic by square-shaped symbols and a description follows in the next paragraph). Q376 is biased by R377 and R373 so operation is nearly Class B to produce more amplification. RF is bypassed from R373 by ferrite bead EP405 and by C396 and loading for the input signal is furnished by R378. C374 is used for impedance matching and RF is blocked from the DC supply by L357. C397 together with inherent lead inductance form a series resonant circuit to provide a path to ground through C395 for signals near 200 MHz. The "Q" of the resonant circuit is lowered by R380 to broaden the response curve of the filter.

Microstrip like that used on the input to Q376 are PC board pads specially shaped to provide a characteristic impedance. Electrically they are transmission lines with series inductance and parallel capacitance distributed along the line. Physical characteristics determining the impedance of a stripline are width of the stripline, PC board thickness and dielectric or PC board material. Since the PC board thickness and material cannot easily be changed, the method used to obtain a desired impedance is usually to alter the width of the pad. Generally, the wider the pad, the lower the characteristic impedance and vice versa.

The output from Q376 is fed to second amplifier Q377 for more amplification. C375, C379 and C380 match the impedance of the microstrip to that of Q377 and base bias is provided from the input signal by L358 and R374. A negative feedback network formed by C398 and R381 prevents self oscillation of the stage. The supply current to Q377 is controlled by the power control circuit and is applied through RF choke L359. By increasing or decreasing the supply current to this stage, the drive to the following stages is controlled, regulating the transmitter power output.

Predriver Q378 provides additional gain needed to drive the power amplifier. The input of Q378 is tuned similar to that of Q377. On the output of Q378, impedance matching with the microstrip is provided by C388 and C389. The output of the microstrip is tuned for 50 ohms by C390 and C391 and the signal is then fed by a 50 ohm coaxial cable to antenna jack J313.

3.4 POWER AMPLIFIER

3.4.1 Driver (Q901)

Driver Q901 provides additional amplification needed to drive the final amplifiers. C901 matches the impedance of the 50 ohm coaxial cable to that of the microstrip and C902, C903 and C945 provide matching to the input of Q901. L901 and R901 form a low frequency filter to prevent self oscillation and R901 and L902 provide base bias from the RF input signal. DC power is taken directly from positive power jack J903 and fed through L903 to the collector of Q901. The output of Q901 is matched to the microstrip by C904 and C905 and then the microstrip output is coupled by C907 to a parallel tuned circuit formed by L913, C942 and R908. This circuit is tuned to the transmit frequency range and filters signals outside this band (R908 lowers the circuit "Q"). C906 and C907 are used to match the microstrip to the 50 ohm impedance of the coaxial cable. The coaxial cable to C911 is 1/4 wavelength long to achieve better matching.

3.4.2 Final Amplifiers (Q902, Q903)

The final amplifier is made up of two amplifier stages operating in push-pull mode. C911 matches the 50 ohm coaxial cable to the 25 ohm input of the amplifiers and also provides 180^{o} out of phase signals needed to drive the push-pull amplifier. C912, C913, and C914 match the microstrip to the input of Q902 and the microstrip is matched to the input of Q903 by C918, C919 and C920. To prevent self oscillation, low frequencies are removed from the input to Q902 by L904 and R902 and from the input to Q903 by L907 and R903. The output of the amplifiers is matched to the microstrip by C915, C916, C921 and C922. The 180^{o} out of phase output signals are combined and matched to a 50 ohm output impedance by C917, C923, C941 and C924. C924 is a variable capacitor that is adjusted to provide maximum power output. The coaxial cables connected across C911 and C941 must each have the center conductor connected to Q903 and the shields to Q902.

The signal at C941 is coupled by a 50 ohm, 1/4 wavelength coaxial cable to a 50 ohm microstrip and then to a low pass filter. This filter, formed by C925, C926, C927, C928, L910, L911 and L912 removes spurs occuring above the frequency band. From the filter, the signal is coupled by another 50 ohm coaxial cable to antenna jack J901.

If the optional duplexer is used, the power amplifier to duplexer coaxial cable must be the correct length for good matching. The cable length is a function of frequency so when repairing or replacing the cable refer to page 41 of the parts list for length and part number.

