MOTOROLA

MX1000/CQP7000 SERIES

Theory and Maintenance Manual

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SPECIAL TERMS AND ABBREVIATIONS

The construction technology and circuits in the MX1000 Series radio require the use of the following special terms and abbreviations.

Term:	Description:
A/D	Analogue-to-Digital
Alert Tones	Audible annunciators of radio status
COPE	Control Of Peripheral Electronics microcomputer (U502)
CORE	Control Of Radio Electronics microcomputer (U400)
DTMF	Dual-Tone, Multi-Frequency (phone interconnect signalling)
Logic 1	A voltage level of approximately 5Vdc
Logic 0	A voltage level of approximately 0Vdc
PA	Power Amplifier
PL	Private-Line (tone coded squelch)
PLL	Phase-Locked Loop
RX	Receive
SINAD	Signal-to-Noise and Distortion ratio
SCI	Serial Communications Interface subsystem (part of CORE, U400)
SPI	Serial Peripheral Interface subsystem (part of CORE, U400)
TX	Transmit
VCO	Voltage Controlled Oscillator

GENERAL DESCRIPTION

1. INTRODUCTION

The frequency-synthesized MX1000/CQP7000 Series portable radios are advanced design, microcomputer-based transceivers that incorporate the latest technology available in two-way radio communications. All channel frequencies and squelch codes are stored in an electrically erasable programmable read only memory (EEPROM), with all transmit and receive operations controlled by a microcomputer.

The functions provided by the radio are identified by the model and option numbers as illustrated by the model and option charts at the front of the relevant service manual. Model and option numbers are also shown on the radio's customer information sheet, which is shipped with each new radio.

a. Physical Description

The channel selector switch, on/off/volume control, multifunction LED, antenna, and emergency button (optional) are located on top of the radio. The PTT switch and monitor button are located on the left side of the radio (viewed from the front), and the the display and keypad (MX2000/CQP7000B and MX3000/CQP7000C models) are an integral part of the front cover. On the back of the radio are the rf connector, and universal connector.

The MX1000/CQP7000 radio is small in size and weight, and constructed of a highly durable, impact resistant, molded polycarbonate-blend housing. O-rings and seals are utilized throughout the radio. All controls, including the PTT switch, the monitor button, and the keypad are weather resistant, and the microphone and speaker are covered with a special diaphragm to provide extra resistance against dirt, dust, and water intrusion. This proven rugged construction offers excellent protection against adverse environmental conditions.

The height of the radio varies with the size of the battery. All other dimensions are standard.

b. Electrical Description

Electrically, the radio can be divided into two basic sections: the main radio board and, on MX2000 and MX3000 radios, the display board. The main radio board performs the transmit and receive, frequency generation and distribution, power generation and distribution, control, and interface functions.

The display board includes circuitry for displaying user information, and an electrically-erasable read-only memory (EEPROM) for storage of user-programmable parameters.

2. STANDARD FEATURES

The MX1000/CQP7000 Series radio has an internal microphone and speaker, but can be operated with an optional external microphone and/or speaker. External rf and "universal" connectors provide easy access for testing, and for attaching a remote antenna and a variety of audio accessories. Radio models are available with up to 100 channels of carrier, tone "Private-Line" (PL), and/or Select 5. Two power levels are offered:- low power (0.1-2.5W on VHF or 0.1-2.0W on UHF models) and high power (1-6W on MID-BAND and VHF or 1-5W on UHF models).

The battery slides onto the bottom of the radio and is held in place by a spring-loaded latch. Batteries are available in three different sizes, which correspond to the battery capacity (light, medium, and ultra-high). The different size batteries affect the operating time between charges as well as the overall height and weight of the radio.

A red multifunction LED on the top of the radio provides feedback to the user. The LED indicates when the radio is in transmit (continuous red), a low battery condition (flashing red in MX1000/CQP7000A radios only), or channel busy (MX2000/CQP7000B and MX3000/CQP7000C radios and MX1000/CQP7000A radios with the "channel busy" option).

3. SPECIAL STANDARD FEATURES

a. Field Programming

The MX1000/CQP7000 Series radio utilizes a reprogrammable EEPROM, which permits operating characteristics to be changed without opening the radio. Programming is accomplished via a programming cable interface to an IBM PC, Laptop PC, or Personal System/2 computers.

b. Private-Line (PL) Coded Squelch and Select 5 Coded Squelch

Coded squelch allows only those calls with a radio's particular code to be heard, and can be enabled on a per channel basis. Thus, a MX1000/CQP7000 Series radio can have carrier squelch on some channels, tone PL and/or Select 5 squelch on others. You can choose from 40 tone PL codes.

c. Secure Capable Radios

The Secure Capable radios can operate in either the secure coded voice mode, or the standard clear voice mode. The mode used for transmission can be controlled by the coded/clear selector switch, or by "strapping" on a per-channel basis using the Radio Service Software. Regardless of the coded/clear selector switch position or the channel strapping, the radio will receive both coded and clear transmissions.

4. PRINTED CIRCUIT BOARDS AND FLEXIBLE CIRCUITS

a. General

Functional circuits in the MX1000 Series radio are contained on the main radio circuit board, and, in MX2000 and MX3000 radios, the display circuit board. Flexible circuits are utilized to eliminate discrete wiring.

b. Main Radio Board

The main radio board is a six-layer printed circuit board containing the rf, i-f, frequency generation, control, power, and audio portions of the radio. With the exception of the circuit modules, most of the board's components are mounted on its top side.

b. Display Board

The display board is a four-layer printed circuit board containing the display circuitry, additional control circuitry, and the EEPROM for the radio.

c. Flexible Circuits

The MX1000 Series radios uses several flexible printed circuits for interconnection. These include:

- PTT/Controls Flex
- Speaker/Microphone Flex
- Universal Connector Flex
- LCD interconnect Flex (MX2000 and MX3000 radios)

5. BATTERIES

The rechargeable nickel-cadmium batteries available for the MX1000 Series radio are listed in Table 1. Battery choice is governed by duty cycle, operating time, and maximum height and weight desired.

Table1. MX1000 Series Radio Batteries

MODEL NUMBER	BATTERY CAPACITY	CHARGE TIME
NTN4537	LIGHT	1 HR
NTN4538	MEDIUM	1 HR
NTN4592	LIGHT	1 HR
NTN4593	MEDIUM	1 HR
NTN4595	ULTRA-HIGH	1 HR
NTN4596	ULTRA-HIGH	1 HR
NTN4992	ULTRA-HIGH	1 HR

* BASED ON A STANDARD CONFIGURATION RADIO WITH A DUTY CYCLE OF 5% TRANSMIT, 5% RECEIVE, AND 90% STANDBY TIME

BATTERY CHARGING

1. AVAILABLE CHARGERS

Available chargers include a single-unit desk top charger, a single-unit porta-pocket charger, and multi-unit chargers that may be mounted on a wall or a bench. The multi-unit chargers will charge up to six nickel-cadmium batteries at one time.

The single-unit desktop and multi-unit chargers are rapid-charge models, while the porta-pocket is a slow-charge model. The slow-charge model will charge any of the batteries, with or without the radio attached, in 16 hours. The rapid-charge models will charge any of the batteries in approximately one hour.

Refer to the MX1000 Series Battery Charger Service Manual for the information on available battery chargers and their applications. For further information, contact your Motorola sales representative.

2. BATTERY CONSTRUCTION *(See Figure 1)*

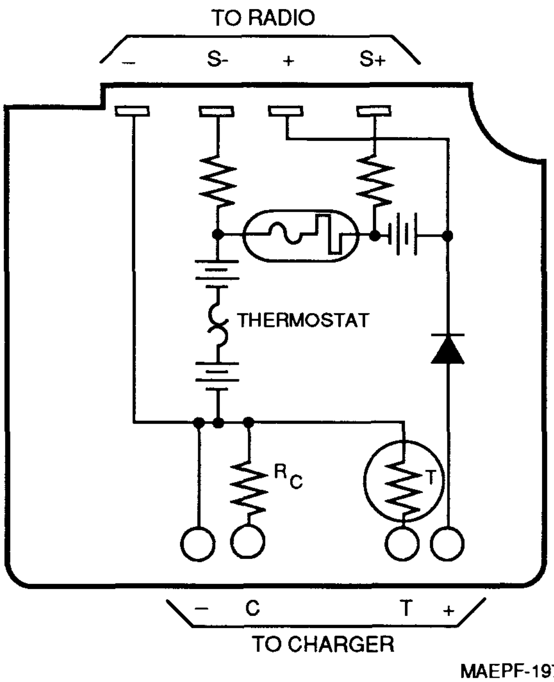

Figure 1. Typical Battery Construction, Rear View

The MX1000 Series rapid-charge battery has four charger contacts, two of which receive the charging current. A third contact connects the internal capacity resistor (RC) to the charger, automatically setting the charging current output to match the capacity of the battery. The fourth contact connect an internal thermistor to the charger. The thermistor senses battery temperature and automatically controls the charger output to permit maximum charger output without overheating the battery.

All rapid-charge batteries contain an internal current-limiting device (thermal fuse) for protection. A diode in the battery prevents damage from an accidental short between the charging contacts.

CAUTION

Sustained shorts across the radio contacts (+, -), excessive current, or excessive heat will destroy the internal thermal fuse, which is not replaceable.

3. BATTERY CHARACTERISTICS

Each nickel-cadmium battery consists of six cells connected in series to provide a nominal 7.5 Vdc output, which remains approximately constant under load until the battery approaches a discharged condition. At this time, a marked decrease in voltage occurs and the discharge condition (1.0 volt per cell) is reached abruptly.

A general characteristic of all rechargeable batteries in storage is self-discharge. If the battery is to be used after an unknown period of storage, it is recommended that it be charged at the full charging rate using an approved battery charger.

4. MAINTENANCE

The battery cells will never require additional electrolyte. The only maintenance required is recharging the battery and keeping its contacts clean. Use only a Motorola approved charger. The use of other chargers, unless approved, will void the battery warranty and may result in permanent damage to the battery.

5. STORAGE

The battery may be stored at room temperature in any state of charge without damage. As previously stated, however, the battery is subject to self-discharge and should be recharged after extended storage.

6. DETERMINING BATTERY CAPACITY

Battery capacity is determined by measuring the time that a fully-charged battery requires to discharge to six volts through a specified load, as described in the following procedure:

NOTE

This procedure requires using a 20-ohm, 1%, 10-Watt load resistor to discharge medium capacity batteries, and an 11-ohm, 1%, 15-Watt load resistor to discharge high capacity batteries.

a. Obtain a Radio Housing Adapter (Motorola part number RTL-4225A) from your nearest Parts Department.

b. Connect the appropriate 20-ohm or 11-ohm load resistor (See Note above) between the gold (+) terminal and a solder lug (-) screw and nut of the housing adapter.

c. Connect a voltmeter across the load resistor and slide a fully-charged battery onto the housing adapter.

d. Monitor the voltmeter as the battery discharges through the load resistor, until the voltage is 6.0 volts. This will erase the memory effect.

e. Disconnect battery from the housing adapter (resistor load) when the cell pack reaches 6.0 volts.

CAUTION

Discharging the battery down to 4.0 volts can cause permanent cell pack damage.

f. Recharge the battery to a complete charge. This will require a 1-hour rapid charge followed by a 16-hour standard charge.

g. Re-attach the battery to the housing adapter (resistor load) and measure the elapsed time until the cell pack reaches 6.0 volts. Disconnect the battery.

h. A good battery will require 48 minutes or longer to discharge, indicating greater than 80% of rated capacity. A weak battery will drop below 6.0 volts in less than 48 minutes.

THEORY OF OPERATION

1. INTRODUCTION

This section of the manual provides a functional description of the MX1000 Series radio. First, overall basic functions are discussed in general terms with each circuit and its relationship to other parts of the radio described. Then, detailed circuit descriptions are given for each circuit and module used in the radio.

2. BASIC FUNCTIONAL DESCRIPTION

a. DC Voltage Distribution *(See Figure 2)*

Operating power for the radio is derived from a 7.5-volt battery. This 7.5 volts (B+), is fed, via the universal connector flex, to P4, pins 4 and 6, on the radio board. B+ is next routed through 5-amp fuse F900, to pin 11 of J2. Then, via the PTT/controls flex, B+ is applied one side of the on/off switch, S800. Raw B+ from the battery (identified on the schematic by the "1" symbol is also applied directly to the power amplifier (PA), U202, pins 6 and 12 (VHF), pins 6 and 8 (UHF) and pin 12 (MID-BAND).

When the radio is turned on, the voltage sources required to operate the various stages of the radio are distributed as shown on the main board schematic diagram in the applicable service manual.

SWITCHED B+ from S800 enters the main radio board via interconnect J2, pin 4. From this point it is distributed throughout the radio to most of the ICs, to OPTION B+ on the universal connector (through R433), to the display board (via jack J1, pin 4), to multifunction LED CR40 (through Q405), and to regulator U103. SWITCHED B+ (source and destination) can be identified by the "2" symbol. Note that SWITCHED B+ is also provided to the emitters of Q204 (base bias to the PA), Q1 (which is connected to the 5-volt regulator contained within U100), Q206 (provides RX 5V), and Q203 (provides TX 5V). Additionally, in the case of the UHF radio, SWITCHED B+ is also supplied to the collector of Q200.

No.1A REGULATED 5V (MID-BAND/VHF radios only) originates at inductor L5, and is identified by the "3a" symbol. No.1A REGULATED 5V is distributed to the following ICs: U101, pins 1, 18, and 39; U700, pins 1 and 22; and U102, pin 14.

No.1 REGULATED 5V (UHF radios only) originates at U100, pin 14, and is identified by the "3" symbol. No.1 REGULATED 5V is distributed to the following ICs: U101, pins 1, 18, and 39; U700, pins 1 and 22; U102, pin 14; U301, pin 4; and U200, pin 1.

No.2 REGULATED 5V, identified by the "4" symbol, is provided by regulator U103 (pin 2). This voltage is distributed to various circuits and ICs within the radio, including pins 2, 4, 19, 28, 29, 32, and 64 of microcomputer U400, and pin 7 of jack J2.

