# Systems SABER™ and SABER AT S™ Handie-Talkie® Portable Radios

# Theory/Maintenance Manual

*68P81060C20-A*

MOTOROLA

# Systems SABER™ and SABER ATS™
## Handie-Talkie® Portable Radios

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# ACCESSORIES

Motorola offers a variety of accessories for SYSTEMS SABER and SABER ATS radios to increase communications efficiency. Many of the accessories available are listed below, but for a complete list, consult your Motorola sales representative.

**Antennas:**

| | |
|---|---|
| NAD6282A | Heliflex (136-150.8 MHz) |
| NAD6471A | Heliflex (136-150.8 MHz) |
| NAD6472A | Heliflex (146-162 MHz) |
| NAD6473A | Heliflex (157-178 MHz) |
| NAD6552A | Heliflex (148-174 MHz) |
| NAE6131A | Heliflex; For Public Safety Microphone (403-433 MHz) |
| NAE6132A | Heliflex; For Public Safety Microphone (440-470 MHz) |
| NAE6133A | Heliflex; For Public Safety Microphone (470-512 MHz) |
| NAE6431A | Heliflex (403-433 MHz) |
| NAE6432A | Heliflex (438-470 MHz |
| NAE6434A | Heliflex (460-520 MHz) |
| NAE6440B | Flexible Whip (403-512 MHz) |

**Audio Accessories:**

| | |
|---|---|
| NMN6128B | Remote Speaker Microphone |
| NMN6129A | Public Safety Remote Speaker/Microphone |
| NMN6166B | Remote Speaker Microphone with Earpiece Jack |
| NSN6050A | Earpiece (Without Volume Control) |
| NTN5039A | Earpiece, Extra-Loud |
| NTN5664A | Adapter, Surveillance |
| ZMN6031A | Earpiece, Microphone and PTT Switch Separate |
| ZMN6032A | Earpiece, Microphone and PTT Switch Combined |

**Batteries:**

| | |
|---|---|
| NTN4537C | Light-Capacity, Nickel-Cadmium, FM Approved Intrinsically Safe (Groups D, F, and G) |
| NTN4538C | Medium-Capacity, Nickel-Cadmium, FM Approved Intrinsically Safe (Groups D, F, and G) |
| NTN4592C | Light-Capacity, Nickel-Cadmium, FM Approved Non-Incendive (Groups A, B, C, and D) |
| NTN4593C | Medium-Capacity, Nickel-Cadmium, FM Approved Non-Incendive (Groups A, B, C,and D) |
| NTN4595C | Ultra-High-Capacity, Nickel-Cadmium, FM Approved Non-Incendive (Groups A, B, C, and D) |
| NTN4596C | Ultra-High-Capacity, Nickel-Cadmium, FM Approved Intrinsically Safe (Groups D, F, and G) |
| NTN4992A | Ultra-High-Capacity, Nickel-Cadmium, FM Approved Intrinsically Safe (Groups C, D, E, F, and G) |

**Battery Chargers:**

| | |
|---|---|
| NTN4734A | Single-Unit, Rapid Rate, 115-Volt |
| NTN4786A | Single-Unit, Rapid Rate, 220-Volt |
| NTN4796A | Multi-Unit, Rapid Rate, 110-Volt |
| NTN4797A | Multi-Unit, Rapid Rate, 220-Volt/240-Volt |
| NTN5563A | Porta-Pocket |
| NLN7967A | Wall Mount for Multi-Unit Charger |
| NLN7968A | Rack Mount for Multi-Unit Charger |

**Carrying Accessories:**

| | |
|---|---|
| NTN4675A | Case, Swivel (For Radio with Light-Capacity Battery) |
| NTN4676A | Case, Swivel (For Radio with Medium-Capacity Battery) |
| NTN4677A | Case, Swivel (For Radio with Ultra-High-Capacity Battery) |

Hardware, and Cables)

# GENERAL DESCRIPTION

## 1. INTRODUCTION

The frequency-synthesized SYSTEMS SABER and SABER ATS Handie-Talkie 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.

**NOTE**

In most instances, SYSTEMS SABER and SABER ATS radios are functionally identical. In the remainder of this manual, unless otherwise noted, consider references to SYSTEMS SABER to also apply to SABER ATS.

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 this manual. Model and option numbers will be shown on the radio's customer information sheet, which is shipped with each new radio.

### a. Physical Description

The rotary selector switch, on/off/volume control, multifunction LED, antenna, transmit mode selector switch (TMSS) and emergency button are located on top of the radio. The push-to-talk (PTT) switch, monitor button, and side (SB 1 and SB 2) buttons are located on the left side of the radio (viewed from the front), and the display and keypad (SYSTEMS SABER III models) are an integral part of the front cover. On the back of the radio are the rf connector and universal connector.

The SYSTEMS SABER 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 total radio height varies according to 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 the controller board. The main radio board performs the transmit and receive, frequency generation and distribution, power generation and distribution, secure voice, control, and interface functions.

The controller board includes circuitry for controlling the signalling and trunking features of the radio, interfacing with the main radio board, displaying user information and processing user input from the radio's keypad (SYSTEMS SABER III radios), and storing user-programmable parameters in an electrically erasable, programmable read-only memory (EEPROM).

## 2. STANDARD FEATURES

The SYSTEMS SABER 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.

Features such as MDC/signalling and trunking are available with up to 16 channels per zone and up to 16 zones. Radio models are available with up to 256 channels of carrier, tone Private-Line (PL), and/or Digital Private-Line (DPL) squelch operation. The type of squelch is enabled on a per channel basis with up to 125 code pairs available per radio.

Four power output levels are offered: medium power (2.5 watts on VHF models and 2 watts on UHF models), high power (6 watts on VHF models and 5 watts on UHF models), and two user-programmable power levels (within the medium- and high-power levels listed above).

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/yellow multifunction LED on the top of the radio provides visual feedback to the user. This LED indicates when the radio is in transmit (continuous red), a low-battery condition (flashing red when transmitting in SYSTEMS SABER I radios only), channel busy (flashing red in receive), and when a Call Alert™ or Private Conversation™ is being received (flashing yellow). The user can enable or disable LED feedback on these and other radio features.

## 3. SPECIAL STANDARD FEATURES

### a. Field Programming

The SYSTEMS SABER 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. Multiple Digital Private-Line (DPL) And Tone Private-Line (PL) 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 SYSTEMS SABER radio can have carrier squelch on some channels, DPL squelch on others, and tone PL squelch on others. You can choose from among 83 DPL codes and 42 tone PL codes.

**c. SECURENET™**

The SYSTEMS SABER SECURENET 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 transmit mode selector switch (TMSS), or by “strapping” on a per-channel basis using the radio service software. Regardless of the TMSS 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 SYSTEMS SABER radio are contained on the main radio circuit board and the controller 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, secure voice, 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.

**c. Controller Board**

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

**d. Flexible Circuits**

The SYSTEMS SABER radio uses several flexible printed circuits for interconnection. These include:

- PTT/Controls Flex
- Speaker/Microphone Flex
- Universal Connector Flex
- Interconnect Flex (between main and controller boards)

**Table1. SYSTEMS SABER Radio Batteries**

| MODEL NUMBER | BATTERY CAPACITY | CHARGE TIME |
|---|---|---|
| NTN4537C | LIGHT | 1 HR |
| NTN4538C | MEDIUM | 1 HR |
| NTN4592C | LIGHT | 1 HR |
| NTN4593C | MEDIUM | 1 HR |
| NTN4595C | ULTRA-HIGH | 1 HR |
| NTN4596C | ULTRA-HIGH | 1 HR |
| NTN4905A | ULTRA-HIGH | — |
| NTN4992A | ULTRA-HIGH | 1 HR |

## 5. BATTERIES

The batteries available for the SYSTEMS SABER radio are listed in Table 1. Battery choice is governed by rechargeability, duty cycle, operating time, and maximum height and weight desired.

All batteries, with the exception of NTN4905A, are rechargeable, nickel-cadmium batteries which require

# 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 ACCESSORIES page at the beginning of this manual for a list of the available battery chargers and their applications. For further information, contact your Motorola sales representative.

