FUNCTION OF RF SEMICONDUCTORS AND OTHER ACTIVE DEVICES

SCHEMATIC KEY	PART NUMBER	CIRCUIT APPLICATION	OPERATING FREQUENCY	INDUSTRY EQUIVALENT
CR4301	4805649Q13	RX VCO FREQ CONTROL	358.15-425.15 MHz	1SV228
CR4302	4862824C01	RX VCO FREQ CONTROL	358.15-425.15 MHz	1SV229
CR4303	4862824C01	RX VCO FREQ CONTROL	358.15-425.15 MHz	1SV229
CR4311	4802245J22	TX VCO FREQ FREQ CONTROL	403-470 MHz	1T363
CR4321	4862824C01	TX VCO MODULATOR	403-470 MHz	1SV229
D0101	4880236E05	DATA SWITCH	230 kHz	MMBD301
D0151	4813833C02	DC SWITCH	DC	MMBD6100
D0179	4813833C02	CLAMP	DC	MMBD6100
D0301	4802245J47	DC SWITCH	DC	RB471E
D0621	4813833C02	DC SWITCH	DC	MMBD6100
D0651	4813833C02	DC SWITCH	DC	MMBD6100
D0660	4813833C02	DC SWITCH	DC	MMBD6100
D0661	4813833C02	DC SWITCH	DC	MMBD6100
D3101	4880154K03	CLIPPER	44.85 MHz	MMBD353
D4001	4862824C01	FRONT END FILTER TUNING	403-470 MHz	1SV229
D4002	4862824C01	FRONT END FILTER TUNING	403-470 MHz	1SV229
D4003	4880154K03	CLIPPER	403-470 MHz	MMBD353
D4004	4862824C01	FRONT END FILTER TUNING	403-470 MHz	1SV229
D4005	4862824C01	FRONT END FILTER TUNING	403-470 MHz	1SV229
D4051	4886143B01	DOUBLE BALANCED MIXER	44.85-470 MHz	SMS3927-99
D4201	4802233J09	VOLTAGE MULTIPLIER	1.05 MHz	IMN10
D4261	4802245J22	REF OSC FREQ CONTROL	16.8 MHz	1T363
D4451	4880236E05	FORWARD POWER DETECTOR	403-470 MHz	MMBD301
D4452	4880236E05	REVERSE POWER DETECTOR	403-470 MHz	MMBD301
D4453	4880236E05	TEMPERATURE COMPENSATION	403-470 MHz	MMBD301
D4471	4802482J02	RF PIN SWITCH	403-470 MHz	MA4P959
D4472	4802482J02	RF PIN SWITCH	403-470 MHz	MA4P959
Q0110	4880048M01	DC SWITCH	DC	DTC144EKA
Q0151	4880048M01	DC SWITCH	DC	DTC144EKA
Q0173	4880052M01	DC SWITCH	DC	RXT-A28
Q0177	4880048M01	DC SWITCH	DC	DTC144EKA
Q0181	4880048M01	DC SWITCH	DC	DTC144EKA
Q0183	4880048M01	DC SWITCH	DC	DTC144EKA

