

**FUNCTION OF RF SEMICONDUCTORS AND OTHER ACTIVE DEVICES**

<b>SCHEMATIC KEY</b>	<b>PART NUMBER</b>	<b>CIRCUIT APPLICATION</b>	<b>OPERATING FREQUENCY</b>	<b>INDUSTRY EQUIVALENT</b>
CR101	48-80973Z02	ANTENNA SWITCH	403-470 MHz	MA4PH261
CR102	48-02245J41	ANTENNA SWITCH	403-470 MHz	HSMP3820
CR105	51-85963A15	POWER AMPLIFIER	403-470 MHz	LM50
CR201	48-02233J09	SYNTHESIZER	16.8 MHz	IMN10
CR203	48-62824C03	TX VCO FREQ	430-470 MHz	1SV232
CR241	48-05649Q13	RX. VCO	355-425 MHz	1SV228
CR242 & CR243	48-62824C01	RX. VCO	355-425 MHz	1SV229
CR251	48-02245J22	TX. VCO	403-470 MHz	1SV229
CR303	48-80154K03	ESD PROTECTION	DC	MMBD353
CR304 & CR305	48-62824C01	RX. SYSTEM	403-470 MHz	1SV229
CR306	48-02245J42	MIXER	403-470 MHz	HPSM2827
CR308	48-02245J41	AGC	DC	HSMP3820
CR310	48-62824C01	2ND OSCILLATOR	90.2 MHz	1SV229
CR414, CR412 & CR413	48-02245J47	REVERSE CURRENT PROTECTION	DC	RB471E
CR440	48-13833C02	REVERSE CURRENT PROTECTION	DC	MMBD6100
CR501	48-80107R01	REVERSE CURRENT PROTECTION	DC	BYD17D
CR503	48-05729G49	LED	DC	BRPY1204W
D300	48-13833C02	REVERSE CURRENT PROTECTION	DC	MMBD6100
Q110	48-02245J55	POWER AMPLIFIER	403-470 MHz	PRF1507
Q111, Q210, Q260, Q261 & Q417, Q506	48-02245J50	DC SWITCH	DC	UMC5N
Q241	48-05218N63	VCO OSCILLATOR	403-470 MHz	BFQ67W
Q301	48-02245J44	RF AMPLIFIER	403-470 MHz	HP415
Q302	48-02245J44	IF AMPLIFIER	45.1 MHz	HP415
Q315, Q505 & Q316	48-80214G02	DC SWITCH	DC	MMBT3904
Q320	48-05218N63	2ND OSCILLATOR	90.2 MHz	BFQ67W
Q400 & Q416	48-09579E18	DC SWITCH	DC	TP0101T
Q403	48-80214G02	DC SWITCH	DC	MMBT3904
Q405 & Q410	48-02245J54	DC SWITCH	DC	UMG5
Q502	58-80159R01	DC SWITCH	DC	LM50
U101	51-055109Z67	TRANSMITTER SYSTEM	403-470 MHz	CUSTOM
U102	51-85765B01	TRANSMITTER SYSTEM	403-470 MHz	CUSTOM
U201	51-85963A27	FGU	16.8 MHz	CUSTOM
U211	51-02463J61	FGU	DC	TC7SET04FU
U241	51-05750U54	FGU	403-470 MHz	CUSTOM
U247	51-05739X05	5V VOLTAGE REGULATOR	DC	ADP3300
U248	51-02463J58	3.3V VOLTAGE REGULATOR	DC	LP2980
U301	51-09632D83	RX. SYSTEM	DC	CUSTOM
U400	51-02463J40	3.3V VOLTAGE REGULATOR	DC	AT49BV020
U404	51-85963A53	AUDIO SYSTEM	AUDIO	CUSTOM
U406	51-02463J42	CONTROLLER SYSTEM	1.83 MHz	TK113
U409	51-02463J59	CONTROLLER SYSTEM	1.83 MHz	MC74HC4066
U410	51-02463J57	3.3V VOLTAGE REGULATOR	DC	TDA8547
U420	51-02463J44	AUDIO AMPLIFIER	AUDIO	TC7SET04FU
VR440-VR444, VR431 & VR506	48-02245J51	ESD PROTECTION DIODE	DC	BZX284_6V8
VR439, VR432, VR433	48-80140L15	ESD PROTECTION DIODE	DC	MMBZ5240B
VR501	48-13830A18	ESD PROTECTION DIODE	DC	MMBZ5235B
Q420	48-05128M67	AMPLIFIER	DC	MMBT3906
Q602 & Q603	48-80214G02	DC SWITCH	DC	MMBT3904
U602	51-02463J49	KEYPAD BOARD	DC	LMC7211

## TUNING PROCEDURES

### 1. Tuning frequencies

These frequencies should be used for transmitter tuning. To avoid interference, the factory should use a frequency offset of 100 kHz from these frequencies for an receiver tuning or testing.