TX 5V, identified by the "5" symbol, is provided by U201's internal TX/RX 5V regulator. This voltage is distributed to many of the transmitter circuits, including the internal microphone biasing, the temperature-sensing circuit of PA U202, and (UHF radios only) the base of Q200.

RX 5V, identified by the "6" symbol, is also provided by U201's internal TX/RX 5V regulator. This voltage is distributed to the following circuits: pin 22 of U201; pin 7 of U1 and pin 2 of T1 (VHF) or pin 3 of U2 (UHF).

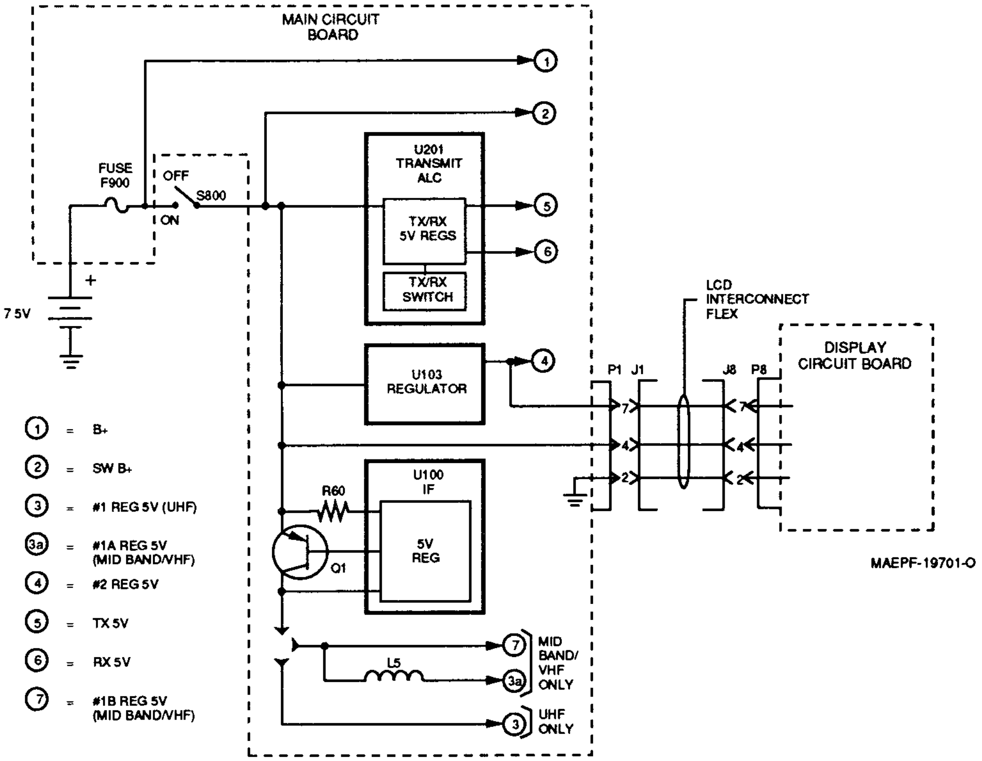

Figure 2. DC Voltage Distribution Block Diagram

No.1B REGULATED 5V (MID-BAND/VHF radios only) originates at U100, pin 14, and is identified by the "7" symbol. No.1B REGULATED 5V is distributed to U200, pin 1, and U301, pin 4.

b. Frequency Generation and Distribution Circuits (U300, U301)

The MX1000 Series radio uses a coherent synthesizer (traditional voltage-controlled oscillators (VCO) and phase-locked loop (PLL)) with state-of-the-art designs to generate frequencies which support a dual-conversion radio with unlimited capabilities in the UHF, VHF and MID-BAND ranges with operating splits of up to 30 MHz.

The rf frequency generation circuits include the reference oscillator, U301, and the synthesizer, U300. The synthesizer has three major subassemblies: oscillator, controller (PLL/divider), and buffer/amplifier. To provide superior system performance, each subassembly is broken down into a separate TX and RX section. The synthesizer (U300, pin 1) uses the 16.8 MHz signal from the reference oscillator (U301, pin 3) in conjunction with its own internal dividers and VCOs to generate and synthesize the following frequencies:

- TX carrier (U300, pin 14),
- local oscillator (1st injection) (U300, pin 15),
- 2nd local oscillator (both high- and low-side injection) (U300, pin 32),
- 2.1 MHz (U300, pin 17), and
- 300 kHz (internal only).

The audio in the MX1000 Series synthesizer is simultaneously modulated at two different ports. The audio is first conditioned (pre-emphasis and limiting) externally by audio filter U101, then sent, via the VCO MOD and REF MOD lines, to two different ports on the synthesizer module, U300.

The reference modulation port (U300, pin 19) accepts low-frequency audio (<70Hz) and modulation is produced by varying the frequency of the synthesizer in proportion to the audio input voltage.

The VCO modulation port (U300, pin 3) accepts high-frequency audio (>70Hz) and modulation is produced by varying the control voltage of the VCO in proportion to the high frequency audio input. The dual-modulation scheme allows for a flat deviation response for all desirable signals which readily supports Motorola's PL/5-TONE channels and sensitive Secure Capable radios.

The following generic (TX or RX) description of the MX1000 Series synthesizer is used because of the symmetrical hardware and operational systems for both the TX and RX sections. The VCO becomes active and generates an output frequency, which is compared to the desired frequency. If the frequencies differ, an error ramp voltage is generated to the VCO which brings the output frequency to the desired frequency. When the output and desired frequencies match, the VCO is locked. The locked state of the synthesizer can be observed externally by looking for zero volts on the LOCK DETECT line of the synthesizer (U300, pin 16).

c. Antenna Switch and Bias Circuits

Steering of rf between receiver and transmitter, and standard and remote antennas is accomplished electronically by a 4-port PIN diode switch located in the filter/detector/switch module, U203. This module also contains a directional coupler and power detector which supply the system with an indication of transmit output power. Low-pass filters are also included to attenuate transmitter and receiver (MID-BAND only) harmonics.

d. Display Circuitry (MX2000 and MX3000 radios only)

The display circuitry for the MX2000 and MX3000 radios includes the liquid crystal display (LCD) and the display circuit board. This board, mounted on the radio's front shield, provides MX2000 and MX3000 radios with additional and expanded capabilities. The display board is a standard 8k board containing the following ICs:

- An MC68HC11 microprocessor, U502. This IC is also called the COPE (control of peripheral electronics).
- An electrically-erasable, programmable.read-only memory (EEPROM), U501. This IC's memory size is eight kilobytes (8k board).
- A liquid crystal display (LCD) driver, U504.
- A serial-to-parallel shift register, U503.
- A dual-tone multi-frequency (DTMF) generator, U505.

The display board communicates with the radio board via the 8-wire LCD interconnect flexible cable (J8); this cable provides both power and signal paths. There is also a 3-wire connection to the speaker/microphone flex (J9) that is used as a DTMF signal path.

e. Secure Circuitry (Secure Capable radios only)

The Secure module (U900) requires an encryption key, or key variable, to perform its encode/decode function. This key is a digital sequence which is loaded into the radio, via the radio's universal connector, from a hand-held key variable loader (such as the T3010BX DVP Keyloader, which is suitable for all radios with the DVP algorithm). In order for the two Secure Capable radios to communicate with each other in the secure mode, both must have the same encryption key loaded.

3. DETAILED CIRCUIT DESCRIPTION

The circuit descriptions contained in the following paragraphs are intended to help the service technician understand the signal processing in various parts of the radio. Refer to the complete schematic diagram in the applicable service manual when repairing a radio.

a. DC Switching

In the receive mode, after a dekey, channel change, or at the end of a power-up sequence, the microcomputer, U400, starts a receiving sequence. The R/T line is set to receive (RX = 1).

The following voltages determine the options selected via pin 7 of the universal connector: 1.235V = external speaker/microphone, 2.5V = public safety microphone, and 3.735 = external antenna only. When the R/T line is set to receive (1), the transmit automatic level control IC, U201, switches the filter/detector switch (U203) PIN diodes to enable the rf from either the standard antenna or the remote antenna to the receiver front end (for MID-BAND and VHF radios).

In UHF radios, if the standard antenna path is to be activated, Q207 is saturated; if the remote antenna is selected, Q208 is saturated. In either case, the current is directed to pin 10 of U203, supplying all the current/voltage for the receiver front end.

In the transmit mode (PTT switch pressed), pin 60 of microcomputer U400 is grounded. This sets the reprogramming of the chip set (audio filter IC, digital/analog converter IC, and the signalling IC) in motion without changing the R/T line status (RX = 1; TX = 0). The internal/external microphone is selected and enabled. The microphone itself will not be enabled until the TX 5V is active. The last chip programmed is the audio filter IC, U101; this will change the status of the R/T line to transmit (0). Once the R/T line status changes, the transmit automatic level control IC, U201, changes several outputs simultaneously, providing the required TX 5V to the transmitter circuits.

b. CORE Microcomputer (U400)

The control of radio electronics (CORE) microcomputer, U400, directly controls many of the MX1000 Series radio's functions. The major functions of the CORE include:

- *IC Programming.* The CORE processor is responsible for programming the radio's support ICs, including the audio filter (U101), the digital-to-analog (D/A) converter (U200), the synthesizer/prescaler (U300), and the signalling IC (U700). The CORE uses its serial peripheral interface (SPI) subsystem to program these ICs. The microprocessor lines that make up the SPI subsystem include the MISO (pin 28), MOSI (pin 29), and SCK (pin 30) lines. In conjunction with the SPI, the CORE uses dedicated output ports to select each individual IC. Examples of when the ICs can be programmed include channel changes, volume changes, transitions from receive to transmit, and transitions from transmit to receive.

- *Serial Bus.* The MX1000 Series radio can have more than one processor in its system; these multiple processors communicate over the serial bus, which runs at a rate of 9600 baud. The CORE processor communicates on the serial bus via its serial communications interface (SCI) subsystem (RD1, pin 22 and TD1, pin 27) and the BUSY line (pin 14). The BUSY line indicates whether the serial bus is active; when the BUSY line is low, the bus is active. Examples of when the serial bus can be active include switch changes, channel changes, and transitions from receive to transmit and transmit to receive.

- *Analog-to-Digital (A/D) Subsystem.* The CORE processor has four A/D inputs for processing analog data. The voltage from the volume potentiometer (R800) is fed to one of the A/D lines (PE5, pin 56). The OPTION SELECT line (PE7, pin 62) is the second A/D input, and the battery voltage (PE4, pin 54) is the third input. The last input (PE6, pin 60) is the SIDE CONTROL line, which has the PTT switch (S803) and monitor switch (S805) connected to it. When the PTT switch is pressed, this line is grounded; the PTT switch has the highest priority, followed by the monitor switch.

- *Frequency Switch.* The CORE processor reads the output of the frequency switch (S803) via four input lines (PE0 through PE4; pins 53, 55, 59, and 61 respectively). The emergency switch (S801) is also connected to the frequency switch. When the emergency switch is pressed, all four input lines are grounded. If the radio is turned on while the emergency switch is pressed, the radio cannot power up because it does not have a valid channel to power-up on.

- *PL Encoding.* The PL encoder is part of the audio filter IC (U101), but is controlled by the CORE processor. The CORE processor feeds (pin 39) a pulse train to the audio filter IC (U101, pin 33) during tone PL encoding; the frequency of the pulse train is 12 times the desired tone PL frequency. For digital PL encoding, U101 is sent bursts of six pulses of every DPL transition.

- *PL Decoding.* The PL filter and hard limiter are also part of the audio filter IC, (U101). The demodulated, filtered, hard-limited signal is sent (U101, pin 28) over the PL DECODE line to the CORE processor (pin 41). At the instant that the CORE wants to sample this line, it sends (pin 39) a latching pulse, via the PL SAMPLE/CLK line, back to U101 (pin 33).

This pulse latches the sample, which can then be read by the CORE processor. The frequency of the pulse is 1071 Hz.

- *Select 5 Encoding.* The Select 5 encoder is part of the signalling IC (U700), but is controlled by the CORE processor. The CORE processor feeds (pin 35) a series of (nominally 5) pulse trains to U700; the frequencies of the pulse trains are 2,6 or 10 times the required Select 5 tone frequencies, depending on the mode of operation of U700 (controlled by CORE processor via UC Interface), which is determined by the tone frequency to be generated. The pulse train is also filtered by U700, before being sent over the TX MOD OUT (pin 14) line to the audio filter IC (U101).
- *Select 5 Decoding.* The Select 5 filter and limiter are also part of the signalling IC, (U700). The limited signal is sent over the LIMITER IN line to the CORE processor (pin 43). The CORE processor performs the decoding operation, by correlating the incoming signal with the wanted decode sequence.