3.5 POWER CONTROL

3.5.1 General

The power control circuitry is contained on the power amplifier board and on the power control board located in the exciter subassembly. The transmitter power output is controlled by two inputs which are RF power output from the power amplifier and ambient temperature of the power amplifier. If the power amplifier temperature becomes excessive, the temperature sensing circuit causes the power output to be cut back to protect the amplifier transistors from damage.

3.5.2 Power Output Sense

A sample of the RF power level is coupled from the microstrip by C930 and rectified by a network consisting of CR902, R905 and RT901. Thermistor RT901 compensates for changes in diode characteristics caused by temperature fluctuation. The signal is then applied across a voltage divider which sets the input level to pin 6 of U401C on the power control board. Thermistor RT400 is used for temperature compensation and causes the DC level on pin 6 of U401C to increase with an increase in temperature and vice versa. Various capacitors such as C931, C956, C409 and C422 filter noise from the DC input. U401C is an amplifier and the level on pin 6 controls the power output level.

A circuit is provided that permits switching to a lower power output level when high power output is not desirable such as when operating on standby power. The resistive branch formed by R412 and R419 controls the low power output level and the branch formed by R420 and R421 controls the high power output level. The low power level is set by R412 with Q402 turned off and the high power level is then set by R420 with Q402 turned on. If the high/low power feature is not used, R412 is set for maximum resistance and power output level is set by R420. With no connection to the high/low power input on J1, pin 6, Q403 conducts and causes Q402 to turn on. When a high is applied to J1, pin 6 from a source such as the power failure alarm card, Q403 and Q402 turn off and the level on pin 6 of U401C increases to cause the power output to decrease.

The amplification of U401C is controlled by the ratio of R415 to R413. When the level on pin 6 of U401C increases, the level on pin 7 decreases causing Q400 to conduct less. Less base/emitter current flows through Q401 so it conducts less and cuts back current to Q377. The power output from Q377 and all the following stages decreases until a balanced condition exists in the circuit. When the power output decreases, the level on pin 6 of U401C decreases and the opposite of the preceding occurs.

3.5.3 Thermal Foldback

The thermal foldback circuit is controlled by the voltage drop across thermistor RT902. RT902 and R400 on the power control board form a voltage divider and as the power amplifier temperature increases the resistance of RT902 decreases to cause a drop in the input voltage to pin 13 of U401A. The bias voltage on pin 12 is developed by R401 and R403 and the gain of U401A is set at unity since the value of R404 is the same as R402. As the input voltage on pin 13 decreases, the output on pin 14 increases but is not fed to U401B until the level is high enough to cause CR400 to conduct.

Under normal operating conditions, the function of U401B is to provide a nominal 0.8 volt biasing voltage on pin 5 of U401C. This biasing voltage is developed by R406 and R407 in conjunction with U401B. When the output on pin 14 of U401A increases above about 6.2 volts, CR400 conducts and the level on pin 2 of U401B increases. This causes the output on pin 1 to decrease which causes the output from U401C to decrease and cut back the power output.

If the overheating problem becomes more severe, the output on pin 14 of U401A increases and CR402 and CR403 conduct when the level reaches about 7 volts. The level on pin 6 of U401C increases and nearly a total power shutdown results.

The VSWR shutdown circuit is not used in the repeater so Q404 and related components are not used. The 9 volt regulated supply to the power control board is provided by CR401, R410, C405 and C406. CR405 is used to increase the regulated voltage by about 0.5 volt.

REPEATER CARD RACK

Refer to the card rack block diagram on page 51, the DC supply block diagram on page 45 and the various schematic diagrams while following this circuit description.

3.6 LEVEL ADJUST CARD

3.6.1 General

The level adjust card contains a 9.6 volt regulator circuit and various amplifiers, switches and potentiometers. The 9.6 volt regulator circuit furnishes a regulated supply voltage to the circuits on the level card and to all other cards in the card rack. Other circuits on the level adjust card control and amplify various input and output signals from the receiver and transmitter.

Bilateral Switches

Four bilateral switches, contained in integrated circuit U701, are used on the level adjust card. A bilateral switch is electrically similar to a single pole, single throw switch. Using U701A as an example, pin 8 is the input, pin 9 is the output and pin 6 is the control input. The switch is open until a positive voltage is applied to pin 6. The switch then closes, allowing the input signal to pass through. The input and output pins are biased at 4.5 volts to prevent a negative going input signal from causing the switch to momentarily close and pass voltage spikes.