Test/Tune Freq			VHF	UHF Band1	
F1			136.025	403.025	
F2			142.025	413.025	
F3			148.025	425.025	
F4			154.825	437.025	
F5			161.025	449.025	
F6			167.025	460.025	
F7			173.825	469.975	

**Table 1.0**

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

- 1) Radio controller refers to the microprocessor in the radio.
- 2) Tester/test controller refers to external test system (hardware as well as software).
- 3) Values in tables may change to improve yield.
- 4) Disable LLE for all tuning and testing.

### 2. PRO -SCANNING PROGRAMMING

#### 2.1 Flashing

#### 2.2 Download default codeplug

#### 2.3 Scan the 2D barcode of the Reference xtal

##### 2.3.1 Decode of the barcode

- a) Decode the crystal code to get crystal maximum ppm, crystal inflection temperature (xtal\_infl\_temp) and crystal curve ppm(t)(crystal ppm at given temperature) and store them in xtal\_max\_ppm, xtal\_infl\_temp and xtal\_curve\_ppm(t). The following equations are used to calculate the above parameters

$$q1=(dig1*10)+dig2$$

$$q2=(dig3*100)+(dig4*10)+dig5$$

$$q3=(dig6*10)+dig7$$

$$xtal\_infl\_temp=q1/10+22$$

$$a1=-q2/1000$$

$$a2=(q3+0.1*q2+410)/(5*10^6)$$

$$\delta\_temp=temps(t)-ref\_temp$$

$$xtal\_curve\_ppm(t) = a1*\delta\_temp+a3*\delta\_temp^3$$

where

q1: Digits 1 and 2 from xtal code

q2: Digits 3,4,5 from xtal code

q3: Digits 6 and 7 from xtal code

ref\_temp:

temps(t): Array of temperature in steps of 5 deg c from -35deg C to 90 deg C

## 2.4 Temperature compensation tuning

### 2.4.1 Oscillator sensitivity measurement

- a) Use SBEP command to program synthesizer to receive frequency F7 of table 1.1 and also set the INFLECTION, COLD HOT AND LINEAR dacs to maximum to turn them off (INFLECTION dac=**63**, COLD dac=127, HOT dac=127, LINEAR dac=**63**)
- b) Use SBEP command to adjust warp dac to get frequency F7 within +/- 0.2 ppm  
Store warp dac value in warp\_dac\_center
- c) Indicate the PASS/FAIL status of the warp dac value  
If FAIL: Failed set warp dac value  
warp\_dac\_center must fall within range of 122 to 390
- d) Obtain warp\_dac\_high and warp\_dac\_low using the equations below:  

$$\text{xtal\_max\_v} = (\text{xtal\_max\_ppm} * 2) / \text{approx\_sens}$$

$$\text{warp\_dac\_range} = \text{ABS}(\text{xtal\_max\_v} / \text{warp\_dac\_step\_v})$$

$$\text{warp\_dac\_high} = \text{INT}(\text{warp\_dac\_center} + (\text{warp\_dac\_range} / 2))$$

$$\text{warp\_dac\_low} = \text{INT}(\text{warp\_dac\_center} - (\text{warp\_dac\_range} / 2))$$

where

$$\text{xtal\_max\_v} = \text{maximum required compensation voltage}$$

$$\text{xtal\_max\_ppm} = \text{calculated in 2.3.1a}$$

$$\text{constants: warp\_dac\_step\_v} = 0.0065 \text{ v/step}$$

$$\text{approx\_sens} = 20 \text{ ppm/v}$$
- e) Use SBEP command to program the radio to warp\_dac\_high
- f) Use DMM to get voltage reading. Store it in V<sub>H</sub>
- g) Use frequency counter to get frequency reading. Store it in F<sub>H</sub>
- h) Use SBEP command to program the radio to warp\_dac\_low
- i) Use DMM to get voltage reading. Store it in V<sub>L</sub>
- j) Use frequency counter to get frequency reading. Store it in F<sub>L</sub>
- k) Calculate the oscillator sensitivity using the equation below;  

$$\text{comp\_range\_v} = V_L - V_H$$

$$\text{ppm\_range} = [(F_L - F_H) / F_H] * 10^6$$

$$\text{osc\_sens} = \text{ABS}(\text{ppm\_range} / \text{comp\_range\_v}) + \text{osc\_sens\_offset}$$

where  
osc\_sens = The sensitivity of the oscillator's frequency to the voltage applied to the varactor constants: osc\_sens\_offset = 0

### 2.4.2 Translate crystal's ppm curve into voltage curve

- a) Convert the crystal ppm curve vs temperature to voltage vs temperature curve as follows;  

$$V(t) = [(\text{xtal\_curve\_ppm}(t) + \text{osc\_contrib}(t)) / \text{osc\_sens}]$$

where  
V(t) = voltage at given temperature  
osc\_contrib(t) = determined by hardware team ! **Currently equal to zero**  
osc\_sens = determined in m
- b) Invert the voltage vs temperature curve for compensation procedure as follows;  

$$\text{comp\_curve\_v}(t) = \text{comp\_curve\_vref} + \text{reg\_contrib}(t) - V(t)$$

where  
comp\_curve\_v(t) = inverted voltage at given temperature  
comp\_curve\_vref = 1/2 of VRO = **2.500V**  
reg\_contrib(t) = determined by hardware team  
V(t) = voltage at given temperature calculated in 2.4.1(a)