The signals and levels to be expected at various pins of the CORE microcomputer (U400) are as follows:

Pin No.	Function	Signal
* 1	Vss	Ground
* 2	Mode B	5V
* 3	Mode A	Ground
4	PD6	5V
5, 6	No connection	Don't care
* 7	E XTAL	7.3728MHz signal (high-impedance)
8, 9	No connection	Don't care
* 10	XTAL	7.3728MHz signal
11	AFIC select	0V when AFIC is being programmed; 5V otherwise
12	No connection	Don't care
13	XMIT power ind.	0V or 5V
14	Busy	5V = Serial bus active; 0V = Serial bus inactive
15	Squelch	5V = Squelch detect; 0V = No squelch detect
16	Lock detect	5V = Synthesizer not locked; 0V = Synthesizer locked
17	Fast squelch	5V = Squelch detect; 0V = No squelch detect
18	Option switch	0V or 5V
* 19	Reset	0V = Reset mode; 5V = Otherwise
* 20	XIRQ	5 Volts
* 21	IRQ	5 V
22	Serial bus data	5V = Bus inactive; Toggles between 0V and 5V at 9600 baud when active
23, 24	No connection	Don't care
* 25	Vss	Ground
26	No connection	Don't care
27	Serial bus data	5V = Bus Inactive; Toggles between 0V and 5V at 9600 baud when active
28	MISO	5V =ICs being programmed; Toggles between 0V and 5V at 115.2 kHz when ICs are not being programmed
29	MOSI	5V =ICs being programmed; Toggles between 0V and 5V at 115.2 kHz when ICs are not being programmed
30	SCK	5V =ICs being programmed; Toggles between 0V and 5V at 115.2 kHz when ICs are not being programmed
31	No connection	Don't care
* 32	Vdd	5V
* 33	Vss	Ground
34	PASF	Don't care
35	Tone clock out	Toggles between 0V and 5V when MDC or tone signalling is being transmitted
36	DTMF clock out	0V or 5V
* 37	AFIC watchdog disable	5V = Normal operating mode; 0V = Radio reset in progress
38	No connection	Don't care
39	PL sample clock	Toggles between 0V and 5V at 1071Hz when TPL decode is enabled; 537Hz when DPL decode is enabled. 12 times TPL frequency (in transmit)
40	MDC reference	Don't care
41	PL decode	Toggles between 0V and 5 V
42	No connection	Don't care
43	Limiter in	Toggles between 0V and 5 V in receive mode
44	No connection	Don't care
45	Adapt	5V = During channel change; 0V = Otherwise
46	D/A IC select	0V = When D/A IC is being programmed; 5V = Otherwise
47	Synthesizer IC select	0V = When synthesizer IC is being programmed; 5V = Otherwise
48	Prescaler IC select	0V = When prescaler IC is being programmed; 5V = Otherwise
49	Signalling IC select	0V = When signalling IC is being programmed; 5V = Otherwise
50	Red LED	5V = LED on; 0V = LED off
51, 52	No connection	Don't care
53	Freq. select 0	This is the least-significant bit of the frequency switch. 0V or 5V
54	Battery voltage	1/2 of the battery voltage
55	Freq. select 1	0V or 5V
56	Volume sense	0V or 5V
57, 58	No connection	Don't care
59	Freq. select 2	0V or 5V
60	Side control	0V = PTT switch pressed; ≈1.23V = Monitor button pressed
61	Freq. select 3	This is the most-significant bit of the frequency switch. 0V or 5V
62	Option select	5V = No option connected; ≈3.73V = Option class 1; ≈2.5V = Option class 2; ≈1.23V = Option class 3
63	VRL	Ground
64	VRH	5V

Note: Ground = 0 volts
* = Needed for processor to power-up correctly.

c. Digital-to-Analog (D/A) Converter (U200)

The digital-to-analog (D/A) converter, U200, is a multifunction CMOS integrated circuit containing two 7-bit D/A converters, one 4-bit D/A converter, six control outputs, two SPDT transmission gates, and a microcomputer interface.

The output (U200, pin 11) of the first 7-bit D/A converter supplies the tuning voltage for the reference oscillator, U301. When the R/T line is low (0V), the output of the second 7-bit D/A converter is routed, via an internal switch, to pin 9. This provides the power control reference voltage for the TX ALC IC, U201, during transmit operation.

In VHF radios only, when the R/T line is high (5V), the second D/A converter's output is switched to pin 8, providing tuning voltage for the VHF 2-pole filter, U1. A combination of resistors R218 and R219, and a microcomputer-interface-controlled switch (connected internally between pins 15 and 16 of U200) allows extension of the 2-pole tuning voltage range beyond that of the 7-bit D/A converter.

In MID-BAND and UHF radios there is no receive tuning adjustment, so the second 7-bit D/A converter is used only for transmit.

The 4-bit D/A converter is not used in MX1000 Series radios, but its four pull-down resistors are used. These resistors, which connect internally to U200, pins 4 through 7, are connected externally to the BCD frequency switch, S823, and U400.

Three of U200's control outputs are used in MX1000 Series radios:

- Pin 2 is the REMOTE ANTENNA ENABLE line; a high output on this line enables the remote antenna.
- Pin 3 is the low-power range enable line (normally low); a high on this line enables the very-low power tuning range.
- Pin 20 is the clock shifter enable line; a low on this line enables the clock shifter.

d. Antenna Switch (U201, U203)

(1) MID-BAND and VHF

When the PTT switch is pressed, or the OPTION SELECT line is brought to 0 Vdc, the microcomputer (U400) sends data to U101 which sets the R/T line low (0V). A logic low on U201, pin 9, causes U201, pin 28 to go high (≈6Vdc). This voltage is applied to the anode side of a series-connected pair of PIN diodes, internal to U203 (pin 8) which control the transmit/receive rf steering. The cathode side of the diode pair is connected to U203, pin 9.

During transmit operation, the PIN diodes are forward biased and a low-impedance path connects U203, pin 1, to the selected antenna. When biased for transmit operation, the voltage dropped between pins 8 (+) and 9 of U203 should be two diode drops or approximately 1.5 volts.

During receive operation, the R/T line goes high (5V), and U201, pin 28 (anode bias), should go to approximately 0Vdc and U201, pin 26 (cathode bias), should pull-up to approximately 7.5V, reverse-biasing the T/R PIN diode pair, resulting in a low-impedance rf path from U203, pin 10, to the selected antenna.

The standard/remote antenna switch position is determined by the voltage on the OPTION SELECT line (U400, pin 62). When the OPTION SELECT line is at 5V or 1.24V, the microcomputer commands U200 to bring the REMOTE ANT ENABLE line (U201, pin 23) low (0V), selecting the standard antenna. When U201, pin 23, is low, U201, pin 24, is also low, and U201, pin 20, is high (7.5V). This reverse-biases the PIN diode pair that makes up the standard/remote antenna switch in U203 (U201, pin 24, is the anode; U201, pin 20, is the cathode). When the diodes are reverse-biased, a low-impedance rf path exists between U203, pin 14 (standard antenna) and the transmitter or receiver. Additional filtering is provided in VHF radios by capacitors C206, C207, and C208, and inductor L201, and in MID-BAND radios by capacitors C207 and C208, and inductor L201.

Setting the OPTION SELECT line to 3.74V or 2.5V causes the microcomputer to instruct U200 to bring the REMOTE ANT ENABLE line high (5V). This causes U201, pin 24, to go high and U201, pin 20, to go low, forward-biasing U203's standard/remote antenna switch PIN diodes, and forming a low-impedance path from U203, pin 12, to the receiver or transmitter.

When the PIN diodes are forward-biased, the voltage dropped between pins 12 (+) and 13 of U203 should be two diode drops or approximately 1.5 volts. In VHF radios, capacitors C222, C223, C224, and C225, and inductor L205 are for rf decoupling; C229 is a dc block and C241 is a matching element. In MID-BAND radios, capacitors C222, C223, and C224, and inductor L205 are for rf decoupling; C229, C231, and L206 provide additional filtering on the remote antenna path. MID-BAND radios also have a reverse-bias circuit, consisting of capacitor C250, inductors L250 and L254, and diode CR250. This circuit prevents the PIN diodes from turning on and starting to generate harmonics at critical levels.

Proper operation of bias circuits in U201 is dependent on correct voltages being present on the TX 5V and RX 5V regulators, as well as resistors R211 through R213. Proper operation of U203 is dependent on correct installation of the 4205577Q01 grounding clip.

(2) UHF

Although the filter/detector/switch module is functionally equivalent in both VHF and UHF radios, the electrical realization of the two 4-port PIN diode rf switches are somewhat different, and require slightly different biasing circuits.

As in the VHF models, the TX/RX antenna switching is controlled by the R/T line (U201, pin 9). When the R/T line is high (5V), the RX 5V regulator in U201 is on and supplying current to receiver U2. The supply current for the RX 5V regulator is drawn from U203, pin 10 (receive path PIN diode cathode). Current flow through the receive path PIN diode causes a low-impedance rf path from U203, pin 9, to the selected antenna. When the R/T line is high, the voltages at pin 26 of U201 and pin 7 of U203 should be approximately 7.5Vdc.

When the R/T line goes low, U201, pin 13, should go high (7.5V), turning off Q206 and bringing pin 10 of U203 high (7.5V). The receive path PIN diodes in U203 are now reverse-biased, turning off the receive rf path. With the R/T line in the low state, U201, pin 26, goes low (≈ 4.7Vdc), allowing dc current to flow through the selected transmit path PIN diodes, forming a low-impedance path from the selected antenna to U203, pin 1.

Selection of the standard or the remote antenna is determined by the state of switching transistors Q207 and Q208. When the REMOTE ANT ENABLE line is low (the standard antenna has been selected), U201, pin 20, is high (7.5V) and Q208 is turned off, causing U203, pin 11, to go low. When U201, pin 20, is high, U201, pin 17, goes low (0V). This turns on Q207, bringing U203, pin 8, high (7.5V) and selecting the standard antenna (U203, pin 14).

When the REMOTE ANT ENABLE line goes high (5V), U201, pin 20, goes low and U201, pin 17 goes high (7.5V), turning Q207 off and turning Q208 on. U203, pin 11, is now high (7.5V), and the remote antenna (U203, pin 12) is selected.

When the radio is transmitting, the voltage dropped between the selected antenna enable (U203, pin 8 or 11) and the TX SINK line (U203, pin 7) should be about 2.5V. The receive sink line (U203, pin 10) should be high (7.5V).

When the radio is receiving, the voltage drop from the selected antenna enable (U203, pin 8 or 11) to receive sink line (U203, pin 10) should be about 1.0V. The TX SINK line (U203, pin 7) should be high (7.5V).

Resistor R225 is necessary for proper RX 5V regulator power-up, C62 is an audio frequency bypass capacitor, and C222 through C225 are rf bypass capacitors.

Operation of the switching circuits in U201 depends on proper operation of the TX 5V and RX 5V regulators, as well as resistors R212 and R219. Proper operation of U203 is dependent on correct installation of the 4205577Q01 grounding clip.

e. Power Detector Circuit (U200, U203)

The detector circuit in U203 provides a dc voltage which is proportional to the transmitter power output. The detector output voltage appears at U203, pin 5, in MID-BAND and VHF models and U203, pin 4, in UHF models. Normally, this voltage should range from 2.4Vdc to 4.0Vdc. Bias for the detector is supplied to U203, pin 6 (MID-BAND, VHF and UHF models).

During normal operation, U200, pin 3 is at 0Vdc and diode CR201 is reversed-biased, allowing no current flow, so all bias current is sourced from the TX 5V regulator through R203 (MID-BAND, VHF) or R218 (UHF).

For low-power operation, U200, pin 3, goes high (≈5V), forward-biasing CR201, and raising the bias level at U203, pin 6. This alters the operating range of the power detector circuit, allowing the system to operate at lower power levels.

On MID-BAND/VHF models, C230 and C217 rf bypass the detector output and bias lines. On UHF models, L210, C230, and C228 perform the same function.

f. Signalling IC (U700)

The signalling IC, U700, has analog and digital circuitry to aid the encoding and decoding functions provided by the radio. The CORE microcomputer, U400, programs the signalling IC via the SPI interface.

Select 5 Encode. The signalling IC is configured by U400, via the UC Interface, to generate the required Select 5 tone, using a multi-level square wave approximation method, from the incoming pulse train. The tone is then filtered, before being passed as TX MOD OUT to the audio filter IC, U101.

Select 5 Decode. The signalling IC filters the incoming RX AUDIO IN signal. The filtered signal is then limited, to provide the square wave LIMITER OUT signal (LIMITER IN at U400, pin 43).

DOS Detection. The digital-operated squelch (DOS) algorithm is in the CORE microcomputer, but the support hardware in in U700. The radio discriminator output from U100 (pin 31) is fed to U700 (pin 31), where it is filtered and hard limited. This hard limiter signal is then fed to an input capture port on U400 (pin 43).

The signals and levels to be expected at various pins of the signalling IC, U700, are as follows:

Pin No.	Function	Signal
1	5 volts	5V
2	Bias resistor	Don't care
3	No connection	Don't care
4	PASF	5V
5	MDC reference	Don't care
6	No connection	Don't care
7	DTMF clock in	0V or 5V
8	Trunking data in	Don't care
9	Tone clock in	Toggles between 0V and 5V when MDC or tone signalling is being transmitted

Pin No.	Function	Signal
10	Clock	5V =IC is being programmed; Toggles between 0V and 5V at 115.2 kHz when IC is not being programmed
11	Data	5V =IC is being programmed; Toggles between 0V and 5V at 115.2 kHz when IC is not being programmed
12	Chip select	0V when signalling IC is being programmed; 5V otherwise
13	No connection	Don't care
14	TX mod out	This line has the analog tone signalling during transmit of MDC or tone signalling
15, 16	No connection	Don't care
17	Side tone out	This line has the analog tone signalling during transmit of `tone signalling
18	No connection	Don't care
19	Ground	Ground
20	2.1 MHz in	2.1 MHz signal
21	No connection	Don't care
22	Digital Vdd	5V
23, 24	No connection	Don't care
25	Limiter out	Toggles between 0V and 5V in receive mode
26	HS bypass	Don't care
27	LS bypass	Don't care
28	No connection	Don't care
29	VAG bypass	Don't care
30	No connection	Don't care
31	RX audio in	The analog demodulated signal
32-34	No connection	Don't care
35	Ground	Ground
36	No connection	Don't care

g. Receiving

The signal received at the antenna is routed through the filter/detector/switch module (U203) and applied to the receiver rf front end module for filtering, amplification, and mixing down to the first i-f.

(1) RF and 1st I-F

(a) MID-BAND (U1, U4)

In the MID-BAND receiver string, rf enters U1, the rf filter/amplifier module. This module consists of a descrete-component, 3-pole bandpass filter, designed to cover either the low (68-84 MHz) or the high (74-88 MHz) bandsplit, and a common-base, transformer feedback amplifier. The entire module provides about 9dB of gain.

The amplified RF from U1 enters U4 at pin 2 and is routed via a 3-pole bandpass filter to the mixer, a passive Schottky ring diode and diplexer, where it is mixed with the local oscillator (LO) signal from U300 (pin 15). Components L51, 52, 53 and C51, 52 and 54 provide blocking and decoupling. The LO signal enters the mixer (pin 3) at a level between +4.5 to +5.0dBm, 53.55 MHz above the channel (rf) frequency.