3.6.2 9.6 Volt Regulator (Q700, Q701)

The 13.8 volt input on pin 21 is filtered by C701 and then applied to Q700 and driver Q701. The base of Q701 is maintained at a constant 11 volts by zener diode CR700 and filtering of this voltage is provided by C702 and C703.

The base-emitter junctions of Q700 and Q701 act like two series diodes with a voltage drop of about 1.4 volts when forward biased. If the regulated output on the emitter of Q700 decreases, the voltage difference across these junctions increases. More base current flows causing both Q700 and Q701 to conduct more. The effective resistance of Q701 decreases and less voltage is dropped which produces an increase in the regulated output. If an increase in the regulated voltage occurs, the opposite of the preceding takes place. The regulated output on the emitter of Q700 is fed to the other stages on the card and to the other cards in the card rack through pin 20.

3.6.3 Call Guard Audio Switch (U701B) and Squelch Inverters (Q703, Q702)

The signal input to Call Guard audio switch U701B is the receive audio signal from the output of audio preamplifier U202A on the receiver board. This signal is fed to pin 11 on the level adjust card and then coupled by C721 to pin 11 of U701B. This bilateral switch is turned on by a high on pin 12 produced when squelch inverter Q702 turns off. The output signal on pin 10 of U701B is coupled by C722 to pin 15 and is then fed to pin 14 on the control card.

The signal input to squelch inverters Q703 and Q702 is the signal from the collector of squelch gate Q208 on the receiver board. When an on-frequency signal is received, the collector of Q208 goes high and this signal is applied through pin 12 to the base of Q703. This transistor turns on and the low output on the collector is applied to the base of Q702 and to pin 16. The output on pin 16 is fed to repeater switch U602A on the control card and the low on Q702 causes the transistor to turn off. This causes the collector to go high and this signal is applied to Call Guard audio switch U701B.

3.6.4 Local Audio Adjust (R710), Transmit Audio Level Adjust (R714), and Transmit Audio Switch (U701A)

The local audio adjust potentiometer R710 controls the volume of the card rack speaker. The receive audio signal output from Call Guard filter U202B on the receiver board is applied across R710 which controls the input level to audio amplifier Q206. The receiver audio amplifier stages provide the power needed to drive the card rack speaker.

The same audio signal applied across R710 is also applied across transmit audio level adjust potentiometer R714. This potentiometer controls the level to deviation adjust potentiometer R702 on the TCXO board. A voltage divider formed by R712 and R713 decreases the level applied across R714. The signal is then coupled by C720 to pin 8 of transmit audio switch U701A.

Transmit audio switch U701A will not pass this signal until a high is applied on pin 6. This high is produced by repeater switch U602A on the control card and is applied through pin 9 on each card. When this enabling signal is applied, the receive audio signal from U701A is fed through Call Guard filter Q705 and Q706 to the audio stages on the transmitter board.

3.6.5 Microphone Audio Switch (U701C), Transmit Switch (Q709) and Inverter (Q708)

When a microphone is plugged into the jack on the front panel of the card rack, a message can be sent or tests performed by keying the push-to-talk switch and speaking into the microphone. The audio from the microphone is fed to pin 13 on the level card and coupled by C757 to pin 1 of U701C. The signal passes through U701C when a high is applied on pin 13 from transmit switch Q709. The microphone audio is then filtered by Q705 and Q706 and fed through pin 18 to the audio stages on the transmitter board.

Transmit switch Q709 is normally turned on except when a low is applied to the base by the local microphone push-to-talk switch. This low input on pin 14 causes Q709 to turn off and a high to be applied to the base of Q708 and to pin 13 of U701C. Keying switch Q708 turns on and the collector drops near ground potential. This low signal is applied through pin 19 to the base of transmit switch Q348 on the transmitter board and causes the transmitter to key.

3.6.7 Call Guard Filter (Q705, Q706)

The input to Call Guard filter Q705 and Q706 is either the receive audio signal or the local microphone audio signal depending on the mode of operation. The purpose of the Call Guard filter is to remove tones 300 Hz or less from the audio to be transmitted.