## 2. BATTERY CONSTRUCTION *(See Figure 1)*

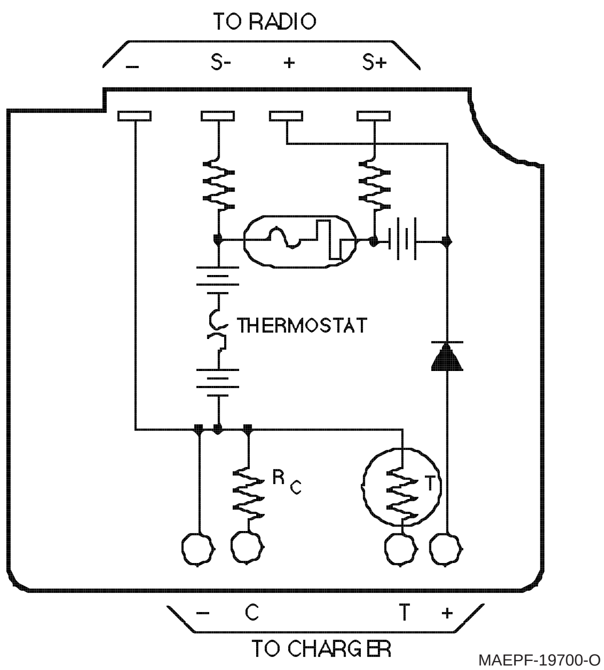


*Figure 1. Typical Battery Construction, Rear View*

The SYSTEMS SABER 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 connects 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 Area Parts Office.

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.

e. **CAUTION**

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

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

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.

## 7. LITHIUM BATTERY HANDLING PRECAUTIONS

Because of their chemical composition, lithium batteries pose particular problems in their handling, disposal, and shipping. The NTN4905A Lithium Battery contains lithium, which is a highly reactive metal that reacts violently with moisture, alcohol, acids, and other oxidants. Lithium may burn spontaneously in moist or humid air.

### a. Safety Precautions

The lithium battery is safe under all environmental conditions for which it was designed. The cells contain a safety vent mechanism to ensure safety in the event of abuse. High-rate cells also contain an intrinsic current and thermal protection system which prevents the cell from overheating if accidentally shorted or discharged at higher than recommended rates. The chemicals are sealed and pose no hazard unless the battery is abused. However, the following handling precautions which should be observed:

**DO NOT** disassemble the battery.

**DO NOT** short the battery.

**DO NOT** attempt to charge the battery; it is not rechargeable.

**DO NOT** connect the battery backwards or to a power source.

**DO NOT** crush or puncture the battery.

**DO NOT** incinerate, or expose the battery to fire or heat in excess of 100°C.

### b. Emergency Precautions

In case of battery cell venting, rupture, or leakage of electrolyte, wash off any affected skin or body contact area with copious amounts of water, flushing the area for 15 minutes. Do not inhale the vapors. Contact a physician.

In case of fire, use lithex extinguisher or rapidly cool the batteries and adjacent structures with large amounts of water. Lithium metal is reactive in water, generating hydrogen and lithium hydroxide during reaction; therefore, if water is used to control the fire, large amounts of water are required to keep the reaction cooled down.

### c. Shipping Requirements

The transportation of lithium batteries within the United States is regulated by the U.S. Department of Transportation (D.O.T.) in the Code of Federal Regulations, CFR49, "Transportation." The NTN4905A Lithium Battery, can be shipped under DOT-E 7052 by motor vehicle, rail freight, cargo vessel, and cargo-only aircraft. The shipping name is "Lithium Batteries" and shipping classification is "Flammable Solid." International air transportation is specified by the International Civil Aviation Organization (ICAO). The ICAO procedures for international air shipment are not necessarily identical to those of the D.O.T. Each local regulatory agency should be contacted to ensure that no additional requirements are specified by the individual state.

### d. Disposal Requirements

Disposal of large quantities of lithium batteries in

## 1. INTRODUCTION

This section of the manual provides a functional description of the SYSTEMS SABER 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. An overall system block diagram is shown in Figure 2.

## 2. BASIC FUNCTIONAL DESCRIPTION

### a. DC Voltage Distribution *(See Figure 3)*

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 to 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) or pins 6 and 8 (UHF).