The resultant first i-f signal (53.55 MHz) from the mixer then passes through U4's i-f amplifier and crystal filter before exiting the module (pin 4). There is a loss of about 6 to 7dB through the mixer, the i-f amplifier provides about 13dB of gain, and the crystal filter has about 3.5dB insertion loss. The crystal filter supplies about 35dB of attenuation at the adjacent channel and 80dB of attenuation at the second image. The bandwidth of the i-f signal leaving U4 is typically 10 to 19 kHz, centered around 53.55 MHz, with a typical gain of 0 to 2dB. The first i-f signal is routed through matching components C49 and L2 before entering the i-f IC, U100.

(b) VHF (U1, Q1, T1, U2, U4)

In the VHF receiver string, rf enters U1, the tunable, 16 MHz-bandwidth, 2-pole filter module. This module has about 2dB of loss. The 2-pole filter can be tuned to cover the entire 146-178 MHz band, depending upon the applied voltage from the digital/analog converter IC, U200.

The rf signal leaves U1 (pin 11) and enters the rf amplifier, Q3. This is a common-base, transformer feedback amplifier, with the output signal leaving through the center tap of transformer T1 (pin 1). The amplifier provides about 10dB of gain over the entire VHF frequency band.

The rf signal next passes through matching components C54 and L52, and into the 5-pole filter, U2 (pin 1). A 32 MHz-bandwidth, stripline filter module containing some discrete components, U2 has a typical insertion loss of about 3.5dB.

After leaving U2 (pin 2), the rf signal enters the front end module, U4 (pin 2), which is mounted directly above U2. Within U4 the signal first moves into the double-balanced mixer, where it is mixed with the local oscillator (LO) signal from U300 (pin 15). The LO signal enters the mixer (pin 3) at a level of +4.5 to +5dBm, and one i-f (53.55 MHz) above the channel (rf) frequency.

The resultant first i-f signal (53.55 MHz) from the mixer then passes through U4's i-f amplifier and crystal filter before exiting the module (pin 4). There is a loss of about 6 to 7dB through the mixer, the i-f amplifier provides about 10B of gain, and the crystal filter has about 3.5dB insertion loss. The crystal filter supplies some 40dB of attenuation at the adjacent channel and 80dB of attenuation at the second image. The bandwidth of the i-f signal leaving U4 is typically 12 to 16 kHz, centered around 53.55 MHz, with a typical gain of 0 to 3dB. The first i-f signal now moves through matching components C49 and L2 before entering the i-f IC, U100.

(c) UHF (U2)

After leaving FDS module U203 (pin 9), the rf signal enters the front end module, U2 (pin 2). Within U2 the signal first passes through a 30MHz-wide stripline filter, an rf amplifier, and another 30MHz-wide stripline filter. The rf amplifier supplies 10dB of gain over one of two bandsplits: 403 - 470MHz or 450 - 520MHz. Next, the rf signal enters a double-balanced mixer, where it is mixed with the local oscillator (LO) signal from synthesizer U300 (pin 15). The LO signal enters the mixer (pin 4) at a level of +4.5 to +5dBm, and one i-f (73.35MHz) below the channel (rf) frequency.

The resultant first i-f signal (73.35MHz) from the mixer then passes through U2's i-f amplifier and crystal filter before exiting the module (pin 4). There is a loss of about 6 to 7dB through the mixer, the i-f amplifier provides about 10B of gain, and the crystal filter has about 3.5dB insertion loss. The crystal filter supplies some 40dB of attenuation at the adjacent channel and 80dB of attenuation at the second image. The bandwidth of the i-f signal leaving U2 (pin 1) is typically 14 to 18kHz, centered around 73.35MHz, with a typical gain of 5.5 to 8.5dB. The first i-f signal now moves into the i-f IC, U100.

(2) 2nd I-F and Squelch (U100)

The i-f IC , U100, performs four basic functions:1st i-f conversion, 2nd i-f limiting, fm demodulation, and squelch control. The 1st i-f signal (53.55MHz for MID-BAND/VHF or 73.35MHz for UHF) enters U100 at pin 10 and passes through an internal pre-amplifier. The output of the pre-amplifier passes out of U100 (pin 9), through external matching components L1 and C46, and back into U100 (pin 12) to one input of the 2nd i-f mixer (VHF/UHF). In MID-BAND radios, the 1st i-f signal is routed directly to the 2nd mixer (pin 10).

The second injection signal from synthesizer U300 (pin 32) is fed to the other input of the 2nd i-f mixer (U100, pin 11). The desired output frequency from the mixer (U100, pin 8) is 450kHz. Therefore, the 2nd oscillator frequency must be 450kHz above or below 53.55MHz; that is, 54MHz (high-side injection) or 53.1MHz (low-side injection).

The resulting 450kHz 2nd i-f signal leaves U100 (pin 8), is filtered by ceramic filters FL3 (between pins 8 and 6), and FL2 (between pins 4 and 3) to reject unwanted mixer output products. There is an internal i-f amplifier stage between the two filters. Next, the 2nd i-f signal is processed through a limiter and applied to the PLL demodulator. Resistor R3 sets the free-run frequency of the demodulator to 450kHz; capacitor C2 is the PLL low-pass filter capacitor.

The output of the demodulator is then fed, via external dc blocking capacitor C3 (between pins 34 and 32), to an internal amplifier stage. The audio output signal from this stage leaves U100 (pin 31) and is fed, via dc blocking capacitor C14, to pins 8 and 9 of the audio filter IC, U101.

U100 also includes squelch controller circuitry which functions as follows: From the audio amplifier output, the noise and audio are sent, via external shaping network R4, R5, C12, and C13, and an internal noise limiter (U100, pins 27 and 26), to the programmable squelch attenuator in U101 (pin 17). The output of this attenuator (U101, pin 19) is fed to the squelch controller circuit in U100 (pin 23).

The output voltage of this rectifier circuit is inversely proportional to the noise level present; therefore, it is directly proportional to the rf signal strength. When the noise level exceeds the threshold level set by the squelch attenuator in U101 (pin 19), the squelch controller's output (U100, pin 18) goes low, indicating the absence of a carrier signal. The microcomputer IC, U400, reads this SQUELCH signal (pin 15) and programs the audio filter IC, U101, to pull the AUDIO PA ENABLE line (U101, pin 3) low, turning off the audio power amplifier in U102. The opposite condition (low noise level) will pull the AUDIO PA ENABLE line high, allowing the audio to be processed.

(3) Receive Audio (U101, U102)

At the audio filter IC, U101 (pins 8 and 9), the recovered audio from U100 is low-pass filtered to separate PL squelch codes and high-pass filtered to separate voice. PL squelch codes are filtered, sampled and sent (U101, pin 28), via the PL DECODE line, to the microcomputer, U400 (pin 41). (Select 5 squelch codes are filtered and limited by U700, and sent, via the LIMITER OUT/IN line, to the microcomputer, U400 (pin 43). If the radio is in the PL or Select 5 squelch mode, U400 turns on its decoding circuitry. When the programmed squelch signals are decoded, U400 sends program signals to a microprocessor interface circuit in U101. Then, U101, via the AUDIO PA ENABLE line, turns on the audio PA IC, U102.

After high-pass filtering, voice audio is de-emphasized, filtered, sent through a programmable attenuator (volume control). Finally, the voice audio passes from U101 (pin 24), through a low-pass filter (C47, R19) to the audio PA (U102, pin 10). 6dB extra gain is switched in for 12.5kHz channel spacing to give equal acoustic level with the lower deviation levels.

Inside U102, the voice audio is applied simultaneously to three amplifiers: the internal PA, the external PA, and the common PA. The common PA is for both internal and external speaker applications in a bridge configuration. Without an external speaker connected, a high input at pin 24 of U102 (SPEAKER SELECT line) biases the internal PA, and audio from the internal and common PAs is 180° out of phase, which drives the internal speaker differentially. Audio from the common amplifier to the the external amplifier is in phase.

If an external speaker is connected to radio's universal connector, the SPEAKER SELECT line (U102, pin 24) is pulled low. This low-biases the external PA, and shifts the audio of the common amplifier 180°. This phase shift does two things: First, it puts the audio output from the common amplifier 180° out of phase with the audio output from the external amplifier, and the external speaker is driven differentially. Second, audio from the common amplifier and the internal amplifier is in phase, resulting in no audio drive for the internal speaker.

h. Transmitting

(1) Transmit Audio (U102, U101, U700)

Pressing the PTT switch (S803) applies a ground to pin 60 of microcomputer U400, activating the reprogramming of the chip set. First, the audio filter IC (U101) is reprogrammed to mute the radio and set up the normal transmit path functions without changing the status of the R/T line ("1" = RX; "0" = TX).

Depending on the status of the MIC SELECT line (0Vdc = external; 5Vdc = internal), either the external or internal microphone will be enabled. With an external microphone, the voltage level on the OPT SEL line from the external microphone (universal connector pin 7) will reflect the type of microphone being used (1.235V = remote speaker/microphone; 2.5V = public safety microphone). The microphone will not actually be enabled until the TX 5V is active.

Initially, an audio signal enters the enabled microphone and the audio is routed to the audio pre-amplifier, U102 (pin 21 for internal microphone; pin 22 for external microphone), where some of the necessary shaping and filtering is done. Next, the output (pin 11) of U102 is fed through capacitor C23, and resistors R17 and R18 (part of the pre-emphasis/limiter circuit) to pins 11 and 10 of audio filter U101.

Within U101, the TX filtering is enabled for flat audio or pre-emphasis, and PL/5-TONE encode is set. From the output of the limiter, the signal is routed through the splatter filter to the summation circuit, where the microphone input is summed with the AUX TX input and the PL/5-TONE encode signal. The PL/5-TONE is generated by U101, using the PL/ sample clock signal (U400, pin 39) as a reference. This clock signal is a square wave multiple of the desired PL frequency. The summation circuit output is routed through a buffer into two attenuators.

A five-bit attenuator adjusts the VCO modulation level, prior to sending the signal (VCO MOD) from U101, pin 21, to pin 3 of synthesizer/VCO module U300. The four-bit attenuator adjusts the reference modulation level, then sends the signal (REF MOD) from U101, pin 20, to U300, pin 19.

(2) Transmit RF (U202)

The frequency-modulated, on-channel signal from U300 (pin 14) is fed to pin 1 of the rf power amplifier (PA), U202. The level of this input is nominally +5dBm.

The MID-BAND PA is a 3 stage amplifier with adjustable gain in the 1.0- to 6.0-watt range. The VHF PA is a 3-stage amplifier, with adjustable gain in either the 1.0- to 2.5-watt range or 2.0- to 6.0-watt range, depending on the radio model. The UHF PA is a 4-stage amplifier, with adjustable gain in either the 1.0- to 2.0-watt range or the 2.0- to 5.0-watt range, depending on the radio model. All rf power amplifiers have nominal input and output impedances of 50Ω.

In the MID-BAND PA, the second-stage collector (U202, pin 6) is used to control PA gain. The third-stage base bias network (U202, pin 7) is also connected to pin 6, providing a variable base bias to maximise efficiency at lower power levels. The third-stage collector (pin 12) is tied directly to battery (unswitched) B+. The first-stage collector (pin 3) is tied to bias switching transistor, Q204, which is turned on only in transmit by the transmit automatic level control IC, U201. A TX 5V regulator in U201 supplies +5V to pin 16 (U201) only during transmit. A switch within U201 causes pin 17 to go low (0V), saturating Q204; R209 is for current limiting. When the radio is not transmitting, the TX 5V is low (0V) and pin 17 is pulled up to approximately +7.5V, which turns off Q204.

In the VHF PA, the first-stage collector (U202, pin 3) is used to control PA gain. The second- and third-stage collectors are tied directly to battery (unswitched) B+ (pins 6 and 12). A switching transistor, Q204, supplies base bias to pin 7. When the TX 5V regulator in transmit automatic level control IC, U201, turns on, +5V is supplied to U201, pin 16. A switch within U201 causes U201, pin 17, to go low (0V), saturating Q204; R209 is a current limiting resistor. When the TX 5V regulator is low (0V), U201, pin 17, pulls up to approximately +7.5V and Q204 is turned off.

In the UHF PA, the first-stage collector (U202, pin 2) is supplied by Q200, which is connected to the TX 5V regulator (U201, pin 16) in an emitter follower configuration. When the TX 5V regulator is on, regulated +4.3V is supplied to U202, pin 2; when the TX 5V regulator is off, Q200 is cut off and no current

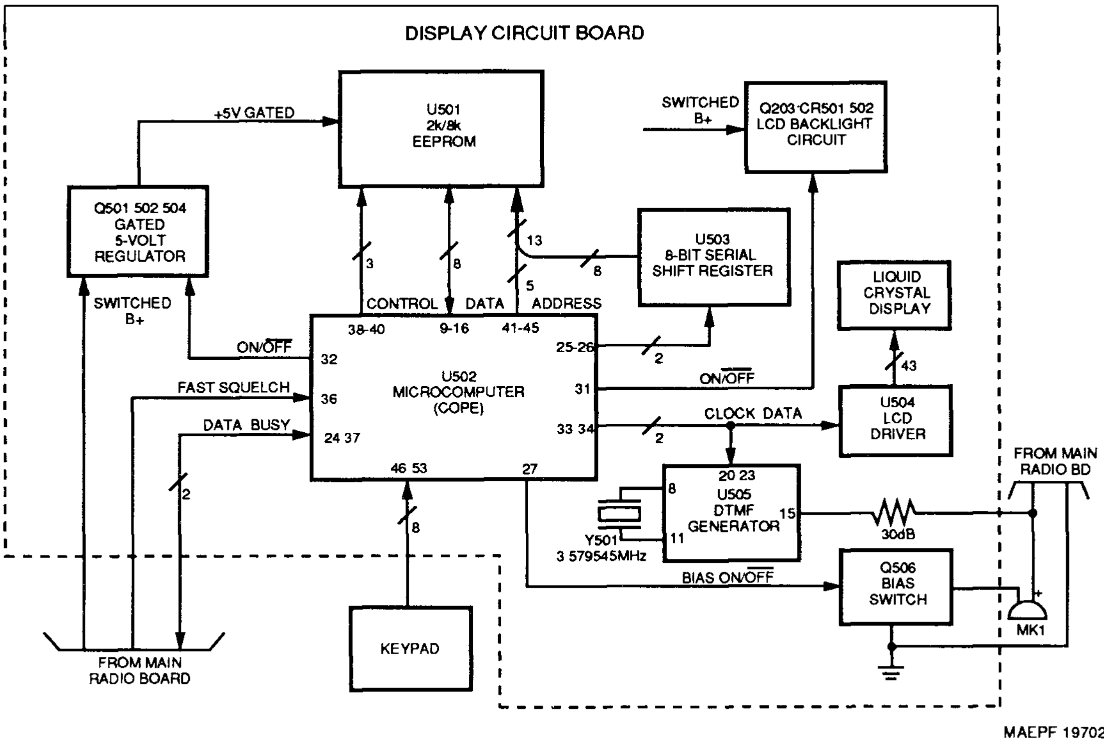

Figure 3. Display Circuitry Block Diagram

passes. The second-stage collector voltage (U202, pin 3) is used to control the gain of the UHF PA. The third- and fourth-stage collectors (U202, pins 6 and 8) are tied to battery B+. Base bias is supplied to U202, pin 4, via switching transistor Q204 (PNP Darlington). The base of Q204 is tied to pin 26 of U201 through current-limiting resistor R209. When the radio is receiving (TX 5V regulator off), U201, pin 26, is pulled up to +7.5V, turning Q204 off. When the TX 5V regulator is on, the voltage at U201, pin 26 drops to approximately +4.5V, saturating Q204.