The filter is composed of two emitter-follower stages. C710 and C711 on the input to Q705 present a high impedance to low frequency signals and R729 provides positive feedback to increase the filtering of the stage. Base bias is provided by R730, R732 and R737 and filtering of the bias supply is provided by C712. The output signal on the emitter of Q705 is fed to Q706 for more filtering and then coupled by C716 to pin 18 which is connected to the audio stages on the transmitter board.

3.6.7 Call Guard Switch (U701D), Call Guard Level Adjust (R705) and Level Amplifier (Q704)

These circuits switch and amplify the Call Guard signal before it is fed to the transmitter. The Call Guard signal originates from the output of audio preamp U202A on the receiver board. The signal is switched by U701B on the level card and then filtered and amplified by U603 and the Call Guard audio compressor circuit on the control card. From the control card, the signal is fed to Call Guard switch U701D on the level card through pin 23 (on both cards).

Call Guard switch U701D passes the Call Guard signal when a high from Q707 is applied to pin 5. The signal from U701D is then applied across Call Guard level adjust potentiometer R705. This control is used to adjust the deviation of the Call Guard tone when it is frequency modulated on the transmitter carrier.

From R705, the Call Guard signal is coupled by C706 to the base of level amplifier Q704. This stage amplifies the signal to a level sufficient to properly modulate the transmitter carrier. A negative feedback network formed by C707 and R727 causes high frequency signals, if present, to be attenuated. The output is on the collector and is coupled by C709 to pin 22 and then to pin 6 of U301C on the transmitter board.

3.6.8 Encode Level Adjust (R700) and Call Guard Switch Control (Q707)

When the Call Guard card is switched to the encode mode to set the frequency of a Call Guard, a tone is generated at the Call Guard frequency. This tone from pin 23 of the Call Guard card is fed to pin 4 on the level card and applied across encode level adjust potentiometer R700. This control adjusts the deviation produced when the encoded Call Guard signal is modulated on the transmitter carrier. The signal is then fed to the level amplifier for amplifcation before being fed to the transmitter audio stages through pin 22.

To prevent any receive Call Guard signal on pin 23 from mixing with the encoded Call Guard signal, switch U701D is opened by Q707 which is turned on by the encoded audio signal. The components on the input of Q707 form a voltage doubler to increase the level of the positive voltage applied to the base. On the negative going half cycle of the input signal, CR702 is reverse biased and C717 charges through R738 and CR701 which is forward biased. On the positive going alternation, CR701 is reverse biased and CR702 is forward biased. The positive going input signal is applied between the positive side of C717 and ground and the input signal and capacitor act like two series connected batteries. This potential is in parallel with C718 and the base-emitter of Q708 and causes C718 to charge to almost twice the peak value of the input signal. C718 never completely charges though, since it discharges through R739 and the base/emitter of Q707 on the negative going half cycles

3.6.9 Squelch Adjust (R717)

The wiper arm of squelch adjust potentiometer R717 is connected through pin 5 to CR206 on the receiver board. By increasing the resistance of R717, a stronger signal (with less noise) is required to turn on squelch gate Q208 and vice versa.

3.7 CONTROL CARD

3.7.1 General

The two main functions of the control card are repeat control and Call Guard tone processing. The repeat control circuitry is based on a 4-input NOR gate which must have all inputs low for the output to go high and key the transmitter. The Call Guard tone processing circuitry provides filtering and amplification of the receive Call Guard signal before it is fed to the Call Guard card for decoding and to the level card for more processing before retransmission.

3.7.2 Time-Out-Timer (Q600, Q601, Q602, Q603)

The input of the time-out-timer is on the base of Q600 and can come from two sources depending on the position of ACCESS switch S601. When the switch is in the "TONE" position, the timer input is from the Call Guard switch line input on pin 15. When the switch is in the OPEN position, the timer input is the squelch switch input on pin 16. In the "TONE" position, a decoded Call Guard tone is required to key the repeater and in the "OPEN" position, only an on-channel signal is required.

The timing cycle starts when a low is applied to the base of Q600. The transistor turns off causing the collector to go positive. C602 then charges and a pulse of current flows through CR600 and the base/emitter of Q603. Q603 conducts and places the positive side of C603 and pin 12 of repeater gate U602A near ground potential. C603, which was charged to almost 9 volts, now has a potential of about 8 volts on the negative side. This negative potential is applied to the base of Q601 and causes it to turn off. The collector goes positive and this voltage is applied to the base of Q603 to keep it turned on. Q602 is turned off by a positive potential on the base from inverter U602B.