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

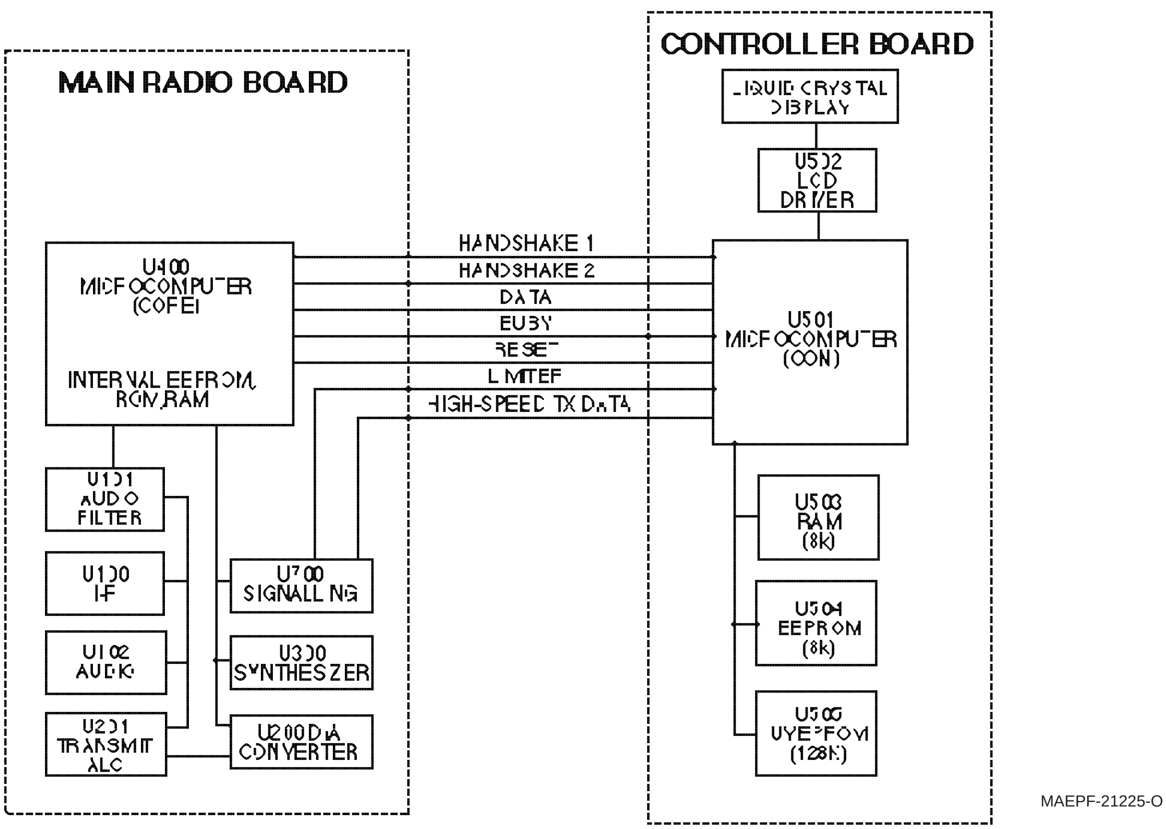


*Figure 2. Overall System Block Diagram*

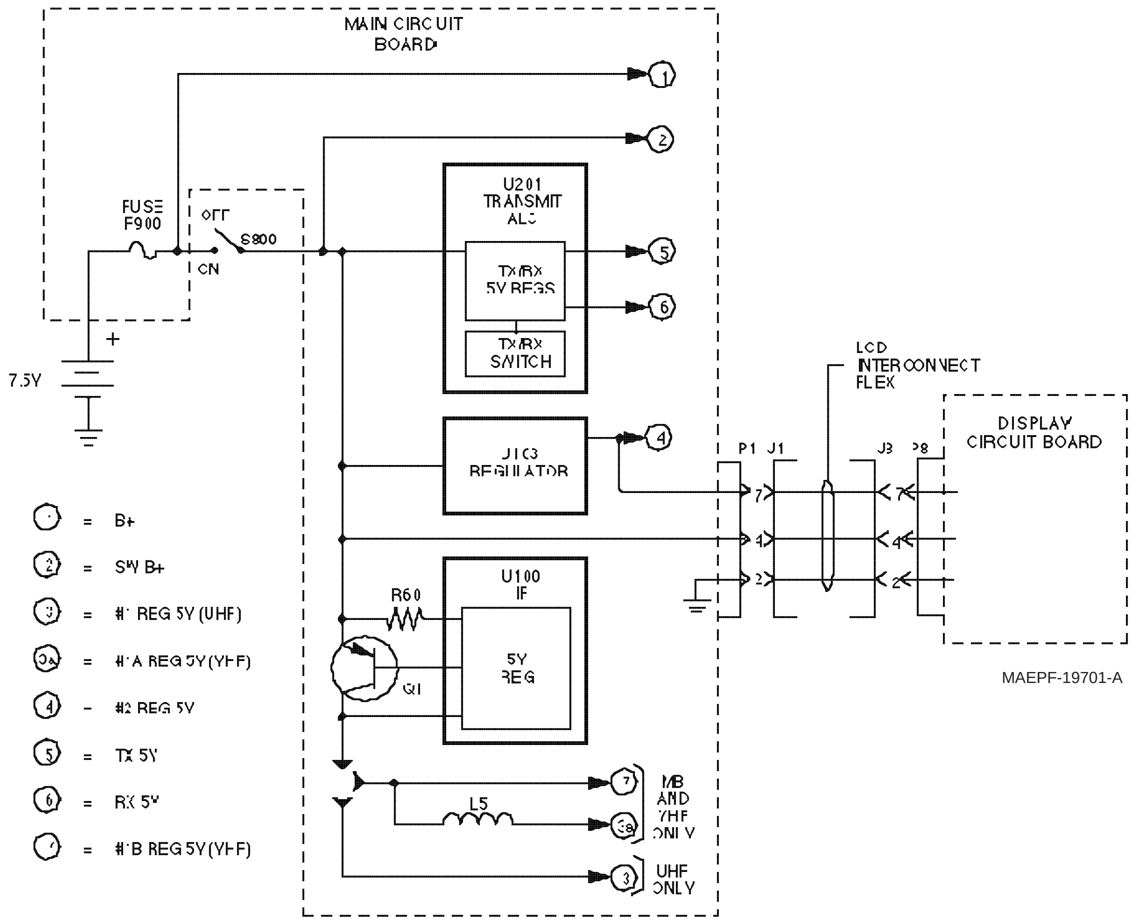


*Figure 3. DC Voltage Distribution Block Diagram*

UHF radio, SWITCHED B+ is also supplied to the collector of Q200.

No.1A REGULATED 5V (VHF radios only) originates at inductor L5, and is identified by the "③" 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).

No.1B REGULATED 5V (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 SYSTEMS SABER 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 and VHF 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 SYSTEMS SABER 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 channels and sensitive SECURENET radios.

The following generic (TX or RX) description of the SYSTEMS SABER 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 harmonics.

### d. Controller and Display Circuitry

The controller/display circuitry for SYSTEMS SABER radios includes an enhanced microcomputer on the controller (CON) circuit board, providing SYSTEMS SABER radios with greatly enhanced capabilities. On SYSTEMS SABER III radios, this board, mounted on the radio's front shield, also includes the liquid crystal display (LCD) and display circuitry. The controller board includes the following ICs:

- An MC68HC11F1 microprocessor, U501. This IC is also called the CON (controller).
- An electrically-erasable, programmable read-only memory (EEPROM), U504. This IC's memory size is eight kilobytes.
- An 8k random-access memory (RAM), U503.
- An ultraviolet-erasable, programmable read-only memory (UVEPROM), U505. This IC's memory size is 128 kilobytes.
- On SYSTEMS SABER III radios, a liquid crystal display (LCD) driver, U502.

The controller board communicates with the main radio board via the 10-wire interconnect flexible cable (J8); this cable provides both power and signal paths. The keypad flex also plugs into the controller board (J7).

### e. SECURENET Circuitry

The SECURENET 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 two SECURENET 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 = 5V; TX = 0 = 0V).

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 3.735V = 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 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 pulled down to 1.0V. The microcomputer informs the CON (U501) via the DATA line that a PTT switch press has occurred. Pulling the OPTION SELECT line (U400, pin 62) low (originated from an attached accessory, such as a public safety microphone) generates the same message. The CON then pulls the HANDSHAKE 1 line (U400, pin 40) low. This tells U400 to start the transmit sequence, which begins by reprogramming the chip set (audio filter IC, digital/analog converter IC, the signalling IC, and synthesizer IC's).

Next, the internal/external microphone is selected and enabled. The microphone itself will not be enabled until the TX 5V is active. Finally, the audio filter IC, U101, is programmed to 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, is slaved to the controller board microcomputer (CON), U501. Following instructions from the CON, the CORE then directly controls many of the SYSTEMS SABER 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 SYSTEMS SABER radio has more than one processor (CORE and CON) in its system; these, and other, 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 TD0, 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. The BUSY line is always low when there is data on the serial bus.
- *Analog-to-Digital (A/D) Subsystem*. The CORE processor has five 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 fourth input (PE6, pin 60) is the SIDE CONTROL line, which has the emergency switch (S801), PTT switch (S803), monitor switch (S805), and the two side button switches (S806 and S807) connected to it. The voltages present on the SIDE CONTROL line when each of the buttons is pressed are as follows: 0V for the emergency button, 1.0V for the PTT button, 2.3V for the monitor button, 3.5V for side button 1, and 4.4V for side button 2. The emergency switch has the highest priority, followed by the PTT switch, the monitor switch, the side button 1 switch, and the side button 2 switch.

  The last input is the receiver signal strength indicator (RSSI) line (PE0, pin 53), an analog voltage from the i-f IC (U100).
- *Frequency Switch*. The CORE processor reads the output of the frequency switch (S823) via four input lines (PA0 and PE1 through PE3; pins 53, 55, 59, and 61 respectively).
- *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 the to the audio filter IC (U101, pin 33) during tone PL encoding; the frequency of the pulse train is12 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 is1071 Hz for TPL or 537 Hz for DPL.
- *Generation of Alert and DTMF Tone Clocks*. The CORE generates the audio alert tone clock (PA7, pin 34) which, after being sent to, and processed by, the audio filter IC (U101), provides the user with audible feedback from the speaker regarding the radio's operating status (bad keypress, low-battery chirp, etc.).

  The CORE also generates the dual-tone, multi-frequency (DTMF) tone clocks. When required (depending on the key pressed), the CON tells the CORE which tone-clock pair (TONE CLOCK [PA6, pin 35] and DTMF CLOCK [PA5, pin 36]) to generate. These clocks are sent to the signalling IC (U700) and processed as tones.
- *Decision of Receiver Unmuting*. The CORE con-

trols carrier squelch and PL unmuting without having to talk to the CON (which facilitates conventional scan). However, some features allow the CON to override the CORE's decision (such as forced muting for data-operated squelch).