FUNCTION OF RF SEMICONDUCTORS AND OTHER ACTIVE DEVICES

SCHEMATIC KEY	PART NUMBER	CIRCUIT APPLICATION	OPERATING FREQUENCY	INDUSTRY EQUIVALENT
Q0185	4880048M01	DC SWITCH	DC	DTC144EKA
Q0271	4813824A10	DC SWITCH	DC	MMBT3904
Q0331	4805921T02	DATA SWITC	1 MHz	FMC2A
Q0641	4880048M01	DC SWITCH	DC	DTC144EKA
Q0661	4805921T02	DC SWITCH	DC	FMC2A
Q0662	4813824A10	DC SWITCH	DC	MMBT3904
Q0663	4880048M01	DC SWITCH	DC	DTC144EKA
Q3101	4813827A07	I-F AMPLIFIER	44.85 MHz	MMBR941
Q3102	4813827A07	I-F AMPLIFIER	44.85 MHz	MMBR941
Q3151	4880048M01	DC SWITCH	DC	DTC144EKA
Q3152	4880048M01	DC SWITCH	DC	DTC144EKA
Q3155	4880048M01	AUDIO SWITCH	AUDIO	DTC144EKA
Q4003	4813827A07	RF AMPLIFIER	403-470 MHz	MMBR941
Q4301	4805218N63	RX VCO	358.15-425.15 MHz	BFQ67W
Q4332	4813827A07	RX VCO BUFFER	358.15-425.15 MHz	MMBR941
Q4333	4802245J50	DC SWITCH	DC	UMC5N
Q4421	5105385Y70	TX PRE-DRIVER STAGE	403-470 MHz	85Y70
Q4431	4805537W01	TX DRIVER STAGE	403-470 MHz	MRF5015
Q4441	4880225C30	TX FINAL POWER AMPLIFIER	403-470 MHz	MRF650
Q4471	4880048M01	DC SWITCH	DC	DTC144EKA
Q4472	4805128M27	CONSTANT CURRENT SINK	DC	BSR33
Q4473	4813824A10	POWER CONTROL DC AMP	DC	MMBT3904
U0101	5102226J56	MICROPROCESSOR	38.4 kHz-7.4 MHz	MC68HC11FL0
U0111	5102463J47	EEPROM	1 MHz	X25320_2.7V
U0121	5186137B01	FLASH ROM	1.85 MHz	AT49F040
U0122	5185963A21	SRAM	1.85 MHz	63A21
U0125	5105625U34	UART	1.85 MHz	CDP65C51A
U0141	5113805A30	DECODER/DEMUX	5 kHz	MC74HC138A
U0211	5183222M49	AUDIO AMPLIFIER	AUDIO	MC3403
U0221	5185963A53	AUDIO FILTER	16.8 MHz	63A53
U0251	5113806A20	AUDIO GATE	AUDIO	MC14053B
U0271	5109699X01	AUDIO POWER AMPLIFIER	AUDIO	TDA1519C
U0301	5102463J53	VOICE STORAGE	1 MHz	ISD33000
U0341	5180932W01	AUDIO AMPLIFIER	AUDIO	LM2904
U0342	5105750U28	AUDIO GATE	AUDIO	TC4S66F
U0351	5102463J40	VOLTAGE REGULATOR	DC	LP2951-ACMM-3.3
U0611	5183308X01	VOLTAGE REGULATOR	DC	LM2941
U0641	5183308X01	VOLTAGE REGULATOR	DC	LM2941
U0651	5113816A07	VOLTAGE REGULATOR	DC	MC78M05
U0652	5113815A02	RESET MONITOR	DC	MC33064

FUNCTION OF RF SEMICONDUCTORS AND OTHER ACTIVE DEVICES

SCHEMATIC KEY	PART NUMBER	CIRCUIT APPLICATION	OPERATING FREQUENCY	INDUSTRY EQUIVALENT
U3101	5186144B01	RECEIVER SYSTEM	455 kHz-44.85 MHz	SA616
U3111	5113805A86	RF SWITCH	455 kHz	MC74HC4066
U3115	5113805A86	RF SWITCH	455 kHz	MC74HC4066
U4201	5185963A27	FREQ. SYNTHESIZER	1.05-470 MHz	63A27
U4211	5105469E65	VOLTAGE REGULATOR	DC	LP2951C
U4301	5105750U54	TX VCO/RX BUFFER/ TX BUFFER	358.15-470 MHz	50U54
U4401	5105109Z67	GAIN CONTROLLED AMPLIFIER	403-470 MHz	09Z67
U4501	5185765B01	TX POWER CONTROL	1 MHz	H99S-4
U4502	5185963A15	TEMPERATURE SENSOR	DC	LM50
VR0151	4813830A15	DC LEVEL-SENSING SWITCH	DC	MMBZ5232B
VR0501	4805656W09	ESD PROTECTION	DC	MMQA20VT1
VR0503	4805656W09	ESD PROTECTION	DC	MMQA20VT1
VR0504	4813830A40	ESD PROTECTION	DC	MMBZ5257B
VR0505	4805656W09	ESD PROTECTION	DC	MMQA20VT1
VR0509	4813830A40	ESD PROTECTION	DC	MMBZ5257B
VR0510	4813830A40	ESD PROTECTION	DC	MMBZ5257B
VR0521	4813830A15	ESD PROTECTION	DC	MMBZ5232B
VR0537	4813830A15	ESD PROTECTION	DC	MMBZ5232B
VR0541	4813830A27	ESD PROTECTION	DC	MMBZ5244B
VR0601	4813832C77	TRANSIENT SUPPRESSOR	DC	MR2835S
VR0621	4813830A14	VOLTAGE REGULATOR	DC	MMBZ5231B
VR4471	4813830A15	CURRENT SINK REFERENCE	DC	MMBZ5232B