In MID-BAND/VHF and UHF radios the gain control voltage for U202, pin 3, (pin 6 MID-BAND only), is supplied by U201 via pass transistor Q202. The PA control circuit inside U201 sets the control voltage to establish the correct ratio between the RF DET voltage from the FDS module, U203 (pin 5 VHF; pin 4 UHF), and the D/A reference voltage from U200, pin 9. This reference voltage is software controlled and depends on the current channel's programmed power level.

In high-power model PA modules, an internal thermistor is connected between ground and U202 (pin 11 on MID-BAND and VHF; pin 9 on UHF). Resistor R210 connects the thermistor to the TX 5V regulator, forming a voltage divider. The resulting temperature sense voltage is fed to pin 8 of U201. Circuitry within U201 causes the PA power to cut back (via the control voltage supplied to U202, pin 3, pin 6 MID-BAND only) if the PA temperature exceeds a preset value. The cutback temperature is determined by the value of R210.

By-pass module U900 effectively by-passes transmit audio modulation. The by-pass module can be replaced with a number of optional customer application specific modules, e.g. Secure Capable (secure speech facility). Details of the option modules are supplied as additions to the relevant Service Manual as part of the option package.

i. COPE Microcomputer (U502)

Refer to Figure 3 and the 8k schematic diagram in the applicable service manual.

The control of peripheral electronics (COPE) microcomputer is the heart of the display board. The COPE has several functions, the main ones being:

- control of the liquid crystal display, which displays information about the state of the radio,
- processing of information input by the user via the radio's keypad,
- communication of channel information (stored in the EEPROM) to the CORE microcomputer, giving the radio expanded channel capability, and
- control of the DTMF generator, U505.

The COPE microcomputer communicates with the radio board over the DATA and BUSY lines. Both of these lines are wired-or; that is, any processor can force the lines to a logic low state (0 volts), but not to a logic high (+5 volts). This is accomplished by using a 10kΩ "pull-up" resistor on each line. These resistors are located on the radio board and are connected to #2 regulated B+.

When the COPE (or any other processor) sends a low over the DATA or BUSY line, it forces the line to the low state by sinking current through the line's output pin. To send a high, the processor switches the output pin to the high impedance state (open), and the pull-up resistor causes the line to go high (as long as no other processor is forcing it low). Normally the DATA and BUSY lines will be in the high state.

Bus messages are indicated by 9600-baud data on the DATA line, accompanied by a logic low on the BUSY line. A constant low on either line indicates a problem which could be either hardware or incorrect programming of one of the microcomputers. To prevent degradation of receiver performance, inductors L501 and L503, and capacitor C507 filter out computer "hash" interference from the DATA and BUSY lines.

The COPE gets its +5V power (#2 regulated 5V from the radio board) through pin 28. Inductor L504 and capacitor C501 provide filtering.

The COPE's RESET line, pin 17, is connected to the radio board's RESET line via filter L502 and pin 5 of the LCD interconnect flex. Whenever the RESET line goes low, then high again, the COPE reinitializes itself, briefly turning on all segments of the display.

Components Y502, C505, C506, and R528 are the external elements of the microcomputer clock circuit. The resulting 3.6864 MHz oscillator signal is divided by four inside the COPE, and becomes the internal clock.

In MID-BAND radios only, divider U506 and R551 are the external elements of the microcomputer clock circuit.

Pins 30 through 40 are control lines for the EEPROM, U501. These lines are normally at a logic high level unless the COPE is accessing data from the EEPROM. None of these lines should ever be at a constant low level.

Pin 32 is a power strobe for EEPROM U501; power strobing is used to reduce current drain. The strobe signal controls the regulator circuit, which consists of Q501, Q502, Q504, R503, and C502. When pin 32 is high, the switched B+ on the emitter of Q501 is regulated down to +5V and applied to pin 16 (Vdd) of EEPROM U501. When pin 32 is low, the voltage on U501, pin 16, is reduced to 0V. Normally, pin 32 will be low; it goes high only when data is being accessed from the EEPROM. On power-up, a series of power pulses, lasting as long as a second or more, are sent from pin 32 as the COPE reads and validates data in the EEPROM.

Pins 9 through 16 make up a bidirectional data bus between the COPE and the EEPROM. These lines are normally at a logic low unless data is being accessed.

Pins 41 through 45 are output lines from the COPE, and form the lower five bits of the EEPROM address. The upper eight EEPROM address bits come from U503, an 8-bit serial-to parallel shift register. These address bits are sent from the COPE over the serial peripheral interface (SPI) bus (pins 22, 25, and 26) at 57.6 kilobaud.

Pin 31 is the control line for the LCD backlight. Two yellow-green LEDs, CR501 and CR502, make up the backlight. These LEDs are driven by a constant-current source consisting of dual-diode CR503, resistors R501 and R504, and transistor Q503. The current through the LEDs (about 20 mA) is drawn from the switched B+ supply. The current remains constant for battery voltages greater than six volts.

Pins 2 and 3 are the MODB and MODA inputs. These pins are tied high and low through R512 and R513, respectively; they determine the mode that the microcomputer will be in after it is reset. MODB must be high and MODA must be low for the COPE to operate properly.

Pin 27 is an open drain output control line for muting the microphone during DTMF sequences. Resistor R527 is a pull-up resistor to +5V. Transistor Q506 completes the bias current path for the microphone, which is located on the speaker/microphone flex. When pin 27 is high (0.7V), Q506 is biased on and the microphone is live; when pin 27 is low (0V), Q506 is off and no microphone signal is produced. The actual voltage at pin 27 can never go above 0.7V (one diode drop).

Pins 33 and 34 form another serial bus. The COPE uses this bus to send serial clock and data information to the LCD driver IC, U504, and to the DTMF generator IC U505. The bus is synchronous; that is, one of the lines (pin 33) is used to clock the data on the other line (pin 34). Resistor R506 provides some isolation on the data line. During data transfer, the receiving ICs acknowledge data by putting a low on the data line. The COPE cannot tristate pin 34 or read the acknowledge; therefore, R506 limits the current which flows if the output from pin 34 is high.

Pins 46 through 53 are keypad input lines. All of these lines are high impedance and need to be pulled high by resistors R517 through R524. The keypad lines are normally all high unless a key is pressed. Each key causes exactly two of the lines to go low (row and column). The COPE decodes the lines and processes the keypress.

Pin 36 is a high-impedance logic input which is connected, via the LCD interconnect flex (pin 8), to the fast squelch line on the main board (U100, pin 21). The fast squelch signal is used by the COPE during scanning to detect the presence of carrier.

j. EEPROM IC (U501)

U501 is an 8k EEPROM IC. In addition to the data and address lines already discussed in the COPE microcomputer section, U501 has four control lines, all of which are active low; that is, a low on the pin activates the associated function.

(1) The $\overline{CC}$ (chip clear) line (pin 17) is an unused input that is normally used to erase the entire memory. To always inhibit this function, the $\overline{CC}$ pin is tied high to the Vdd pin (16).

(2) The $\overline{CE}$ (chip enable) line (pin 7) is used to enable the EEPROM for either read or write.

(3) The $\overline{WE}$ (write enable) line (pin 15) is used in conjunction with the $\overline{CE}$ line to write to the EEPROM. Resistor R502 ensures that the $\overline{WE}$ line is held inactive during power-up and power-down so that inadvertent writes are avoided.

(4) The $\overline{OE}$ (output enable) line (pin 11) is used in conjunction with the $\overline{CE}$ line to read from the EEPROM. The $\overline{OE}$ signal causes the data I/O pins (2 through 6, 30 through 32) to become outputs.

k. LCD Driver IC (U504)

The LCD driver IC, U504, interfaces with the COPE microcomputer via a 2-wire synchronous bus (pins 30 and 31). The COPE sends LCD display data over the bus to the LCD driver. The driver does not require "refreshing"; that is, once the data has been sent to the driver, the driver will maintain the display without further service from the COPE. Only when the display requires changing does the COPE again communicate with the driver.

The LCD driver has its own internal clock, controlled by resistor R516, which determines the frame frequency of the driver waveforms. Pin 41 (VLCD) is used to set the driver output level, which affects the contrast, viewing angle, and segment crosstalk of the display. Resistors R507 and R511 set the voltage level at pin 41 to about 0.5V, the optimum level for the type of LCD being used. The lower the dc voltage on VLCD, the greater the driver output level.

The LCD driver outputs two types of waveforms to the LCD: backplane and segment. The three backplane waveforms, output from pins 42 through 44, are shown in the applicable service manual. These signals resemble "staircase" waveforms, and are displaced apart in phase from each other by 120 degrees. Four discrete voltage levels are used: 0.5, 2.0, 3.5, and 5.0 volts; voltages which differ much from these values indicate a problem. The frequency of the backplane waveforms should be close to 50 Hz.

The other type of waveform, the segment driver waveform, is sent to the LCD via pins 1 through 29, and 45 through 56 (a total of 40 segment waveforms). Each segment waveform drives three display segments (the small lines or bars that make up the individual characters), or annunciator symbols (such as the battery symbol). The actual appearance of the segment waveforms depends on the data being displayed. Generally, the segment waveforms will contain the same voltage levels as the backplane waveforms discussed above; however, a segment waveform may contain only two of the four levels (0.5V and 5.0V *or* 2.0V and 3.5V). All four levels may also be seen.

The display driver is initialized at power-up with all segments and annunciators turned on, However, certain annunciators may have been disabled through programming; these annunciators will not be displayed.

l. DTMF Generator IC (U505)

The dual-tone multi-frequency (DTMF) generator IC, U505, generates DTMF tone pairs for transmission over the air. The DTMF generator IC interfaces (pins 20 and 23) with the COPE over the same serial bus as the LCD driver IC. To send a message to the correct destination, the COPE includes the bus address of the desired IC as part of the communications protocol.

When it is not being used, the DTMF generator is in the quiescent state and draws very little current. The COPE sends a message on the bus to "awaken" the DTMF generator, causing the generator to start its 3.579545 MHz crystal oscillator, Y501. The DTMF generator listens for messages, which turn tone pairs on or off. These tone pairs are sent from pin 15 through resistor R526 to the main radio board.

Resistor R526 is part of a voltage divider which attenuates the 0.9-volt peak-to-peak signal (by about 30 dB) to a level that is in the same range as the microphone output level. The other resistor in the divider is R9 on the main radio board. R526 also serves to isolate the DTMF generator from the microphone circuit when transmitting voice. C503 filters out high-frequency clock noise which might corrupt the DTMF signal.

In MID-BAND radios, isolation between the DTMF generator and microphone circuit is provided by an FET.

The DTMF signal shares the same line as the microphone on the front shield. During DTMF sequences, the COPE mutes the microphone by interrupting its bias current via Q506.

m. SECURE Module (U900) (Secure Cable radios only)

The SECURE module, U900, uses pins 4, 5, 7 and 16 for keyloading. If the encryption key is lost or destroyed, the module will indicate this by sending a logic low level from pin 16 whenever the radio's PTT switch is pressed and, periodically, when the radio is not transmitting or receiving.

When the radio is transmitting, the SECURE module is put into the appropriate mode (coded or clear) by its microcomputer, which gets the information from U400 via the DATA line (U900, pin 11). In the coded mode, the audio signal from the audio filter IC (U101, pin 22) enters the module (U900 pin 17), where it is converted to a 12-kilobit/second digital format. Within U900, the signal is then encoded, filtered, and returned, via pin 1, to U101, pins 15 and 16. In the clear mode, the audio enters U900 on pin 17 and the module's microcomputer switches it right back out on pin 1.

When the radio is receiving, the SECURE module continuously monitors (at U900, pin 2) the output of the discriminator (U100, pin 31). The module determines if the code (or key) is correct. If the received code is correct, the SECURE module decrypts the signal and sends it (U900, pin 3) to the audio filter IC (U101, pin 7). At the same time, U900, via the DATA line (pin 11), tells the radio's microcomputer (U400, pins 22 and 27) that the received signal is encrypted. The radio's microcomputer then sends appropriate data to the audio filter IC, U101, so that it will process the decrypted audio as it is routed out of the SECURE module (U900, pin 3).

The easiest way to determine if the SECURE module, U900, is faulty is to replace it with the SECURE bypass module (Modorola part number NTN4720A). By replacing this module, all functional tests (receiver quieting, transmitter audio, etc.) can be checked with the radio in the clear mode.

MAINTENANCE

1. INTRODUCTION

This section of the manual describes recommended repair procedures, special precautions regarding maintenance, and recommended test equipment. Each of these topics provides information vital to the successful operation and maintenance of the MX1000 Series radio.