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 | Handshake 2 | 0V pulses during conventional scan until an active channel is found; 5V = otherwise, including power-up |
| 13 | XMIT power ind. | 0V or 5V |
| 14 | Busy | 5V = Serial bus inactive; 0V = Serial bus active |
| 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 | Coded/clear sense | 5V = Coded mode; 0V = Clear mode |
| * 19 | Reset | 0V = Reset mode; 5V = Otherwise |
| * 20 | XIRQ | 5V |
| * 21 | IRQ | 5V |
| 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 | Alert tone clock | Toggles between 0V and 5V when an alert tone is being generated; 5V = Otherwise |
| 35 | Tone clock out | Toggles between 0V and 5V when DTMF is being generated; 0V = Otherwise |
| 36 | DTMF clock out | Toggles between 0V and 5V when DTMF is being generated; 0V = Otherwise |
| * 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 1071 Hz when TPL decode is enabled; 537 Hz when DPL decode is enabled. 12 times TPL frequency (in transmit) |
| 40 | Handshake 1 | 0V for transmit, 5V for receive, with 0V pulses in conventional scan until an active channel is found |
| 41 | PL decode | Toggles between 0V and 5V |
| 42 | No connection | Don't care |
| 43 | Freq. select 0 | This is the least-significant bit of the frequency switch; 0V or 5V |
| 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 | Emergency keep-alive | 5V = Emergency mode; 0V = Otherwise |
| 52 | Yellow LED | 5V = LED on; 0V = LED off |
| 53 | Receiver signal strength indicator (RSSI) | Analog voltage in the 0.7 -2.2V range; ≈0.7V with no input signal; ≈2.2V with high input level (0dBm or 1mW) rf signal |
| 54 | Battery voltage sense | 1/2 of the battery voltage |
| 55 | Freq. select 1 | 0V or 5V |
| 56 | Volume sense | 0V through 5V |
| 57, 58 | No connection | Don't care |
| 59 | Freq. select 2 | 0V or 5V |
| 60 | Side control | 0V = emergency button pressed; 1.0V = PTT switch pressed; 2.3V = monitor button pressed; 3.5V = SB1 pressed; 4.4V = SB2 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 the two SPDT transmission gates allow extension of the 2-pole tuning voltage range beyond that of the 7-bit D/A converter.

*In UHF radios only,* the two SPDT transmission gates are used to enable or disable the auxiliary transmit modulation path.

The 4-bit D/A converter is not used in SYSTEMS SABER 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 SYSTEMS SABER 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) VHF*

When the CON microcomputer (U501) receives a message to transmit from the CORE (U400), the CON tells the CORE to begin the radio transmit procedure via the HANDSHAKE 1 line. After the R/T line changes status following the chip set programming, the logic low on the R/T line input (pin 9) to the transmit automatic level control IC, U201, causes U201's pin 28 to go high (≈6Vdc). This voltage is applied to the anode side of a series-connected pair of PIN diodes, internal to filter/detector/switch module U203 (pin 8), which controls 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). 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 and 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.

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. Capacitors C222, C223, C224, and C225, and inductor L205 are for rf decoupling; C229 is a dc block and C241 is a matching element.

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 (U203) is functionally equivalent in both VHF and UHF radios, the electrical realization of the two 4-port PIN diode rf switches is somewhat different, and requires 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 and 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 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 (all 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 (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 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, generates, shapes, and filters DTMF, MDC signalling, and high-speed trunking data in the transmit mode. The IC shapes and filters MDC signalling and trunking data in the receive mode

The CORE microcomputer, U400, programs the signalling IC via the SPI interface.

- *MDC Encode*. The signalling IC is fed a digital line from the CON, U501, which controls U700's MDC encoder. The encoding signal is filtered within U700 before being sent to the audio filter IC, U101.
- *DOS Detection*. The digital-operated squelch (DOS) algorithm is in the CON microcomputer, but the support hardware is in U700. The radio discriminator output from U100 (pin 31) is fed to U700 (pin

| Pin No. | Function | Signal |
|---|---|---|
| 1 | 5 volts | 5V |
| 2 | Bias resistor | ≈1.3 to 1.4V |
| 3 | No connection | Don't care |
| 4 | No connection | Don't care |
| 5 | MDC reference | ≈2.0 to 2.1V |
| 6 | No connection | Don't care |
| 7 | DTMF clock in | Toggles between 0V and 5V when DTMF is being generated; 5V = otherwise |
| 8 | Trunking data in | Toggles between 0V and 5V when MDC signalling or high-speed trunking data is being generated; 0V = otherwise |
| 9 | Tone clock in | Toggles between 0V and 5V when DTMF is being generated; 5V = otherwise |
| 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 | ≈2.2 to 2.5V |
| 27 | LS bypass | ≈2.2 to 2.5V |
| 28 | No connection | Don't care |
| 29 | VAG bypass | ≈2.2 to 2.5V |
| 30 | No connection | Don't care |
| 31 | RX audio in signal | The analog demodulated |
| 32-34 | No connection | Don't care |
| 35 | Ground | Ground |
| 36 | No connection | Don't care |

31), where it is filtered and hard limited. This hard limiter signal is then fed to an input capture port on U501 (pin 43).

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

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

In the VHF receiver string, rf enters U1, the tunable, 16MHz-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 32MHz-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 3 dB. The first i-f signal now moves through matching components C49 and L2 before entering the i-f IC, U100.

*(b) 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 (73.35 MHz) below the channel (rf) frequency.

The resultant first i-f signal (73.35 MHz) 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 18 kHz, centered around 73.35 MHz, with a typical gain of 5.5 to 8.5 dB. 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 (53.55 MHz for VHF or 73.35 MHz for UHF) enters U100 at pin 10, and passes through an internal preamplifier. The output of the preamplifier 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.

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 450 kHz. Therefore, for VHF radios the 2nd oscillator frequency must be 450 kHz above or below 53.55 MHz; that is, 54 MHz (high-side injection), or 53.1 MHz (low-side injection). For UHF radios the 2nd oscillator frequency must be 450 kHz above or below 73.35 MHz; that is, 73.8 MHz (high-side injection), or 72.9 MHz (low-side injection). A lookup table in the EEPROM IC (U504) on the controller circuit board determines which injection to use for both VHF and UHF.

The resulting 450kHz 2nd i-f signal leaves U100 (pin 8), and 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 450 kHz; 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 squelch codes and high-pass filtered to separate voice. Squelch codes are filtered, sampled, and sent (U101, pin 28), via the PL DECODE line, to the microcomputer, U400 (pin 41). If the radio is in the PL/DPL squelch mode, U400 turns on its decoding circuitry. When the 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. Finally, the voice audio passes from U101 (pin 24), through a low-pass filter (C47, R19) to the audio PA (U102, pin 10).

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 the 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 approximately 1.0 volt to pin 60 of the CORE microcomputer, U400. This change in switch status is sent by the CORE to the CON microcomputer (U501) via the data line. The CON then pulls the HANDSHAKE 1 line to a logic low, which tells the CORE to start the radio transmit procedure. The CORE begins by reprogramming 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/DPL encode is set. From the output of the limiter, the signal then goes through the splatter filter to the summer, where the microphone input is summed with the AUX TX input and the PL/DPL encode signal. The PL tones are 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 summer output then goes through a buffer into two attenuators.

A five-bit attenuator adjusts the VCO modulation level, then sends 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.

*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 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 all radios* the gain control voltage for U202, pin 3, is supplied by U201 via pass transistor Q202. The PA control circuit inside of 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 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) if the PA temperature exceeds a preset value. The cutback temperature is determined by the value of R210.

### i. CON Microcomputer (U501)

*Refer to Figure 4 and the controller board schematic diagram in the applicable service manual.*

The controller (CON) microcomputer, U501, is the heart of the SYSTEMS SABER radio. The CON has several functions, the main ones being:

- controlling the conventional signalling and trunking features of the radio,
- processing of information input by the user via the radio's switch settings (sent directly from the CORE, U400),
- sending the CORE the TX/RX data it requires (data stored in EEPROM IC U504),
- instructing the CORE to go into the transmit or receive (or scan) mode,
- informing the CORE about other function(s) that must be carried out (such as setting up the signalling IC to transmit trunking data, etc.),
- processing non-voice receive signals, such as those from trunking or MDC signalling,
- synthesizing non-voice transmit signals, such as those for trunking or signalling,
- telling the CORE when to turn on the radio's LED and when to generate alert and DTMF tones,
- overriding of the CORE's carrier squelch and PL unmuting decisions, depending on enabled features (such as forced muting for data-operated squelch),
- processing of information input by the user via the radio's keypad (SYSTEMS SABER III radios only), and
- control of the liquid-crystal display (LCD), which displays information about the state of the radio (SYSTEMS SABER III radios only).

The CON microcomputer communicates with the main 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 main radio board and are connected to #2 regulated 5V.