About 3 minutes after the transmitter is keyed, C603 has discharged through R607 to a level which turns Q601 on (about + 0.6 V). The collector of Q601 drops near ground potential causing Q603 to turn off. Pin 12 of U602A goes high and the transmitter unkeys. The output of inverter U602B goes low and turns Q602 on to keep the base of Q601 positive. The timer remains timed out and the transmitter unkeyed until the unit transmitting to the repeater unkeys. Q600 then turns on and timing begins when the next signal is received. The timer can also be reset by pushing the TIMER RESET button on the front panel of the control card. C602 discharges through timer reset switch S602 and R609 and then charges again when the switch is released. This causes Q603 to turn on.

3.7.3 Repeater Gate (U602A)

U602A is a 4-input NOR gate which has a high output on pin 13 (which keys the repeater) only if all four inputs are low. If one or more inputs are high, the output of U602A is low. The input signals to U602A are derived as follows:

a. Pin 11 of U602A is connected to repeat switch S600. When the switch is in the "OFF" position pin 11 is high since it is connected to the 9 volt regulated line through R611. This input causes the output on pin 13 to go low to prevent the repeater from keying. When S600 is in the "ON" position, pin 11 is low since it is connected to ground through R651. CR604 and the base station control input on pin 21 are not used in repeaters.

b. Pin 12 of U602A is connected through R610 to the time-out-timer output. This input is low when the timer is timing and is high when the timer is not timing or is "timed out".

c. Pin 10 is connected to the squelch switch input on pin 16. This input goes low when an on-frequency signal is received and the receiver squelch circuit activates.

d. Pin 9 is connected to the Call Guard squelch line input on pin 15. When a tone is decoded by a Call Guard, this input goes low. When access switch S601 is in the OPEN position, no Call Guard tone is needed to activate the repeater so pin 9 is grounded through access switch S601.

When all the inputs to U602A are low, all the requirements for keying the repeater have been met. The output on pin 13 goes high and the repeater keys. This signal is fed to the base of Q604 and also to transmit audio gate U701A on the level card via pin 9.

3.7.4 Transmit Control and Delay Circuit (Q604, Q605, U602B and Q606)

When pin 13 of U602A goes high, the base of Q604 goes positive and turns on. Current then flows through the base/emitter junction of Q605, through R655 and through delay selector resistors, R615, R653 and R654. Q605 is turned on and C605 charges to about 9 volts. The collector of Q605 drops to near ground potential and the low input to all 4 inputs of NOR gate U602B causes the output on pin 11 to go high. Darlington transistor Q606 is turned on and the low output on the collector, applied to the transmitter via pin 19, causes the repeater to key.

A time delay circuit formed by C605, R615, R653 and R654 is used to keep the repeater keyed for about 3 seconds after a signal is no longer received. This delay eliminates a squelch tail if the interval between messages is less than 3 seconds and also prevents loss of signal between units. In addition, if the repeater had to come up between message exchanges, the first part of the message could be lost. When a unit ends a transmission to the repeater, the Call Guard switch line on pin 15 of the control card goes high followed by the squelch switch line on pin 16. The output of U602A goes low and causes Q604 to turn off and transmit audio switch U701A on the level card to open. C605 discharges through the delay selector resistors, through R655 and through the base/emitter of Q605 until the discharge current drops below the turn on point of Q605 (about 3 seconds). Q605 then turns off and the repeater unkeys. The delay time can be shortened by adding jumpers to R653 or R654 and provision has been made on the PC board to add a potentiometer for adjustable transmit delay.

3.7.5 Low Pass Filters (U603)

The receive audio signal containing the Call Guard tone is fed from Call Guard audio switch U701B on the level card to pin 14 of the control card. The signal is coupled by C606 to a voltage divider formed by R620 and R657 which decreases the input level to the first filter stage. Call Guard filtering is performed by R621, R622, R623, C608 and C609 together with operational amplifier U603A. This filter removes high frequency signals and passes only low frequency Call Guard tones. The signal passes through three more identical stages to achieve a higher degree of filtering. The output of the last stage on pin 14 is fed to the Call Guard audio compressor and to the buffer/amplifier circuit.