2. PREVENTIVE MAINTENANCE

The MX1000 Series radio does not require a scheduled preventive maintenance program; however, periodic visual inspection and cleaning is recommended.

a. Inspection

Check that the external surfaces of the radio are clean, and all external controls and switches are functional. A detailed inspection of the interior electronic circuitry is not needed or desired.

b. Cleaning

The following procedures describe the recommended cleaning agents and the methods to be used when cleaning the external and internal surfaces of the radio. External surfaces include the front cover, housing assembly, and battery case. These surfaces should be cleaned whenever a periodic visual inspection reveals the presence of smudges, grease, and/or grime. Internal surfaces should be cleaned only when the radio is disassembled for servicing or repair.

The only recommended agent for cleaning the external radio surfaces is a 0.5% solution of a mild dishwashing detergent in water (one teaspoon of detergent per gallon of water). Stronger cleaning agents may be used only to remove soldering flux from circuit boards after making repairs.

CAUTION

The effects of certain chemicals and their vapors can have harmful results on certain plastics. Aerosol sprays, tuner cleaners and other chemicals should be avoided.

Never allow any alcohol- or solvent-based product to contact any plastic or rubber radio part.

(1) Cleaning External Surfaces

The detergent-water solution should be applied sparingly with a stiff, non-metallic, short-bristled brush to work all loose dirt away from the radio. A soft, absorbent, lintless cloth or tissue should be used to remove the solution and dry the radio. Make sure that no water remains entrapped near the connectors, cracks, or crevices.

(2) Cleaning Internal Circuit Boards and Components

NOTE

Always use a fresh supply of alcohol and a clean container to prevent contamination by dissolved material (from previous usage).

Isopropyl alcohol may be applied with a stiff, non-metallic, short-bristled brush to dislodge embedded or caked materials located in hard-to-reach areas. The brush stroke should direct the dislodged material out and away from the inside of the radio.

Alcohol is a high-wetting liquid and can carry contamination into unwanted places if an excessive quantity is used. Make sure that controls or tunable components are not soaked with the liquid. Do not use high-pressure air to hasten the drying process, since this could cause the liquid to puddle and collect in unwanted places.

Upon completion of the cleaning process, use a soft, absorbent, lintless cloth to dry the area. Do not brush or apply any isopropyl alcohol to the frame, front cover, or back cover.

3. DISASSEMBLY AND REASSEMBLY

For disassembly and reassembly of the radio, refer to the DISASSEMBLY/REASSEMBLY PROCEDURES, exploded views, and exploded view parts lists in the applicable service manual.

Several special tools are required to completely disassemble the radio. Refer to the "Specialized Tools and Test Equipment" and the "Torque Specifications" charts in the applicable service manual.

NOTE

The MX1000 Series radio contains complementary metal-oxide semiconductor (CMOS) devices, which are highly susceptible to damage in handling due to static discharge. The entire printed circuit board should be treated as static sensitive. Damage can be latent, resulting in failures occurring weeks or months later.

DO NOT attempt to disassemble the radio without first referring to the "Safe Handling of CMOS Devices" paragraph in this section of the manual.

4. SAFE HANDLING OF CMOS DEVICES

Complementary metal-oxide semiconductor (CMOS) devices are used in the MX1000 Series radio. While the attributes of CMOS are many, their characteristics make them susceptible to damage by electrostatic or high voltage charges. Damage can be latent, resulting in failures occurring weeks or months later. Therefore, special precautions must be taken to prevent device damage during disassembly, troubleshooting, and repair. The following handling precautions are mandatory for CMOS circuits, and are especially important in low humidity conditions.

a. All CMOS devices must be stored or transported in conductive material so that all exposed leads are shorted together. CMOS devices must not be inserted into conventional plastic "snow" or plastic trays of the type that are used for storage or transportation of other semiconductor devices.

b. All CMOS devices must be placed on a grounded bench surface and the technicians must ground themselves prior to handling the devices. This is done most effectively by having the technician wear a conductive wrist strap in series with a 100k-ohm resistor to ground.

c. Do not wear nylon clothing while handling CMOS circuits.

d. Do not insert or remove CMOS devices with power applied. Check all power supplies to be used for testing CMOS devices, and be certain that there are no voltage transients present.

e. When straightening CMOS device leads, provide ground straps for the apparatus used.

f. When standing, use a grounded soldering iron.

g. All power must be turned off in a system before printed circuit boards containing CMOS devices are inserted, removed, or soldered.

5. REPAIR PROCEDURES AND TECHNIQUES

CAUTION

Leadless component technology requires the use of specialized equipment and procedures for repair and servicing of the MX1000 Series radio. If you are not totally familiar with leadless component repair techniques, it is strongly recommended that you either defer maintenance to qualified service personnel and service shops or take the recommended video taped leadless component repair training program, MAV-PACK 3 (VID-952) (see paragraph 7b, **Service Aids and Recommended Tools**, in this section). This is of paramount importance as irreparable damage to the radio can result from service by unauthorized persons. Unauthorized attempts to remove or repair parts may void any existing warranties or extended performance agreements with the manufacturer.

a. Parts Replacement and Substitution

Special care should be taken to be as certain as possible that a suspected component is actually the one at fault. This special care will eliminate unnecessary unsoldering and removal of parts, which could damage or weaken other components or the printed circuit board itself.

When damaged parts are replaced, identical parts should be used. If the identical replacement component is not locally available, check the parts list for the proper Motorola part number and order the component from the nearest Motorola Communications Parts office listed in the "Replacement Parts Ordering" section of this manual.

b. Rigid Circuit Boards

The MX1000 Series radio uses bonded multi-layer printed circuit boards. Since the inner layers are not accessible, some special considerations are required when soldering and unsoldering components. The printed through holes may interconnect multiple layers of the printed circuit. Therefore, care should be exercised to avoid pulling the plated circuit out of the hole.

When soldering near the module socket pins, use care to avoid accidentally getting solder in the socket. Also, be careful not to form solder bridges between the module socket pins. Closely examine your work for shorts due to solder bridges. When removing modules with metal enclosures, be sure to desolder the enclosure ground tabs as well as the module pins.

c. Flexible Circuits

The flexible circuits are made from a different material than the rigid boards, and different techniques must be used when soldering. Excessive prolonged heat on the flexible circuit can damage the material. Avoid excessive heat and excessive bending. For parts replacement, use the ST-1087 Temperature-Controlled Solder Station with a 600 or 700 degree tip, and use small diameter solder such as ST-633. The smaller size solder will melt faster and require less heat being applied to the circuit.

To replace a component on a flexible circuit, grasp the edge of the flexible circuit with seizers near the part to be removed, and pull gently. Apply the tip of the soldering iron to the component connections while pulling with the seizers. Do not attempt to puddle out components. Prolonged application of heat may damage the flexible circuit.

6. TEST EQUIPMENT AND SERVICE AIDS

The following paragraphs describe the test equipment and service aids required for maintaining the MX1000 Series radio. Your Motorola sales representative will assist in analyzing your specific requirements and help you select the latest available equipment to suit your individual needs. In addition, your sales representative can advise you of the availability of new test equipment and service aids that become available after the printing of this manual.

Refer to Figure 4 for an illustration of the troubleshooting, programming, and test equipment setup.

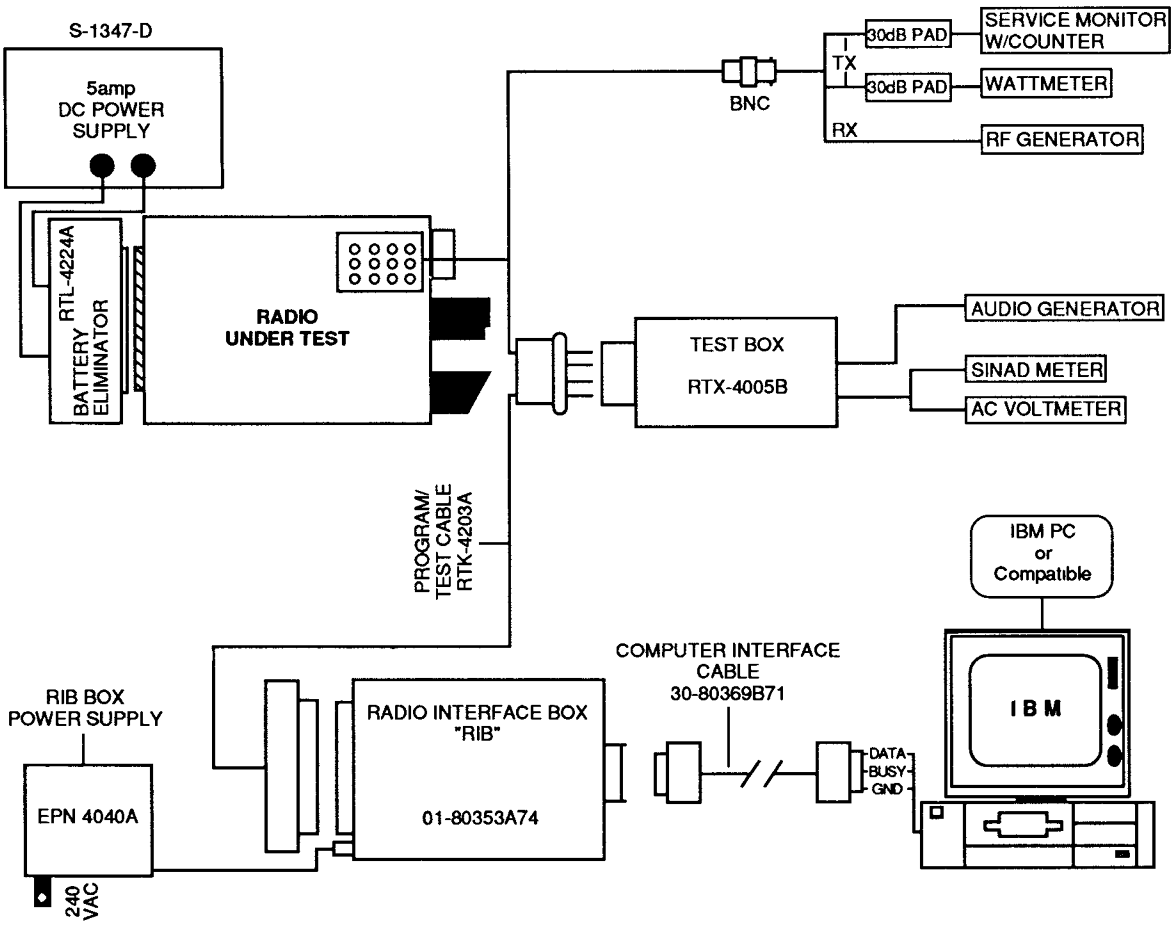

Figure 4. Troubleshooting, Programming, and Test Equipment Setup Detail

a. Recommended Test Equipment

The list of equipment contained in Table 2 includes all of the standard test equipment required for servicing two-way portable radios, as well as several unique items designed specifically for servicing the MX1000 Series radio. Battery operated test equipment is recommended when available. The "Characteristics" column is included so that equivalent equipment may be substituted; however, when no information is provided in this column, the specific Motorola model listed is either a unique item or no substitution is recommended.

Table 2. Test Equipment

MOTOROLA MODEL NUMBER	DESCRIPTION	CHARACTERISTICS	APPLICATION
R2200, R2400, or R2000 Series	Service Monitor	This monitor will substitute for items with an asterisk (*)	Frequency/deviation meter and signal generator for wide-range troubleshooting and alignment
*R1047A	Digital Multimeter		Two meters recommended for ac/dc voltage and current measurements
*R1150A	Audio Oscillator	67 to 161 4Hz tones	Used with service monitor for injection of PL tones
R1053	Dual-Trace Oscilloscope	20MHz bandwidth 5mV/cm - 20V/cm	Waveform measurements
*S1350C *ST1214B (VHF) *ST1224B (UHF) *T1013A	Watt Meter Plug-in Element RF Dummy Load	50-ohm, ±5% accuracy 10 Watts, maximum 0-1000MHz, 300W	Transmitter power output measurements
S1339A	RF Millivolt Meter	100µV to 3V rf 10kHz to 1 2GHz	RF level measurements
*R1013A	SINAD Meter		Receiver sensitivity measurements
S1347D or S1348D (programmable)	DC Power Supply	0-20Vdc, 0-5 Amps current limited	Bench supply for 7 5Vdc

* R2200, R2400, or R2001D will substitute for items with an asterisk (*)

b. Service Aids and Recommended Tools

Refer to the appropriate MID-BAND, VHF or UHF service manual ("SERVICE AIDS" and "RECOMMENDED TOOL LIST") for a listing and description of the service aids and tools designed specifically for servicing the MX1000 Series radio, as well as the more common tools required to disassemble and properly maintain the radio. These kits and/or parts are available from the Motorola Communications Parts office listed in the "Replacement Parts Ordering" section of this manual.

7. FIELD PROGRAMMING

The MX1000 Series radio can be field programmed. Field programming requires specific equipment and accompanying instructions. Refer to the MX1000 Series "Radio Service Software User Guide" (Motorola number 68P81061C95) for complete field programming information, supplied only with Software part number EVNxxxx.

TROUBLESHOOTING

1. INTRODUCTION

Servicing the MX1000 Series radio requires the localization of the malfunctioning circuit before the defective component can be isolated and replaced. Since localizing and isolating a defective component constitutes the most time consuming part of troubleshooting, a thorough understanding of the circuits involved will aid the technician in performing efficient servicing. The technician must know how one function affects another; he must be familiar with the overall operation of the radio and the procedures necessary to place it back in operation in the shortest possible time.

The radio service manual, schematic diagrams, and troubleshooting procedures provide valuable information for troubleshooting purposes. The service manual provides signal flow information in a simplified format, while the schematic diagrams provide the detailed circuitry and the biasing voltages required for isolating malfunctioning components. By using the diagrams, troubleshooting procedures, and deductive reasoning processes, the suspected circuit may be readily found.

To determine if analysis of the radio is required, perform checks such as 12dB SINAD and rated audio performance for the receiver, and current drain, frequency error, and deviation for the transmitter. These should give the technician a general indication of where the problem is located.

After the general problem area of the radio has been identified, careful use of a dc voltmeter, rf millivoltmeter, and an oscilloscope should isolate the problem to an individual component.