When the CON or CORE (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, resistors R510 and R512, and capacitors C504 and C506 filter out computer "hash" interference from the DATA and BUSY lines.

The CON gets its +5V power (#2 regulated 5V)

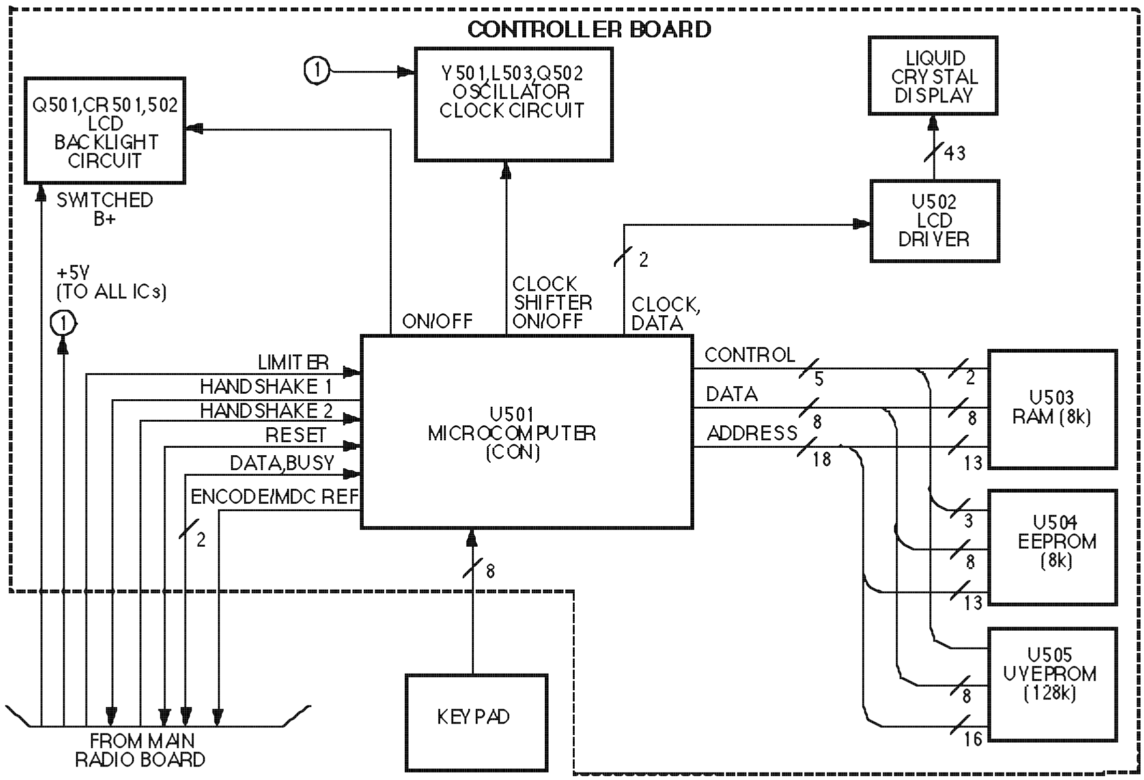


*Figure 4. Controller/Display Circuitry Block Diagram*

from the main radio board through the VDD pins (D8, E8). Inductor L502, and capacitors C510 and C511 provide filtering.

The CON's RESET line, pin B4, is connected to the main radio board's RESET line via filter C507 and R514, and pin 5 of the interconnect flex. Whenever the RESET line goes low, then high again, the CON reinitializes itself; the display may briefly show "***LCD_TEST***", "***GENERIC***" and/or other messages.

Components Y501, C513, C514, and R516 are the external elements of the microcomputer clock circuit. The resulting 7.3728MHz oscillator signal is divided by four inside the CON and becomes the internal clock. Additional components C515, L503, and Q502 form a clock shifter circuit; a logic low at the base of Q502 enables the shifter by placing L503 and C515 in the series path of Y501.

CON pins A5, A6, B6, B7, C5, C6 and D2 are control lines for the RAM (U503), EEPROM (U504), and UVEPROM (U505). Pin B7 controls the paging of which 64k block of data is to be accessed in the UVEPROM. These lines are normally at a logic high level unless the CON is accessing data from any of the memory ICs. None of these lines should ever be at a constant low level.

Pins A2, A3, B1 through B3, and C2 through C4 make up a bidirectional data bus between the CON and the memory ICs. These lines are normally at a logic low unless data is being accessed.

Pins E7, F3, F6, G3 through G7, H3 through H7, and J3 through J7 are the eighteen address lines from the CON to the memory ICs. Each memory IC receives the lower twelve address bits (lines), while the EEPROM receives an additional line and the UVEPROM receives four additional lines.

Pin F8 (PA5) is the control line for the LCD backlight. Two 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 R502, and transistor Q501. 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. This line and its associated parts are not used on SYSTEMS SABER I radios.

Pins E2 and E3 are the MODB and MODA inputs. These pins are both tied high through R503 and R506, respectively; they determine the mode that the microcomputer will be in after it is reset. Both inputs must be high for the CON to operate properly.

Pins D4 and D5 form another serial bus. The CON uses this bus to send serial clock and data information to the LCD driver IC, U502. The bus is synchronous; that is, one of the lines (pin D5) is used to clock the data on the other line (pin D4). Pin D7 and components Q503, R520 and R522 invert and delay the serial data on pin D4; this inversion and delay facilitates the CON's communication with the LCD driver, U502.

Pins B8, E4, F1, F2, G1, G2, H1, H2, and J2 are keypad input lines. These are high-impedance lines which need to be pulled high by resistors R526 through R533. The keypad lines are normally all high unless a key is pressed. Each key press causes exactly two of the lines to go low (row and column). The CON decodes the lines and processes the key-press. Resistors R538 through R545 are used to attenuate computer "hash" on the keypad lines.

Pins G8 and F5 are the HANDSHAKE lines (1 and 2, respectively) connected to the CORE via the inter-connect flex. The HANDSHAKE 1 line is an output from the CON, and the HANDSHAKE 2 line is an input to the CON; both lines are normally high. These lines are used in different ways during conventional trans-mit, conventional receive scan, and trunking transmit.

For conventional transmit, the CORE sends the PTT switch press to the CON via the DATA line; the CON then pulls the HANDSHAKE 1 line low. This tells the CORE to initiate the radio’s transmit sequence. The CON holds this line low until all information has been transmitted. This information is either voice, upon which the user releases the PTT switch, or a sig-nalling word, upon which the radio completes trans-mission of the word before ending transmit. The HANDSHAKE 2 line remains high during transmit.

For conventional receive scan, the CORE sends a logic low pulse denoting channel status via the HANDSHAKE 2 line. If the channel is clear, a short pulse is sent; if the channel is active, a long pulse is sent. The CON sends the CORE a low pulse on the HANDSHAKE 1 line telling the CORE to change the channel. The pulse lengths on the HANDSHAKE 2 line are approximately 275 microseconds for a short pulse and approximately 530 microseconds for a long pulse. Once an active channel is found, these pulses stop. The HANDSHAKE 2 line always remains high during conventional and trunking receive (no scan).

For trunking transmit, the CORE tells the CON, via the DATA line, that the user has pressed the PTT switch. The CON tells the CORE to transmit on the control channel by pulling the HANDSHAKE 1 line low; the red LED briefly blinks once to indicate that the inbound signalling word (ISW) transmission has been sent on the control channel. This request for a voice channel is sent to the trunking central controller. The radio next goes into receive (HANDSHAKE 1 is high) awaiting a response.