COMMENTS: The Motorola designators are special code numbers for active devices used in Motorola radios. These devices are either identical or derived from the device family listed under Industry Equivalent, by the manufacturer or are proprietary to Motorola. Service people do not have access to any cross-references or given any information on proprietary devices and are prevented from making unauthorized substitution.

TUNING PROCEDURES

Tune Up Information

All transmitter adjustments are performed by electronic means. The transmitter contains no electromechanical components for the purpose of transmitter tuning or adjustment.

The tuning elements that are used for transmitter adjustment are:

Location	Type of Element	Function
U0101	Microcomputer	Supplies data to Audio Filter IC, Fractional-N Synthesizer, Temperature Compensated Crystal Oscillator, and Power Control IC for Transmitter Modulation, Frequency and Power Adjustment
U4201	Programmable Attenuator	VCO Modulation Sensitivity
U4201	Programmable Attenuator	Reference Modulation Sensitivity
U0221	Programmable Attenuator	Deviation Adjustment
U4201	Temperature Compensated Crystal Oscillator	Transmitter Frequency Adjustment
U4501	Digital to Analog Converter	Transmitter Power Adjustment

The value of a particular tuning element is determined by data sent to that tuning element by microcomputer U0101. This data is generated by the microcomputer based on tuning information that is stored in the microcomputer's EEPROM (Electrically Erasable Programmable Read Only Memory).

Tuning information is stored in the EEPROM during factory adjustment or by qualified field service facilities, using the attached procedure and recommended test equipment.

TUNING PROCEDURE

This procedure was written in the sequence the radio is to be tuned. The following points should be noted:

1. Table 1 shows the frequencies to be used for tuning receive, transmit and synthesizer circuits. To reduce tuning times, not all the frequencies are used for tuning each parameter. Table 19 shows which frequencies to use.
2. Radio controller refers to the microprocessor in the radio.
3. Tester/test controller refers to external test system (hardware as well as software).
4. Values in tables may change to improve yield.
5. Radios may not support all combinations of signalling modulation. Deviation should only be adjusted on the modulation types actually available in the radio.
6. The mobile radio tuning and testing must be performed at a supply voltage of 13.6V unless otherwise specified.

1. REFERENCE OSCILLATOR WARPING

Adjustment of the reference oscillator is critical for proper radio operation. Improper adjustment will not only result in poor operation, but also a misaligned radio that will interfere with other users operating on adjacent channels. For this reason, the reference oscillator should be checked every time the radio is serviced. The frequency counter used for this procedure must have a stability of 0.1 ppm (or better).

General Tuning Procedure

1) **Set the power supply to 13.6V and power up the radio.**
Set the radio to the Carrier Squelch Environment**.**
3) **Disable modulation** (Environment Override) **and remove any audio input signals to minimize frequency inaccuracy**
4) **Set the radio to the transmit frequency indicated in table 19.**
5) **Key up the radio.**
6) **Measure the transmit frequency and compare it with the specification limits shown in table 10.**
7) **If the measured frequency is within the specification limits.**
(A) Dekey the radio.
(B) **Reference Oscillator Tuning** done.
8) **If the measured frequency is outside the specification limits.**
(A) Read the codeplug value for the **Oscillator Warp**. While the transmit frequency is outside the specification limits.
(i) Update the IC value of the Oscillator Warp **without codeplug update.**
(ii) Re-measure the transmit frequency and compare it with the specification limits.
(iii) Repeat steps (i) (ii) until the transmit frequency is within the specification limits.
(B) Write the value of the tuned **Oscillator Warp** to the codeplug.
(C) Dekey the radio.
(D) Reference Oscillator Tuning done.