2. PRELIMINARY CHECKS

When a radio performs unsatisfactorily, the following procedures should help localize the fault.

a. Check Battery

The first step in localizing a trouble is to ensure that the battery is fully charged; ideally, verify the operation of the radio on a battery eliminator. Follow the troubleshooting procedures in this manual, and the appropriate service manual.

b. Alignment

Strict adherence to the published procedures is a prerequisite to accurate alignment and proper evaluation of the performance of the radio. The selection of test equipment is critical. The use of equipment other than that recommended should be cleared through your Motorola Area Representative to ensure that it is of equivalent quality.

The service technician must observe good servicing techniques. The use of interconnecting cables that are too long, poorly positioned (dressed), or improperly terminated will result in erratic meter readings. As a result, it will not be possible to tune the radio to the desired specifications.

Use the recommended test equipment setup and proper connections for alignment and adjustments. Refer to the detailed procedures supplied in the applicable service manual.

c. Check Overall Transmitter Operation

If the battery voltage is sufficient, check the overall performance of the transmitter. A good overall check of the transmitter is the rf power output measurement. This check indicates the proper operation of the transmitter amplifier stages. A properly tuned and operating transmitter will produce the rated rf output into a 50-ohm load with a dc input of 7.5 volts. If the power is less than rated rf output, refer to the applicable transmitter troubleshooting chart.

d. Check Overall Receiver Operation

(1) 12dB SINAD

This procedure is a standard method for evaluating the performance of an FM receiver, since it provides a check of the rf, i-f, and audio stages. The method consists of finding the lowest modulated signal necessary to produce 50% of the radio's rated audio output with a 12dB or better ratio of signal + noise + distortion / noise + distortion. This is termed "usable sensitivity."

To perform this measurement, connect the leads from a SINAD meter to the audio output of the test box. Set the Motorola service monitor or rf signal generator to output a 1-millivolt signal. Modulate the rf signal with a 1kHz tone at 3kHz deviation for 25kHz channel spacing and 1.5kHz deviation for 12.5kHz channel spacing. Introduce the signal to the radio at the exact channel frequency through the universal connector. Set the volume control for rated audio output (3.74Vrms). Decrease the rf signal level until the SINAD meter reads 12dB. The signal generator output (12dB SINAD measurement) should be less than 0.35µV on MID-BAND/VHF receivers or less than 0.35µV on UHF receivers. If the radio does not meet this specification, refer to the receiver troubleshooting procedure.

3. VOLTAGE MEASUREMENT AND SIGNAL TRACING

To aid in troubleshooting, ac and dc voltage readings are provided (in red) on the main circuit board, and 8k display circuit board schematic diagrams in the service manual. When making these voltage checks, pay particular attention to any notes that may accompany the voltage reading of a particular stage.

CAUTION

> When checking a transistor or module, either in or out of the circuit, do not use an ohmmeter having more than 1.5 volts dc appearing across the test leads or an ohms scale of less than x 100.

Replacing a transistor or module before a thorough check is made is not recommended. Read the voltages around the suspected stage. If these voltages are not close to those specified, the associated components should be checked.

A low-impedance meter should not be used for measurement. If all dc voltages are correct, the signal should be traced through the circuit to show any possibility of breaks in the signal path.

CAUTION

> The integrated circuits and modules in the radio are static sensitive devices. DO NOT attempt to troubleshoot or disassemble the radio without first referring to the "Safe Handling of CMOS Devices" paragraph in the **MAINTENANCE** section of this manual.

4. TROUBLESHOOTING PROCEDURES

The troubleshooting procedures on the following pages will help isolate troubles in the different sections of the radio. Start at the first step of the appropriate procedure and make the checks as indicated. Most usual malfunctions will respond to the systematic approach to troubleshooting.

a. Initial Checks

(1) Power-up the radio, then check standby current: current should be either 65mA (programmed) or 40mA (unprogrammed). If unprogrammed, complete step (8) and check current again.

(2) Check the regulators: No. 1 regulator = 5Vdc (Q1 collector); No. 2 regulator = 5Vdc (U103, pin 8); receive regulator = 5Vdc (U201, pin 12).

(3) Check that the RESET line (J1, pin 5) = 5Vdc.

(4) Check that the IBP crystal (Y400) frequency = 7.37 MHz; measure at U400, pin 10.

(5) Check for data activity (J4, pin 15) when the radio is powered-up.

(6) Check for 2.1 MHz at pin 17 of synthesizer module (U300).

(7) Check that the R/T line (U201, pin 9) = 5Vdc in receive mode; 0Vdc in transmit mode.

(8) Always ensure that a known good checksum (test file) is loaded into the radio. If the radio has customer data, save that particular file and load the test file.

b. Radio Will Not Program

(1) Check that the IBP crystal (Y400) frequency = 7.37 MHz.

(a) Check the dc levels on both sides of the crystal; these levels are derived from microcomputer U400. The levels should be approximately 2.0Vdc and 2.5Vdc.

(b) 1. If the correct dc levels are present and there is no 7.37MHz signal, piggyback another crystal and check for the correct frequency.

2. If the correct dc levels are not present, make sure that all dc voltages to U400 are correct.

(c) Check the continuity of L400 with an ohmmeter.

NOTE

> Transistor Q403 is only used to shift the crystal frequency; this does not affect the operation of the crystal.

(2) Check the WATCHDOG TIMER DISABLE output line of the microcomputer (U400, pin 37) for a 5Vdc level. Use an oscilloscope for this check and be sure that the line is not toggling.

NOTE

> Pin 37 of U400 should always indicate 5Vdc; this indicates proper operation of the microcomputer. If there is a checksum (software) or hardware error in the microcomputer, this line will either toggle or remain low.

(a) If the voltage reading is incorrect, attempt to reprogram the radio:

1. If the radio will not program, go to step b (8).

2. If the radio will still not program, check that pin 19 of U400 is at a constant 5Vdc level and is not toggling.

(b) Place a jumper across R405; this disables the RESET line to the microcomputer. Check U400, pin 37 again.

1. If the line does not read 5Vdc, suspect U400.
2. If the line does read 5Vdc, attempt to reprogram the radio. If the radio will still not program, check pin 30 of U101 for 4Vdc. If pin 30 = 4Vdc, then suspect U101.

(3) Check the volume control (R800) voltage range:

(a) Check the voltage range at J2, pin 6, with an oscilloscope by rotating the volume knob from minimum to maximum volume. The indication should be a linear level increase from 0 to 5Vdc.

(b) Repeat step b (3) (a) at pin 56 of U400. If the volume potentiometer does not show a linear increase, check the continuity of the PTT/control flex circuit.

(4) Check the frequency switch (S823) positions:

(a) Take measurements at J2, pins 5, 8, 9 and 10. Rotate the switch through all channel positions and verify (with oscilloscope) that each line has a 0Vdc and a 5Vdc level.

(b) Repeat step b (4) (a) at pins 53, 55, 59, and 61 of U400.

If there are no indications on either step (a) or (b), check for the presence of 5Vdc on the common line of the frequency switch.

(5) Verify with an oscilloscope that the BUSY line (J4, pin 12) is at a constant 5Vdc level.

NOTE

The BUSY line of U400 reads low only when the DATA lines (pins 22, 27) are active. This is the case when the radio is first powered up.

(6) (a) Check the microcomputer data output line (U400, pins 28, 29) conditions with an oscilloscope:

- Condition 1 - With the radio in the standby mode, there should be no data activity.
- Condition 2 - When the volume control, frequency switch, PTT switch, or monitor button are actuated, there should be data activity.

(b) The DATA output lines from U400 control the microprocessor interface units in U101 (pin 31), U700 (pin 11), and U200 (pin 23), and channel information to U300 (pin 30). If any of these devices is defective, it could hold the DATA line inactive

1. Check the dc level of each of these devices.
2. Make sure that the 2.1 MHz signal from U300 (pin 17) is correct.
3. Make sure that there is data activity at U400, pin 11, during volume adjustment, channel changing, and pressing of the PTT and monitor switches.

(7) Check the voltage references of microcomputer U400 (pin 63 = 0Vdc and 0Ω to ground; pin 64 = 5Vdc).

NOTE

These two voltage points on U400 set up an internal voltage reference table within the microcomputer. If the voltages are incorrect, certain functions of the radio may operate erratically; for example, monitor, volume, etc.

(8) Check the transmit 5Vdc line (U201, pin 11). Ensure that there is no dc level with the radio in the standby mode. If a dc level is present, this may indicate a microcomputer lockup condition.

Another lockup condition may be present if all checks seem to be normal, but the radio still fails to communicate with the PC. If this appears to be the case, then perform steps (a) and (b):

(a) Turn the radio off and ground pin 3 of J4. Then, while pressing the PTT switch, turn the radio on. Remove the ground and release the PTT switch.

(b) With the radio in this condition, program the radio. If the radio will not program, go to step b (2) (a) 2.

c. Radio Will Not Keyload (SECURE radios only)

(1) Verify that the correct keyloader is being used for the particular type of encryption present in the radio.

(2) Replace the SECURE module, U900, with a test module having the same kit number. If the problem persists, continue troubleshooting.

(3) (a) Check that U900, pin 9, =5Vdc.

(b) Check that U900, pins 15 and 18, =7.5Vdc.

(c) Verify that activity is present on pins 6 and 11 of U900 when the radio is turned on.

(d) Check that the KEYLOAD line (U900, pin 5) goes low when the keyloader cable is attached to the radio's universal connector. If it does not go low, suspect a bad cable or an open between pin 10 of the universal connector and pin 5 of U900.

(e) Check that the WRITE ENABLE line (U900, pin 7) momentarily goes low while attempting to load a key. If it does not go low, suspect an open between pin 5 of the universal connector and pin 7 of U900.

(f) Check that there is data applied to the KEY/FAIL line (U900, pin 16) while attempting to load a key. If no data is applied, suspect an open between pin 9 of the universal connector and pin 16 of U900.

(g) Check that there is data applied to the KEY INSERT DATA (KID) line (U900, pin 4) while attempting to load a key. If no data is applied, suspect an open between pin 11 of the universal connector and pin 4 of U900.

d. Standby Current

(1) Verify that the radio has a good checksum, and is squelched. If the standby current is consistently high (>80 mA), replace the rf PA module, U202. If the current is still bad, replace the remaining modules, one at a time, with test modules.

(2) Make a visual check of the main circuit board. Ensure that all tantalum capacitors are placed correctly (proper polarity). Check for solder bridges.

(3) Check the transmit 5Vdc line (U201, pin 11). Ensure that there is no voltage with the radio in the standby mode.

NOTE

Both number 1 and number 2 regulators must be operational for the microcomputer (U400) to function properly.

(4) Check that the voltage at the collector of number 1 regulator Q1 = 5Vdc. If the voltage is lower than 4.8Vdc or higher than 5.2Vdc, then complete this step:

(a) Check that the resistance of Q1 collector to ground = approximately 4kΩ (negative side of the probe connected to ground).

(b) Check the bias levels of Q1: emitter = 7.5Vdc; base = 6.7Vdc. If the levels are wrong, suspect the i-f IC, U100.

(5) Check that the voltage at the output (pin 2) of number 2 regulator U103 = 5Vdc.

NOTE

This regulator rarely fails, so be sure to check for solder shorts and assembly on the main board.

(a) Check the parameters of U103: the voltage at pin 8 (input) should be 7.5Vdc; pin 5 should read 5Vdc (ensure that this line (RESET) is not toggling).

(b) Check that the resistance from U103, pin 2, to ground is 4kΩ.

e. No Transmit Capability

(1) (a) Check that the voltage at pin 60 of microcomputer U400 is 0Vdc when the PTT switch is pressed.

(b) Check that the voltage at pin 60 of U400 is 5Vdc in standby (PTT switch not pressed).

(c) Check that the voltage at U400, pin 62, is 2.5Vdc with the test box connected to the radio. This line should also be at 0Vdc with the external PTT switch pressed.

(2) Check to see if the radio unlocks during transmit (tone). Observe the LOCK DETECT line (U300, pin 16) with an oscilloscope while keying and dekeying the radio. The line should remain low, with no 0-to-5V transition.

(a) First, verify that the channel under test is not designated a "blank" transmit channel.

(b) A tone emitted when the PTT switch is pressed indicates either that the synthesizer is unlocked, or that the channel information from U400 is incorrect.

1. Replace the synthesizer with a test synthesizer. If the synthesizer is still unlocking during transmit, check to see if the codeplug is correct.
2. Reprogramming of the radio may be required.

(3) (a) Check the 16.8MHz reference frequency (U300, pin 1) with a 50Ω probe and a frequency counter.

(b) Check pin 4 of U301 for 5Vdc; check pin 1 of U301 for 2Vdc to 4.5Vdc.

(c) Remove synthesizer module U300 and repeat step (a).

NOTE

Ensure that the reference oscillator pad is placed correctly.

(4) (a) The R/T line is a logic line from the microprocessor interface (pin 42) of U101 to the Tx/Rx switches of U101 (internal), U200 (pin 10), and U201 (pin 9). Check that the R/T line goes from 5Vdc to 0Vdc during transmit.

(b) If the R/T line is not switching, make sure that there is data activity at pins 11, 28, and 29 of U400 when the radio is keyed. The clock line (pin 30) should also be active during PTT.

(5) (a) Check the transmit 5Vdc line (U201, pin 11) for 5Vdc during transmit. If the voltage is correct, measure the current drain during transmit; the drain should be ≥ 800mA.

1. If the current drain is ≈400mA, the rf PA is not being enabled; go to step d (6).

(b) (*For VHF radios only*). Check pin 17 of U201. The voltage should be 7.5Vdc with the radio unkeyed and 0Vdc with the radio keyed. If a bad reading is obtained, remove U202 and recheck the voltage.

NOTE

Pin 8 of U201 is the temperature sense control line only.

(c) Check pin 4 of U201. The voltage should be 7.5Vdc with the radio unkeyed and 6.3Vdc with the radio keyed. If a bad reading is obtained, remove U202 and recheck the voltage

(d) Pins 21 and 25 of U201 set up the current control levels. These pins should read 2.5Vdc for proper operation.