If the trunking controller responds by not granting the request, an alert tone is sent to the speaker (low-

| Pin No. | Function | Signal |
|---|---|---|
| A2 | D4/Data line | 5V p-p during normal operation |
| A3 | D6/Data line | 5V p-p during normal operation |
| * A4 | XIRQ | 5V |
| A5 | CSGEN/Control | 5V p-p during normal operation |
| A6 | CS102/Control | 5V p-p when active;<br>5V = otherwise |
| A7 | PG1/Clock Shifter | 5V = clock shift not enabled;<br>0V = clock shift enabled |
| B1 | D0/Data line | This is the least-significant bit of the CON data bus; 5V p-p during normal operation |
| B2 | D2/Data line | 5V p-p during normal operation |
| B3 | D5/Data line | 5V p-p during normal operation |
| * B4 | Reset | 0V = reset mode;<br>5V = otherwise |
| * B5 | IRQ | 5V |
| B6 | CS101/Control | 5V p-p during normal operation |
| B7 | PG2/Control | 5V p-p during normal operation |
| B8 | PG0/Row 3 | 5V = no key pressed in row 3 of keypad; 0V = key pressed in row 3 |
| * C1 | XTAL | 7.3728MHz signal |
| C2 | D1/Data line | 5V p-p during normal operation |
| C3 | D3/Data line | 5V p-p during normal operation |
| C4 | D7/Data line | This is the most-significant bit of the CON data bus; 5V p-p during normal operation |
| C5 | CSPROG/Control | 5V p-p during normal operation |
| C6 | PG3/Control | 0V = normal operation |
| C7 | RXD | Receive data port on serial data bus; 5V = bus inactive; toggles between 0V and 5V at 9600 baud when active |
| C8 | TXD | Transmit data port on serial data bus; 5V = bus inactive; toggles between 0V and 5V at 9600 baud when active |
| D2 | R/W | 5V p-p during normal operation |
| * D3 | E XTAL | 7.3728MHz signal (high-impedance) |
| D4 | MISO | Serial data bus to LCD driver IC; 5V = bus inactive; toggles between 0V and 5V when active |
| D5 | SCLK | Serial clock to LCD driver IC; 5V = inactive; toggles between 0V and 5V when active |
| D6 | SS | 5V |
| D7 | MOSI | 0V = inactive; toggles between 0V and 0.6V when MISO is active |
| * D8 | Vdd | 5V |
| E1 | VRH | 5V |
| * E2 | MODB | 5V |
| * E3 | MODA | 5V |
| E4 | PE7/Row 1 | 5V = key not pressed in row 1 of keypad; 0V = key pressed in row 1 |
| * E5 | Vss | Ground |
| * E6 | Vss | Ground |
| E7 | PA7/Control | 5V p-p during normal operation |
| * E8 | Vdd | 5V |

| Pin No. | Function | Signal |
|---|---|---|
| F1 | PE6/Row 2 | 5V = key not pressed in row 2 of keypad; 0V = key pressed in row 2 |
| F2 | PE3/Row 4 | 5V = key not pressed in row 4 of keypad;0V = key pressed in row 4 |
| F3 | A0/Address line | 5V p-p during normal operation |
| F4 | PA2/Busy | 5V = Serial bus inactive; 0V = otherwise |
| F5 | PA4/Handshake 1 | 0V for transmit; 5V for receive with 0V pulses in conventional scan until an active channel is found |
| F6 | PA6/Address line | 5V p-p during normal operation |
| F7 | PA3/Encode/ MDC Ref | Toggles between 0V and 5V when MDC/Signalling or high-speed trunking data is being generated; 0V = otherwise |
| F8 | PA5/LED | 5V = LED (LCD backlight) is on; 0V = LED (LCD backlight) is off |
| G1 | PE5/Column 1 | 5V = key not pressed in column 1 of keypad; 0V = key pressed in column 1 |
| G2 | PE1/Row 5 | 5V = key not pressed in row 5 of keypad; 0V = key pressed in row 5 |
| G3 | A1/Address line | 5V p-p during normal operation |
| G4 | A4/Address line | 5V p-p during normal operation |
| G5 | A8/Address line | 5V p-p during normal operation |
| G6 | A12/Address line | 5V p-p during normal operation |
| G7 | A15/Address line | 5V p-p during normal operation |
| G8 | PA1/Handshake 2 | 0V pulses during conventional scan until an active channel is found; 5V = otherwise |
| H1 | PE2/Column 2 | 5V = key not pressed in column 2 of keypad; 0V = key pressed in column 2 |
| H2 | PE0/Row 3 | 5V = key not pressed in row 3 of keypad; 0V = key pressed in row 3 |
| H3 | A2/Address line | 5V p-p during normal operation |
| H4 | A5/Address line | 5V p-p during normal operation |
| H5 | A7/Address line | 5V p-p during normal operation |
| H6 | A11/Address line | 5V p-p during normal operation |
| H7 | A14/Address line | 5V p-p during normal operation |
| H8 | PA0/Limiter | 5V p-p during receive mode; 0V during transmit mode |
| J2 | PE4/Column 3 | 5V = key not pressed in column 3 of keypad; 0V = key pressed in column 3 |
| J3 | A3/Address line | 5V p-p during normal operation |
| J4 | A6/Address line | 5V p-p during normal operation |
| J5 | A9/Address line | 5V p-p during normal operation |
| J6 | A10/Address line | 5V p-p during normal operation |
| J7 | A13/Address line | 5V p-p during normal operation |

frequency "bah-bah-bah"), telling the user to release the PTT switch and try again. If the request is granted, the CON tells the CORE to transmit on the open voice channel (HANDSHAKE 1 line is low), and the user hears a different alert tone (high-frequency "di-di-dit" chirps). The user then begins transmitting voice, and the radio LED remains on until the user releases the PTT switch. This entire sequence takes less than one second. The HANDSHAKE 2 line is not used.

Internally, the F1 version of the MC68HC11 contains one kilobyte of RAM, 512 bytes of EEPROM, and no ROM. This version includes expanded control line capabilities for addressing 64 kilobytes of physical memory at a given time. Extra control lines allow memory paging of the EEPROM and UVEPROM ICs for logically accessing larger amounts of memory.

The initialization of a SYSTEMS SABER radio occurs upon power-up or when the RESET line is pulsed low. The CON then receives checksums/status from its memory ICs and from the CORE. If no bad checksums or status are received, the CORE sends the CON its radio switch settings via the DATA line. The CON then sends the CORE the appropriate data (via the DATA line) that it requires, including the receive and transmit data.

The signals and levels to be expected at various pins of the CON microcomputer, U501, are as follows:

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

### j. LCD Driver IC (U502) (SYSTEMS SABER III Radios Only)

The liquid-crystal display (LCD) driver IC, U502, interfaces with the CON microcomputer via a 2-wire synchronous bus (pins D4 and D5). The CON sends LCD display data over the bus to the LCD driver. The data is inverted and delayed, using pin D7, and components Q503, R520, and R522, to facilitate communications from the CON. 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 CON. Only when the display requires changing does the CON again communicate with the driver.

The LCD driver has its own internal clock, controlled by resistor R525, 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 R523 and R524 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 one or more messages briefly displayed (such as "***LCD_TEST***," "***GENERIC***," and/or other messages).

**k. RAM IC (U503)**

The eight kilobytes of random-access memory (RAM) contained in RAM IC U503 supplement the one kilobyte of RAM contained in the CON (U501), yielding a total of nine kilobytes of usable RAM.

**l. EEPROM IC (U504)**

The electrically-erasable, programmable read-only memory (EEPROM) IC, U504, contains eight kilobytes of EEPROM, of which only two kilobytes are actively addressed (paged) at a time. This allows for more efficient use of addressable memory space. The IC's write-enable line (pin 15) must be low to write data into the IC. A pre-programmed ultraviolet-erasable, programmable read-only memory (UVEPROM) IC, U505, must be present for this IC to be written into.

**m. UVEPROM IC (U505)**

The UVEPROM IC, U505, contains two 64-kilobyte pages of UVEPROM. Either page is selected via the CON's B7 pin (pin C1 on U505). To program this IC, it must be removed from the controller board and placed in a special fixture; a pin configuration different from that found on the controller board is required.

**n. SECURENET Module (U900)**
**(SECURENET- Equipped Radios Only)**

The SECURENET module, U900, uses pins 4, 5, 7, and 16 for keyloading. If the encryption key is lost or destroyed, the module will indicate the loss by sending a logic low level from pin 16 whenever the radio’s PTT

# 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 SYSTEMS SABER radio.

## 2. PREVENTIVE MAINTENANCE

The SYSTEMS SABER 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 fro

**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, control top, 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.