2. PA BIAS TUNING

This procedure must be done before the transmitter is keyed the first time. To avoid FET device damage care must be taken not to exceed the drain current and dissipation limits of the devices by setting a too high bias voltage during tuning. The use of a power supply with an appropriate current limitation setting is recommended. The tune procedure should be done as fast as possible to keep the device temperature low and to achieve the required quiescent current accuracy.

The following tuning procedure does not simply determine the settings for the PA Bias Voltage DACs, it also provides a gain balancing between the device, used to control the RF output power, and the PA FET devices. If the hardware has the control voltage DAC and the PA bias voltage DAC connected via a resistive network, the bias voltages will be modified along with the control voltage for any control voltage and the bias voltages connected via diodes will require to preset the control selected power level. This will maintain gain and power dissipation balanced over a wide RF output power range. For these radios the value **Control Voltage Limit** in table 8 is set to 0. Radios which have the voltage DAC. For these radios the value **Control**

Voltage Limit in table 8 is set to a value higher than 0. Tuning of the **PA Voltage Limit** is then skipped in the procedure below.
List of variables used in the tuning procedure:

- **VL0_B0_CURRENT**: DC current with **Control Voltage** and all **PA Bias Voltages** set to zero.
- **VL_B0_CURRENT:** DC current with **Control Voltage** set for a specified PA current and all **PA Bias Voltages** set to zero.
- **PA Voltage Bias [n]:** DC current with **Control Voltage** set for a specified PA current, **PA Voltage Bias [n]** set for a specified quiescent current of **FET[n]** and all remaining **PA Bias Voltages** set to zero.
  General Tuning Procedure

1) Set the power supply to 13.6V and power up the radio.

2) Set the radio to PA Bias Voltage Test Environment**. The IC values for** PA Voltage Limit **and** PA Voltage Bias 1...3 **are set to zero and for** Transmit Power **to maximum.**

3) If the value of Control Voltage Limit **in table 8 for the radio model is greater than 0**

(A) Set the IC value of the **PA Voltage Limit** without codeplug update to the value of **Control Voltage Limit**.

(B) Measure the DC current the radio draws from the power supply. Note the measured current as **VL_B0_CURRENT**. This is the DC current with all PA Bias Voltages switched off and is used as reference for the following steps.

4) If the value of Control Voltage Limit **in table 8 for the radio model is 0**

(A) Measure the DC current the radio draws from the power supply. Note the measured current as **VL0_B0_CURRENT**. This is the DC current with all PA devices switched off and is used as reference for the following steps.

(B) If the measured current is outside the limits specified for **VL_B0_CURRENT** in table 8:

(i) While the measured DC current is outside the limits specified for VL_B0_CURRENT**:**

a) Modify the IC value of the PA Voltage Limit **without codeplug update.**

b) Re-measure the DC current the radio draws from the power supply. Note the measured current as VL_B0_CURRENT **and compare the value with the specified limit.**

c) Repeat steps (i)(ii) until the measured DC current VL_B0_CURRENT **is within the specified limits.**

NOTE: If the current did not increase although the IC value of the PA Voltage Limit **has reached the maximum value $7F, the radio hardware has a failure. Tuning should then be terminated without updating the codeplug.**

(C) The quiescent current of the device, which controls the output power, is now set to a defined value. The current **VL_B0_CURRENT** is used as reference for the following steps.

5) This procedure is to be performed for all supported PA Voltage Bias Softpots**. Radios can have up to 3 PA FET devices which require tuning. Tuning must be done in the sequence** Bias 1, 2, 3 (n=1, 2, 3)**. If less than 3 PA FET devices are used, the radio will respond with an unsupported opcode message when trying to read the softpot. This is the indication that no further bias softpots require tuning and the tuning procedure is done.**

A) Read the codeplug value for the **PA Voltage Bias [n]**.