(e) Resistor R207 (U201, pin 30) sets up a transmit current limiting level. This resistor should measure 14.7kΩ for MID-BAND/VHF or 15kΩ for UHF.

(6) Check all transmit parameters of rf PA U202:

(a) While keying the radio, either (VHF) check pins 7 and 11 (VHF), pins 3 and 11 (MID-BAND) of U202 for 6.5Vdc and 2.8Vdc respectively, or (UHF) check pins 4 and 9 of U202 for 6.5Vdc and 2.8Vdc respectively.

(b) While keying the radio, check pin 3 (pin 6 MID-BAND) of U202 for 2.5 to 6.5Vdc; 6.5Vdc indicates the maximum power setting.

(c) While keying the radio, check pins 21 and 25 (MID-BAND/VHF) or pin 25 (UHF) of U201 for 2.5Vdc.

f. No Transmit Power

(1) Perform step d (6) before continuing with this procedure.

(2) Check the output (pin 14) of synthesizer U300:

(a) While keying the radio, measure, with an rf millivoltmeter, the synthesizer output where it enters the rf PA (U202, pin 1). A level of 200 to 500mVac should be measured.

1. (*VHF only*). Check L210 for contin

2. (*MID-BAND only*). Check L210, L211 for continuity.

(b) While keying the radio, measure, using a frequency counter with a 50Ω probe (use the guide pin of the rf PA module for ground), the frequency of the synthesizer output where it enters the rf PA (U202, pin 1). The carrier frequency should be observed.

1. If the frequency measured is incorrect or not present, repeat the check using a spectrum analyzer with U202 removed. Check for proper drive level (250mV) and verify that the signal is "clean" (no parasitics).

(3) Verify the power output of the rf PA (U202):

(a) Remove FDS module U203.

(b) Connect a 50Ω probe with a 30dB pad to a power meter, and probe pin 13 (MID-BAND/VHF) or pin 10 (UHF) of rf PA U202. Make sure that the probe is grounded (use the ground side of C204 on MID-BAND/VHF radios; use a screw head for ground on UHF radios). ***Do not*** touch pin 13 (MID-BAND/VHF) or pin 10 (UHF) with your finger during this check.

(c) Key the radio. Six to seven watts should be measured (high-power PA).

1. If the power level is incorrect, check the V-control line of (pin 3) U202 (pin 6, MID-BAND only). With the FDS module (U203) removed, this line should go to the maximum level (6.8 to 7.0 Vdc).

(d) Reinstall FDS module U203.

1. If the voltage level in step e (3) (c) 1 was low, dekey the radio. Short pins 3 and 6 (pins 12 and 6 MID-BAND) of U202 together. This will force the rf PA into maximum gain. Read the power level again as in step e (3) (c).

(4) Verify the operation of the PA control circuit in U201:

(a) While keying the radio, measure the voltage on the RF DETECT line at U203, pin 5 (MID-BAND/VHF) or pin 4 (UHF). The voltage should be from 2.5 to 5Vdc.

1. The rf detect line of U203 should change as the power word is changed. Short pins 3 and 6 (pins 12 and 6 MID-BAND) of U202 together and verify that this line goes to approximately 4.0Vdc.

(b) While keying the radio, measure the D/A reference voltage at U201, pin 7; this voltage sets the power level of the radio. The reference voltage should be from 2.5 to 4.5Vdc; 4.5Vdc is the maximum setting.

1. The reference voltage should change when the power level word from the field programmer is changed. If there is no change, check pin 21 of U200 with an oscilloscope and verify that this line goes active when the power word is being changed.

(c) Verify the operation of the op amps in U201 by applying the formula, (V x 2) - 4 = Vr. V = the voltage measured in step e (4) (a); Vr = the voltage that should have been measured in step e (4) (b).

(5) (a) Check the FDS parameters (remote port) by keying the radio and measuring the voltage levels at the following pins of U203:

- *(For MID-BAND/VHF radios)*. Pin 8 = 6Vdc; pin 9 = 4.5Vdc; pin 12 = 6.5Vdc; pin 13 = 5.0Vdc.
- *(For UHF radios)*. Pin 7 = 4.7Vdc (transmit) and 7.4Vdc (receive); pin 8 = 0Vdc; pin 11 = 7.5Vdc.

(b) If any of the voltages measured were incorrect, check that U201, pin 23, is set to remote antenna enable (4.6Vdc). This sets up the biasing to the diodes in FDS module U203 via the transmit ALC IC, U201, pins 20, 24, 26, and 28 (MID-BAND/VHF) or pins 16, 17, and 20 (UHF).

g. No Receive / Poor Receive

(1) Inject 53.55MHz (MID-BAND/VHF) or 73.35MHz (UHF) from a frequency generator at or near the antenna and listen for the presence of a 1kHz tone. Use the generator's HI-LEVEL output @ 0dB (1kHz modulation, 3kHz deviation for 25kHz channel spacing and 1.5kHz deviation for 12.5kHz channel spacing). If the tone (signal) is present, continue with this procedure; if no tone is heard, go to step f (3).

(2) Check the radio's rf section:

(a) Using a frequency counter with a 50Ω probe, check the synthesizer's input to the 1st LO (U4, pin 3 for MID-BAND/VHF; U2, pin 4 for UHF), using the guide pin of the front end module (MID-BAND/VHF) or the front-end screw head (UHF) for ground. The reading should indicate 53.55MHz + carrier frequency (MID-BAND/VHF) or carrier frequency - 73.35MHz (UHF).

1. If the desired frequency cannot be read, remove the front end module and check the input again, using the ground side of capacitor C51 (MID-BAND/VHF) or C212 (UHF) for probe ground. If the desired frequency is present, continue with this procedure (radio in remote):

a. *(For UHF radios only).* The UHF front end module (U2) and the RX 5Vdc regulator (U201) will not function if the FDS module (U203) is not in place.

(1) If the FDS module is in place but there is still no RX 5Vdc at pin 3 of U2, check the voltages on pin 7 (7.4Vdc), pin 8 (0Vdc), and pin 11 (7.5Vdc) of U203 in remote only.

(2) Another indication would be to key the radio momentarily, then check RX 5Vdc. If the voltage is correct, check Q207 and Q208, and/or replace the FDS (U203).

b. Check that the 16.8MHz reference signal is present at pin 1 of U300.

NOTE

This will occur only after turning the radio on, but before transmitting.

2. If the desired frequency is present, continuewith this procedure (radio in remote):

(b) Using a 50Ω probe, inject the carrier frequency at pin 2 of U4 (MID-BAND/VHF) or pin 9 of U203 (UHF). The signal level should be approximately 0.68μV (MID-BAND/VHF) or 0.4μV (UHF) for 12dB SINAD.

If a good reading was obtained, continue with this step (MID-BAND/VHF) or go to step g (2) (f) (UHF); if the reading was less than 12dB SINAD, go to step g (3).

(c) *(For MID-BAND radios only).* Using a 50Ω probe, inject the carrier frequency at pin 1 of rf amplifier module U1; use pin 11 of U203 for probe ground. The signal level should be approximately 027μV for 12dB SINAD.

(d) *(For VHF radios only).* Using a 50Ω probe, inject the carrier frequency at pin 11 of two pole filter U1; use pin 2 of U203 for probe ground. The signal level should be approximately 0.27μV for 12dB SINAD. Check that the TUNING VOLTAGE level at U1, pin 5, is 0.7Vdc at 146MHz.

(e) *(For VHF radios only).* Check the bias voltages at the rf amplifier, Q3. If these voltages are incorrect, suspect T1.

(f) Using a 50Ω probe, inject the carrier frequency at pin 12 of U203; use pin 11 (MID-BAND/VHF) or pin 13 (UHF) of U203 for probe ground. The signal level should be approximately 0.27μV for 12dB SINAD.

(g) Check the dc voltages of U203.

(h) Replace the FDS module, U203, and repeat step g (2) (e).

(3) Using a frequency counter with a 50Ω probe, check the synthesizer's input (U300, pin 32) to the 2nd LO, using the ground side of CR800 for ground. The reading should indicate 53.1MHz or 54.0MHz (MID-BAND/VHF), or 72.9MHz or 73.8MHz (UHF).

(4) Using a 50Ω probe, inject 53.55MHz (MID-BAND/VHF) or 73.35MHz (UHF) at inductor L1 (VHF/UHF) only; place the positive end of the probe where C46 and L1 connect. Use the ground screw of the front end module (VHF) or pin 3 of J2 (UHF) for probe ground. The signal level should be approximately 90 to 100μV (VHF) or 1.2μV (UHF) for 12dB SINAD.

For MID-BAND place probe across L2, using guide pin of the Front end module for ground. The signal level should be approximately 0.95μV for 12dB SINAD.

(5) Using a 50Ω probe, inject 450kHz at filter pin 1 of FL3 (MID-BAND/VHF) or pin 1 of U2 (UHF). Use pin 2 of FL3 (MID-BAND/VHF) or a screw head (UHF) for probe ground. The signal level should be approximately 3.5μV for 12dB SINAD. If this step fails, go to the Receive Audio procedure.

h. Receive Audio

(1) Using a 50Ω probe, inject 450kHz at filter pin 1 of FL3 (MID-BAND/VHF) or pin 1 of U2 (UHF). Use pin 2 of FL3 (MIDBAND/VHF) or a screw head (UHF) for probe ground. Set the input signal level at -60dBm. Set the radio to rated audio (3.7Vac) and measure the distortion level. If the distortion level is greater than 5%, or 3.7 Vac cannot be obtained, continue with this procedure.

(2) (a) Check the voltages of the i-f IC, U100 (voltages are approximate): pin 8 = 4.5Vdc; pin 9 = 1.5Vdc; pin 10 = 0.9Vdc; and pin 12 = 1.5Vdc. These voltages determine if the op amps in the IC are functional. If the voltages are correct, continue the procedure.

(b) Ensure that the No.1 regulator voltage is not below 4.8Vdc when set to rated audio.

NOTE

The current drain should be approximately 200mA at rated audio.

(c) Inject 450kHz (-60dBm) at pin 1 of FL3 (MID-BAND/VHF) or pin 1 of U2 (UHF). Check the discriminator output (U100, pin 31) with an oscilloscope for a symmetrical sine wave. When no signal is applied, the reading should be 3.5Vac of noise. If the result is not symmetrical or if the signal is low, check resistor R3.

(3) (a) Inject a modulated 1kHz signal (-30dBm) at capacitor C14. Adjust the radio for rated audio and measure the distortion level.

(b) Vary the volume level and monitor the audio at capacitor C22. The signal should not "clip" until approximately 4.0Vac.

NOTE

If the audio processing bit has been set or tuned lower, the audio will clip at a lower level. This will affect distortion measurements.

(4) (a) Inject a modulated 1kHz signal (-30dBm) at capacitor C22. Adjust the radio for rated audio (3.7Vac) and measure the distortion level.

(b) Check pins 4, 28, and 31 of U102 for 6.5Vac p-p. At maximum volume, the waveform should be clipped.

i Receive Coded Audio (Secure Capable radios only)

(1) Replace U900 with a SECURE bypass module (NTN4720). Verify that the radio operates properly in the clear mode.

(2) (a) Replace U900 with a test module. Ensure that the transmitting and receiving units have the same encryption key.

(b) Set the service monitor or rf signal generator to output a 1-millivolt signal. Introduce the signal to the radio at the exact channel frequency through the universal connector. Modulate the rf signal with an encrypted 1kHz tone at 4kHz deviation. Set the volume control for rated audio output (3.74Vrms).

(c) Check that a 1kHz tone is present at the speaker.

(d) Check that an eye pattern is present at U900, pin 2.

(e) Check that a 1kHz signal is present at U900, pin 3 and U101, pin 7.

(f) Decrease the rf signal to 1µV. Check that a 1kHz tone is still present at the speaker.

j. Transmit Audio

(1) (a) Inject a 1kHz signal (-60 dBm) through the universal connector. Key the radio and observe the service monitor scope for a symmetrical sine wave. If the signal appears distorted, replace the synthesizer module, U300, and retest.

(b) Check pins 21 and 22 of U102 for 3.5Vdc with the radio keyed. This voltage turns on the amplifiers in U102.

(2) (a) Using a 50Ω probe, inject a 1kHz signal (-60 dBm) at capacitor C23. Key the radio and observe the service monitor scope for a symmetrical sine wave.

(b) Ensure that the signal is reaching pins 10 and 11 of U101; the level at pin 10 will be considerably lower than that at pin 11. Also, ensure that the signal is reaching pins 15, 16, and 22 of U101.

(3) Inject 1kHz (3kHz deviation for 25kHz channel spacing, 1.5kHz deviation for 12.5kHz channel spacing) at 1Vac at R16 (U101 side). Key the radio and observe the service monitor scope for a symmetrical sine wave. If the signal appears distorted, replace the synthesizer module, U300, and retest.

(4) This step checks the quality of the synthesizer's output signal. All previous steps in this procedure should be performed prior to performing this step.

(a) Inject a 1kHz (3kHz deviation for 25kHz channel spacing, 1.5kHz deviation for 12.5kHz channel spacing) signal (-60 dBm) through the back connector. Using a 50Ω probe with a spectrum analyzer, probe pin 1 of the rf PA, U202, and key the radio The modulation on the carrier and the carrier signal itself should not exhibit "spurs" or parasitics. If this step fails, go to the Transmit Power procedure.

k. Transmit Coded Audio (Secure Capable radios only)

(1) Replace U900 with a SECURE bypass module (NTN4720). Verify that the radio operates properly in the clear mode.

(2) (a) Replace U900 with a test module. Ensure that the transmitting and receiving units have the same encryption key.

(b) Inject a 1kHz signal (25mV) through the universal connector. Place the radio in the coded mode. Key the radio and observe the service monitor for a symmetrical eye pattern with 4kHz of deviation.

(c) Check that a 1kHz signal is present at U900, pin 17.

(d) Check that an eye pattern is present at U900, pin 1.

(e) Using a properly equipped service monitor or test radio, with the same encryption key, decrypt the coded signal and verify that a 1kHz signal is recovered.