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**CAUTION**

The SYSTEMS SABER 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

## 4. SAFE HANDLING OF CMOS DEVICES

Complementary metal-oxide semiconductor (CMOS) devices are used in the SYSTEMS SABER 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 soldering, use a grounded soldering iron.

**CAUTION**

Leadless component technology requires the use of specialized equipment and procedures for repair and servicing of the SYSTEMS SABER 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 6b, **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

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

### 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 SYSTEMS SABER 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.

### 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 (Motorola part number) 0180382A38 Temperature-Controlled Solder Station with a 600 or 700 degree tip, and use small diameter solder such as (Motorola part number) 1010041A60. 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 SYSTEMS SABER 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 5 for an illustration of the troubleshooting, programming, and test equipment setup.

### a. Recommended Test Equipment

The list of equipment contained in Table 2 includes

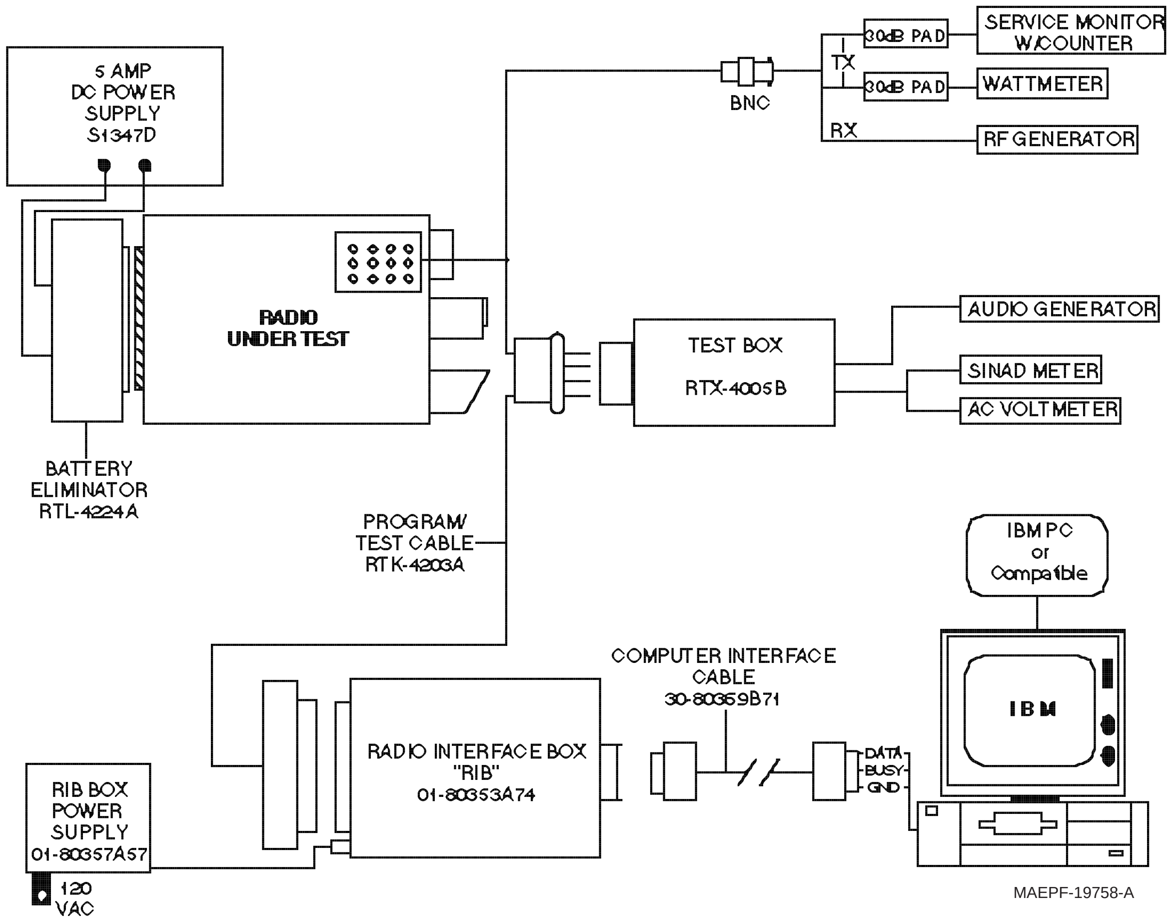


*Figure 5. Troubleshooting, Programming, and Test Equipment Setup Detail*

**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 |
| *R1150B | Audio Oscillator | 67 to 260Hz tones | Used with service monitor for injection of PL tones |
| R1056A | Dual-Trace Oscilloscope | 20MHz bandwidth 5mV/cm - 20V/cm | Waveform measurements |
| *S1350C<br>*ST1213B (VHF)<br>*ST1223B (UHF)<br>R1066 | Watt Meter<br>Plug-in Element<br><br>RF Dummy Load | 50-ohm, ±5% accuracy<br>10 Watts, maximum<br><br>0-1000MHz, 25W | Transmitter power output measurements |
| S1339A | RF Millivolt Meter | 100µV to 3V rf<br>10kHz to 1.2GHz | RF level measurements |
| *R1013A | SINAD Meter | | Receiver sensitivity measurements |
| S1347D or<br>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 (*)

all of the standard test equipment required for servicing two-way portable radios, as well as several unique items designed specifically for servicing the SYSTEMS SABER 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.

**b. Service Aids and Recommended Tools**

Refer to the appropriate 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 SYSTEMS SABER 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.

*(1) MAV-PACK 3 (VID-952)*

The Motorola Video Visual Package (MAV-PACK) is a VHS videotape in standard half-inch format. The following MAV-PACK, as well as others, is available from:

Motorola C&E, Inc.
National Service Training Center
1300 N. Plum Grove Road
Schaumburg, Illinois 60195.

This MAV-PACK is a video tape training program on leadless component repair techniques and is strongly recommended for technicians who intend to service this and other Motorola radios using leadless components. This VHS format video cassette and supplemental literature describe the removal and replacement of leadless components using the following specialized equipment:

- RRX-4033 Laurier Hot Gas Bonder
- RPX-4234A Regulator and Hardware Kit
- 0180386A62 Heated Tweezers
- RSX-1002 Desoldering Station
- RSX-1008 Weller Soldering Station
- F.A.S.T. # 9 - Using the RSX-4057A Repair Station

*(2) F.A.S.T. Video Tape # 52*

National Service Training's Field Assist Service Training (F.A.S.T.) Video Tape # 52 introduces the

# TROUBLESHOOTING

## 1. INTRODUCTION

### a. General Troubleshooting

Servicing the SYSTEMS SABER radio requires the localization of the malfunctioning circuit before the defective component(s) 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, and the theory of operation and troubleshooting procedures in this manual, provide valuable information for troubleshooting purposes. The service manual includes radio specifications, component location diagrams, disassembly and reassembly procedures, and schematic diagrams. The schematics provide the detailed circuitry, voltages, and waveforms 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.

### b. Special Test Modes

When the SYSTEMS SABER radio is operating in the trunking environment (within the range of the trunking system), it is assigned a specific identity in addition to the identity of the system to which it belongs. The system's central controller accepts requests and gives grants for voice channel assignment. Thus, if a radio is removed from the trunking environment (no longer in the range of the system), it will be unable to receive commands from the system. Because of this situation, the controller board's EEPROM (U504) provides software to support two different testing modes: airtest and factory test, enabling a technician to test a radio in two different ways.

*(1) Airtest Mode*

The "airtest" mode enables the radio to be tested without being connected to a computer. To put the radio into the airtest mode, the following must happen simultaneously: the RADIO OPTION SELECT line must be grounded, the radio's monitor button must be pressed, and the radio must be turned off and then back on again.

The airtest mode can be used for tuning and troubleshooting "trunking only" radios without having access to a trunking system central controller. The airtest mode puts the radio into the conventional or non-trunked operating mode. The airtest allows the testing of various signalling paths, including PL, DPL, connect tone, ISW, and (if equipped with a SECURENET module) secure voice.