3.7.6 Buffer/Amplifier and Limiter (U601B, CR601 and CR602)

The Call Guard tones are coupled by C622 to a buffer/amplifier and limiter circuit which transforms the signal into a square wave. The signal is fed to pin 8 of operational amplifier U601B and amplified an amount set by the ratio of R641 to R640. The clipped sine wave output on pin 9 is coupled by C623 to a limiter circuit formed by CR601, CR602 and biasing resistors R644, R645 and R646. From the limiter, the square wave signal is coupled by C624 to pin 13 and then is fed to the Call Guard card for decoding.

3.7.7 Call Guard Audio Compressor (Q607, Q608, Q609, U601A)

The output from the low pass filter is coupled by C618 to a compressor circuit which provides a constant level output signal. The input signal is applied across two parallel resistive networks formed by R636 and R637/Q607. R637 and Q607 form a variable voltage divider to control the input level to Q608. The signal is amplified by Q608 and the output is developed across R639.

The amplified signal from Q608 is coupled by C619 to pin 6 of operational amplifier U601A. The signal is am-amplified an amount set by the ratio of R650 to R638 and then coupled by C620 to the base of Q609 and by C607 to pin 23. With no signal input, C621 charges to about 9 volts through R656 and this potential is felt on the gate of Q607. The 9 volt potential turns Q607 off which results in maximum signal input to Q608. When a signal is applied to the circuit, Q609 conducts on the negative half cycles causing C621 to partially discharge. The degree of discharge is controlled by the signal amplitude on the base of Q609. The potential on the gate of Q607 goes negative causing Q607 to turn on more. The effective resistance of Q607 decreases resulting in a decrease in the signal level to Q608 until a balanced condition exists in the circuit. This produces a constant output with a varying Call Guard signal input level.

NOTE

Q607 is a "P" channel JFET and Q608 is an "N" channel JFET. They are depletion type transistors so maximum conduction occurs when the gate/source voltage is zero. The conduction of Q607 decreases as the gate voltage goes positive and the conduction of Q608 decreases as the gate voltage goes negative (with respect to the source).

3.8 CALL GUARD CARD

3.8.1 General

Each Call Guard card contains four separate decode type Call Guards. Each Call Guard can be tuned to any of the subaudible tone squelch frequencies and produces a low output when the correct tone has been decoded. These Call Guards do not encode or generate a tone except for alignment purposes.

A rotary switch on the front panel of the Call Guard card is used to switch each Call Guard to the encode or tone generating mode so the correct frequency can be set. During normal repeater operation, this switch is set to the "OFF" position which switches all four Call Guards to the decode mode. An ON-OFF switch for each Call Guard is located on the PC board to allow a Call Guard to be disabled if not used.

3.8.2 Buffer/Amplifier (U503A) and Pass Filter (U503B, U503C)

NOTE
Call Guard 3 is used in the following description for discussion purposes only. All four Call Guards use identical circuits.

The square wave Call Guard audio input signal on pin 13 is coupled by C514 to pin 2 of buffer amplifier U503A. The buffer amplifier provides a high input impedance so up to sixteen Call Guards can be paralleled without loading down the input signal. The buffer amplifier produces no amplification since the value of feedback resistor R543 is the same as input resistor R542.

From U503A the signal is fed to the bandpass filter formed by U503B, U503C and associated resistors and capacitors. This is an adjustable active filter formed from operational amplifiers and has a bandpass of about 2.5 Hz at Call Guard frequencies. The bandpass frequency is adjusted by R548 and the adjustment range of R548 can be increased or decreased by inserting or removing jumpers A, B and C. The position of these jumpers for various Call Guard frequencies is shown in the table on the schematic diagram. To adjust the Call Guard bandpass frequency, the Call Guard is switched to the encode mode which is discussed later or the filter output can be monitored at TP503 with an AC VTVM.