B) If the radio does not support the requested **PA Voltage Bias [n]** Softpot and responds with an unsupported opcode message

(i) Set the radio to Carrier Squelch Test Environment **and the lowest power level.**

(ii) PA Bias Tuning **done.**

3. TRANSMITTER POWER TUNING

Overview: The softpots used for PA power setting do not contain the DAC values directly like they do in the portable radio. Instead they store the parameters (Mcp, Kcp) for approximation of the dependency between power and DAC setting. This procedure allows to set any power within the range of the PA without retuning. The PA output power (Pcp) levels are stored in the softpots for HIGH and LOW POWER. The following equations are used to calculate the DAC value for the desired power.

$$DAC\ PWR\ SET = 100 * \frac{Pcp - Kcp}{Mcp} \quad \textbf{Equ. 1}$$

$$Pcp = 25 * \sqrt{desired\ power} \quad \textbf{Equ. 2}$$

The power is not stored directly in the softpots to avoid square root calculation by the radio software.

General Tuning Procedure

The **PA Bias** must already be tuned for this procedure to be valid.

(1) Set the power supply to 13.6V and power up the radio.
(2) Read the tuning parameters from the radio and determine the values for DAC1 **and** DAC2**.**
(3) Set the radio to the Carrier Squelch Environment **and** highest Transmit Power Level**.**
(4) Disable modulation (Environment Override) **and remove any audio input signals to minimize frequency inaccuracy.**
(5) This procedure is to be performed for all Power Tuning Channels **indicated in table 19.**

A) Set the radio to the appropriate transmit frequency.
(B) Key up the radio.
(C)Set the IC value of the **PA Control Voltage Limit** to maximum ($3F) without codeplug update.
(D) Set the IC value of the **Transmit Power** to the value **DAC1**.
(E) Measure the transmit power and note the value as **P1**.
(F) Set the IC value of the **Transmit Power** to the value **DAC2**.
Measure the transmit power and note the value as **P2**.
(G) Dekey the radio.

Calculate Mcp and Kcp with the following equations:

$$M = \frac{\sqrt{P2} - \sqrt{P1}}{DAC2 - DAC1} \quad \textbf{Equ. 3}$$

$$Mcp = 2500 * M \quad \textbf{Equ. 4}$$

$$Kcp = 25 * \sqrt{P1} - M * DAC1 \quad \textbf{Equ. 5}$$

Write the values Kcp and Mcp the codeplug.

Repeat steps (A) to (J) for all the channels that require actual tuning. Values for the untuned channels are to be interpolated by the test controller and programmed into the codeplug.

(6) Transmit Power Tuning **done.**

4. MODULATION BALANCE TUNING

"Modulation Balance" balances the modulation sensitivity of the VCO and reference modulation (synthesizer low frequency port) lines. Balance algorithm is critical to the operation of signaling schemes that have very low frequency components (e.g. PL) and could result in distorted waveforms if improperly adjusted. The radio stores only one set of tuning data for all supported channel spacings (12.5, 20 and 25 kHz). Therefore, tuning should only be performed for 25 kHz channel spacing.

General Tuning Procedure

(1) Set the power supply to 13.6V and power up the radio.

(2) Set the radio to the External Signal Modulation Balance Environment**, to** 25kHz Channel Spacing **and to the lowest transmit power level to reduce current drain during tuning.**

(3) This procedure is to be performed for all Modulation Balance Attenuator Tuning Channels **indicated in table 19.**

Set the radio to the appropriate Modulation Balance Attenuator Tuning Channel.

(M) Remove any audio signals applied to any audio inputs to avoid a transmit frequency offset.

(N) Key up the radio.

(O) Update the IC value of the **VCO Attenuator** to its maximum setting ($255) without codeplug update.

(P) Apply an **80Hz tone @ 100mV RMS** to the **Auxiliary Transmit Audio Path.**

(Q) Measure the transmit deviation, note the value as **D1**.

(R) Apply a **3kHz tone @ 100mV RMS** to the **Auxiliary Transmit Audio Path.**

(S) Measure the transmit deviation, note the value as **D2**.

(T) Find the ratio of the measured transmit deviation values in dBs using equation **20*log(D1/D2)**.

(U) If the ratio of the measured transmit deviations is within **0.15 dB**

Dekey the radio.