*(2) Factory Test Mode*

In the "factory test" mode, the radio is tuned and tested using the radio service software alignment menu and the troubleshooting, programming, and test equipment setup shown in Figure 4.

## 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 adequately charged; ideally, verify the operation of the radio on a battery eliminator. Follow the troubleshooting procedures in this manual, and refer to 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 the recommended equipment 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 may result in erratic or erroneous 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

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 rf power measured is less than the rated output power, refer to the applicable transmitter troubleshooting procedure.

**d. Check Overall Receiver Operation**
*(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. 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 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

**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.

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

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.

**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.

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.

## 4. GENERAL 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.

**NOTE**

- The radio *should not* be operated with the controller board's 10-pin interconnect flex disconnected from the main radio board.
- To determine whether the problem is with the main radio board or the controller board, a known good controller board (test controller board) may be substituted to help isolate the problem area. When the side of the radio on which the trouble exists has been determined, refer to the appropriate troubleshooting procedures in this manual
- During the radio's power-up sequence, it is typical to measure an initial current drain of 200 to 300mA before the radio settles down to its normal standby current of ≈90mA.

**a. Initial Checks**

(1) Power-up the radio, then check standby current: current should be either 90mA (programmed) or 70mA (unprogrammed). If unprogrammed, complete step a (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.

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.

(b) 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 (SECURENET Equipped radios only)**

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

| U900 Kit No. | Keyloader Kit No. | Description |
|---|---|---|
| NTN4711/NTN5832 | T3010 | DVP |
| NTN4713/NTN5834 | T3014 | DVP-XL |
| NTN4715/NTN5836 | T3012 | DVI-XL |

(2) Replace the SECURENET 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 (>105 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, pin2, to ground is 4kΩ.

**e. No Transmit Capability**

(1) (a) Check that the voltage at pin 60 of microcomputer U400 is ≈1Vdc 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 "receive-only" 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 e (3) (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 ≥ 700mA.

1. If the current drain is ≈400mA, the rf PA is not being enabled; go to step e (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 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 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 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 (VHF) or pin 25 (UHF) of U201 for 2.5Vdc.

**f. No Transmit Power**

(1) Perform step e (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.

- (*VHF only*) check L210 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.

- 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 (VHF) or pin 10 (UHF) of rf PA U202. Make sure that the probe is grounded (use the ground side of C204 on VHF radios; use a screw head for ground on UHF radios). *Do not* touch pin 13 (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. 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 f (3) (c) 1 was low, dekey the radio. Short pins 3 and 6 of

U202 together. This will force the rf PA into maximum gain. Read the power level again as in step f (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 (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 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 f (4) (a); Vr = the voltage that should have been measured in step f (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 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 (VHF) or pins 16, 17, and 20 (UHF).

**g. No Receive / Poor Receive**

(1) Inject 53.55MHz (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). If the tone (signal) is present, continue with this procedure; if no tone is heard, go to step g (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 VHF; U2, pin 4 for UHF), using the guide pin of the front end module (VHF) or the front-end screw head (UHF) for ground. The reading should indicate 53.55MHz + carrier frequency (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 (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. Turn the radio off, then back on again, then do the following:

(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.

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

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

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

(c) *(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.

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

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

(f) Check the dc voltages of U203.

(g) 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 (VHF), or 72.9MHz or 73.8MHz (UHF).

(4) Using a 50Ω probe, inject 53.55MHz (VHF) or 73.35MHz (UHF) at inductor L1; 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.

(5) Using a 50Ω probe, inject 450kHz at filter pin 1 of FL3 (VHF) or pin 1 of U2 (UHF). Use pin 2 of FL3 (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 (VHF) or pin 1 of U2 (UHF). Use pin 2 of FL3 (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 220mA at rated audio.

(c) Inject 450kHz (-60dBm) at pin 1 of FL3 (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 (SECURENET-Equipped radios only)**

(1) Replace U900 with a SECURENET bypass module (NTN4720A). 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 (6.0mV) 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 (0.5 to 1.0 Vac) 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 at 1 Vac 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 signal (75 mV) 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 (SECURENET-Equipped radios only)**

(1) Replace U900 with a SECURENET bypass module (NTN4720A). 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 1 kHz 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.

## 5. TRUNKING TROUBLESHOOTING PROCEDURES

Trunking is the automatic, systematic sharing of some 5 to 20 communications channels by a number of users. This allows the members of a trunked system to automatically utilize a few transmit and receive paths. The primary advantage of trunking over conventional communication is a reduction in user access time and overall response time for channel availability.

In a trunked system, user radios are grouped by talkgroup rather than by allocated frequency. In other words, the radio is not recognized by its frequency, but rather by its talkgroup ID (TG ID) number and its system ID number. Both ID numbers are required for system access.

Most necessary for the proper operation of a trunking system are the system central controller (SCC), the base repeater stations, and the rf control station. The SCC provides all intelligence for channel switching, channel availability, timing, and controlling the rf output of the control channel. Several base repeaters are used as a group; each repeater is used for both transmitting and receiving. This arrangement is commonly called "paired channels." An rf control station is basically a repeater that is dedicated to generating a continuous background word (the outbound signalling word or OSW) which is used as a reference signal for timing.

In order for normal operating conditions to exist, the radio must be within the range of the SCC in the standby mode, properly lock onto the OSW, and have a minimum of one voice channel (VC) free.

**NOTE**

Radios in SMARTNET II™ trunking systems have four control channels stored in their EEPROM (U504); when these radios are powered-on they will search through the four highest frequencies assigned to the trunking system until the designated control channel is found.

If, for some reason, a programming error exists and the radio does not have the correct control channel stored in its memory, then there will be no communication with the SCC. This also applies to system ID and user talkgroup ID codes.

It is possible for a radio to be successfully tested in both the "airtest" and "factory test" modes and still not be able to access the SCC. There are two methods by which the actual trunking personality can be tested: either (a) the radio can be tested live on-the-air in a trunking system, or (b) a Motorola R2001 Trunking Analyzer that is equipped with option R2014D-0900 can be used. The trunking analyzer acts as a complete trunking system, providing SCC, VCs and control channels (CCs). The second method is probably the more feasible overall because in many instances the radio to be tested will not be within range of any trunking system.

**a. Low-Speed Connect Tone Problems**

(1) Put the radio into the airtest mode.

(2) Press the side button until the radio's display shows "***MODE 4***."

(3) Key the radio and monitor the signal.

(4) 105.88 Hz at 1 kHz deviation should be observed. If this is correct, check for correct codeplug programming of the trunking connect tones.

**b. High-Speed Data Problems**

(1) Put the radio into the airtest mode.

(2) Press the side button until the radio's display shows "***MODE 5***."

(3) Key the radio and monitor the transmit output on a communications monitor. A 900Hz, slightly rounded square wave of 3kHz deviation should be observed.

(4) If the correct signal is not present, check the ENCODE line (pin 8) of U700.

(5) (a) If a signal *is not* present at U700, pin 8, the trouble is most likely related to the controller board. Replace the existing controller board with the test controller board and check U700, pin 8 again.

1. If a signal is now present, reinstall the original board and probe the suspected area of the controller board for shorts and opens.

2. If a signal still is not present, reinstall the original board and check C501 on the main radio board for a possible short.

(b) If a signal *is* present at U700, pin 8, check the MODULATION OUT line (pin 14) of U700.

1. If modulation is present, check pin 14 of U101. Check both sides of C37 (possible open or short).

2. If a signal is present, continue to troubleshoot the signal path logically, out to the synthesizer.

**c. Outbound Signalling Word (OSW) Problems**

If a radio cannot receive the OSW of the designated control channel, it will not be able to generate an inbound signalling word (ISW). This could be due to incorrect codeplug programming or poor receiver sensitivity. If the programming is correct, a receiver performance test should be done.

If the problem is system related (SCC down), the radio will be automatically assigned to a conventional repeater. This mode is known as the "failsoft" (using the trunking repeater for conventional communications) mode. If the radio does not enter the failsoft mode, check the trunking personality for the correct

# NOTES