3.8.3 Threshold Detector (U503D) and Call Guard Switch (Q505)

The output of the bandpass filter is on pin 7 of U503B and is fed to pin 13 of threshold detector U503C. The threshold level of the operational amplifier is determined by the voltage level on pin 12 which is established by voltage divider R559/R560. The 4.6 volt potential across these components is developed by R552 and R553 which are across the 9.6 volt regulated line. Various AC signals are filtered from the DC by C517, C518 and C519. With no signal input to the threshold detector, pin 13 is about 4.6 volts and pin 12 is about 4.0 volts. Since the inverting input is at a higher level, the output is 0 volts. When the bandpass filter decodes a signal, a sine wave input on pin 13 is produced. When the negative going alternations drop below the level on pin 12, positive pulses are produced on the output. These pulses cause C520 to charge through CR502 and turn on Call Guard switch Q505 (which is a high-gain Darlington transistor). The collector drops near ground potential and current flows through LED CR506 and R584. The Call Guard switched line output on pin 15 is the voltage drop across Q505 and CR506 (about 2.2 volts).

3.8.4 Encode Switch (Q504) and Encode Audio Switch (Q508)

In the decode mode, encode switch Q504 is turned on by a negative potential on the base fed through R566. This effectively shorts the collector to the DC input line. Any AC from the input of the threshold detector that is fed through R558 is passed to ground through Q504 and bypass capacitors on the DC line (namely C517). This effectively removes any positive feedback to pin 3 of U503A.

Encode audio switch Q508 is turned off by a positive potential on the base from pin 7 of ENCODE switch S500. In the decode mode, the switch is in the "OFF" position so pin 1 is connected to pin 6 and pin 7 is connected to pin 12. Since pin 12 is connected to the 9.6 volt regulated line, the base of Q508 is at 9.6 volts. With Q508 turned off, the Call Guard audio input on pin 13 is not shorted to the 9.6 volt regulated line.

3.8.5 Circuit Operation in the Encode (Tone Generating) Mode

In the encode mode, more positive feedback is applied and the bandpass filter becomes an oscillator. Oscillation is at the bandpass frequency so the Call Guard can be adjusted to decode the desired tone by measuring the frequency of this signal.

Encode Switch (Q504) and Encode Audio Switch (Q508)

(For purposes of this discussion, the ENCODE switch is turned to Call Guard 3 which connects pin 6 to pin 4 and pin 12 to pin 10.)

In this mode, encode switch Q504 is turned on by a positive potential on the base from pin 10 of S500. With Q504 turned off, the feedback signal from R558 is no longer filtered out through C517 but is applied through R557 to pin 3 of U503A. This provides enough positive feedback to cause oscillation to occur. The amplitude of the oscillations is controlled by a voltage divider and limiter circuit formed by R591, R592, CR512 and CR513. The diodes are connected on one side to the DC input line which presents a virtual ground for AC signals. The AC voltage at the junction of R291 and R292 is the voltage drop across R292, CR512 and CR513. The output of the oscillator on pin 7 of U503B is fed through pins 4 and 6 of S500 to the encoded Call Guard output line on pin 4. The oscillator frequency can be measured at TP503 or encoded on the transmit signal and measured from the RF output.

Encode audio switch Q508 is turned on because the base is near ground potential. This causes signals on the Call Guard audio input line to be shorted to the 9.6 volt regulated line through C529 and Q508. This prevents any signals on the Call Guard audio input line from interfering with the oscillator.

3.9 25 AMPERE POWER SUPPLY

This power supply uses a ferroresonant transformer which provides the needed regulation. T1 can be wired to operate from a 60 Hz supply of 120 or 230 VAC. The output on each secondary section is a relatively constant 16 VAC if some loading is provided. CR3 and CR4 function as a full-wave rectifier and the output is filtered by C1, C2, C3 and L1.

R1 provides some loading for T1 and also discharges C1 and C3 when the AC power is turned off. Q1 in parallel with R1 draws additional current under light load conditions to cause a voltage drop across the secondary of T1 that prevents the output from rising too high. The base of Q1 is maintained at about 14 volts by zener diodes CR1 and CR2 and this places the emitter at about 14.7 volts (with a base/emitter PN junction drop of 0.7 volts). If the output increases, Q1 conducts more to cause more voltage to be dropped across the secondary of T1. CR7 prevents Q1 from turning on too hard so excessive current is drawn and R3 provides current limiting.

A battery takeover/charge kit consisting of R10 and CR10 allows power to be drawn from a standby battery connected to P1 and J1 if AC power should fail. R10 provides a trickle charge to maintain the standby battery in a fully charged condition.