Modulation Balance Tuning **for the set** Tuning Channel **done. Continue with step (A) for the next** Modulation Balance Attenuator Tuning Channel

(V) If the ratio of the measured transmit deviations is **NOT** within **0.15 dB**

(i) Read the codeplug value for the Modulation Balance Attenuator**.**

(ii) While the ratio of the measured transmit deviations is outside the Disable modulation (Environment Override) **to minimize frequency offset.**

Update the IC value of the Modulation Balance Attenuator **without codeplug update. Enable modulation** (Environment Override)**.**

Repeat steps (E) to (I).

Repeat steps (a) to (d) until the ratio of the measured transmit deviations is inside the specification limits

NOTE 1: Modulation must be removed from the Fractional–N Synthesizer while it is being programmed.

Dekey the radio.

Write the value of the tuned Modulation Balance Attenuator **to the codeplug.**

Modulation Balance Tuning **done.**

5. MODULATION LIMIT TUNING

Modulation limit tuning sets the maximum deviation of the carrier. The radio stores only one set (7 values across the frequency band) of tuning data for 25kHz channel spacing. Therefore, tuning across the frequency band must only be performed for 25 kHz channel spacing. For 12.5 and 20kHz channel spacings an offset value in the codeplug is used to reduce the deviation. The offset value should be tuned at one frequency only.

General Tuning Procedure

The **Modulation Balance Tuning** must already be done for this procedure to be valid.

(1) Set the power supply to 13.6V and power up the radio.

Set the radio to the Carrier Squelch Environment**, to** 25kHz Channel Spacing **and to the lowest transmit power level to reduce current drain during tuning.**

Enable the microphone path (Environment Override)**.**

This procedure is to be performed for all Modulation Limit Tuning Channels **indicated in table 19.**

Set the radio to the appropriate **Modulation Limit Tuning Channel**.

Remove any audio signals applied to any audio inputs to avoid a transmit frequency offset. Key up the radio.

Apply a **1 kHz tone @ 500mV RMS** to the **External Microphone Audio Path.**

Measure the transmit deviation and compare it with the specification limits in table 18a.

If the measured transmit deviation is within the specification limits Dekey the radio.

Modulation Limit Tuning **for the set** Tuning Channel **done. Continue with step (A) for the next** Modulation Limit Tuning Channel

If the measured transmit deviation is outside the specification limits

Read the codeplug value for the VCO Attenuator**.**

While the measured transmit deviation is outside the specification limits.

Update the IC value of the VCO Attenuator **without codeplug update.**

Re-measure the transmit deviation and compare it with the specification limits.

Repeat steps (a) (b) until the measured transmit deviation is inside the specification limits Dekey the radio.

Write the value of the tuned VCO Attenuator **to the codeplug.**

VCO Attenuator Tuning for the set Tuning Channel **done. Continue with step (A) for the next** Modulation Limit Tuning Channel

This procedure is to be performed for all remaining Modulation Limit Tuning Channel Spacings (12.5 and 20kHz) **and the** Modulation Limit Tuning Channel **indicated in table 19.**

Enable the microphone path **(Environment Override)** and set the appropriate **Modulation Limit Tuning Channel Spacing**.

Set the radio to the appropriate VCO Attenuator Tuning Channel for the set channel spacing.
Remove any audio signals applied to any audio inputs to avoid a transmit frequency offset.
Key up the radio.
Apply a **1 kHz tone @ 500mV RMS** to the **External Microphone Audio Path**.
Measure the transmit deviation and compare it with the specification limits in table 18a.
If the measured transmit deviation is within the specification limits Dekey the radio.
VCO Attenuator Tuning for the set **Channel Spacing** done. Continue with step (A) for the next **Modulation Limit Tuning Channel Spacing**

If the measured transmit deviation is outside the specification limits
Read the codeplug value for the VCO Attenuator**.**
While the measured transmit deviation is outside the specification limits.
Update the IC value of the VCO Attenuator **without codeplug update.**
Re-measure the transmit deviation and compare it with the specification limits.
Repeat steps (a) (b) until the measured transmit deviation is inside the specification limits Dekey the radio.
Write the value of the tuned VCO Attenuator **to the codeplug.**
Modulation Limit Tuning **for the set** Tuning Channel **done. Continue with step (A) for the next** Modulation Limit Tuning Channel.
Modulation Limit Tuning done.