### 2.4.3 Search the IC's T.C. table for best compensation curve

- a) Compare the converted crystal curve to the table of compensation of voltage curves located in the file given to the factory to find the curve which gives the minimum error over the entire temperature range. The curve fitting would give cold, hot and linear dacs values

**2.4.4 Align the crystal curve to the IC's compensation curve**

- a) Send SBEP command to program the LVFRACN with a warp value of warp\_dac-center found in 2.4.1(a) with inflection, cold hot and linear dacs are off
- b) **Measure the voltage on the IC's WARP pin** . Store it in ic\_infl\_ref
- c) Send SBEP command to program the LVFRACN with inflection, cold, hot and linear dacs to settings in 2.4.2(a)
- d) Use SBEP command to adjust inflection dac setting to get the **WARP voltage as close to the ic\_infl\_ref in 2.4.3(a)**. Store it in ic\_infl\_set\_amb
- e) Use thermo-hunter to get the temperature at crystal. Store it in ic\_temp
- f) Calculation of inflection dac setting using the equation below;  

$$\text{infl\_dac} = \text{INT}(\text{ic\_infl\_set\_amb} + (1/\text{infl\_dac\_step}) * (\text{ic\_temp} - \text{xtal\_infl\_temp} + \text{infl\_tmp\_offset}))$$
 where  
 infl\_dac=inflection dac value  
 ic\_infl\_set\_amb=inflection dac value in 2.4.4d)  
 ic\_temp=temperature measured in 2.4.4e)  
 xtal\_infl\_temp=temperature read from 2D code in 2.3.1a)  
 constants: infl\_dac\_step=0.33 deg/step  
 infl\_tmp\_offset=0 deg
- g) Use SBEP command to save inflection,cold, hot and linear dac settings in the codeplug

**2.4.5 Reference oscillator warping (Final warp)**

- a) Use SBEP command to adjust warp dac setting to get frequency F7 of table 1.1.
- b) Use SBEP command to save warp dac setting in codeplug

**3. TRANSMITTER POWER ADJUSTMENT**

**3.1 General description of PA bias adjustment.**

Tuning of the PA Bias is required to compensate for FET device tolerances due to lot to lot variation during the FET die fabrication process. To obtain optimum power and efficiency, the bias should be tuned in the factory after it is built or after a repair.

- a) Program the FRACN to switch off the RF signal by setting VCO IC to battery saver mode. If this is not possible for hardware reasons set the VCO to RX mode. This step should be performed by setting the bias tuning environment.
- b) If the VCO IC cannot be set to battery saver mode, set the following receive frequencies:

Frequency Band	Test Frequency
VHF	F7
403-470MHz	F7

Table 1.2

This should be done automatically by the radio when entering the bias tuning environment. Previous radios required frequency setting by the tuning system.

- c) Initialize the PCIC for bias tuning by setting the following parameters
  - TX mode
  - switch on the PIN diodes (RX to low, ANO on)
  - set power D2A (D2A#1) to maximum
  - set voltage limit D2A (D2A#2) to minimum
  - set PA bias D2A (D2A#3) to minimum

This allows controlling the power control voltage by the voltage limit D2A. The PIN diodes should be on to avoid instabilities. For the same reason the antenna output must be terminated with 50 Ω. In case of PA oscillation an RF induced additional current would lead to tuning inaccuracies.

- d) Measure the dc current the radio draws from the voltage supply. Note the measured value as “VL0 B0 CURRENT”.
- e) Increase the voltage limit D2A (D2A#2) until the dc current is within the limits of the “VL0 B0 CURRENT“ as specified in table 1.3 “VL CURRENT“. Note the measured value as “VL B0 CURRENT“. The additional current is drawn by the driver.
- f) Increase the PA bias D2A (D2A#3) until the dc current exceeds the “VL B0 CURRENT“ as specified in table 1.3 “B CURRENT “. The additional current is drawn by the FET. After this step a balance between the FET current (gain) and the driver current (gain) has been achieved. The balance is maintained when the RF output power is altered.
- g) Store the PA bias D2A value in the PA bias softpot.

**3.2 Transmitter PA bias adjustment procedure**

- a) Set radio environment for PA bias tuning. This relates to steps (a)-(c) of section 3.1
- b) Measure the radio dc current and note the value as “VL0 B0 CURRENT“. This relates to step (d) of section of 3.1
- c) Increase the voltage limit D2A (D2A#2) until the dc current is within the limits of the “VL0 B0 CURRENT“ as specified in table 1.3 “VL CURRENT’ . Note the measured current as “VL B0 CURRENT“. This relates to steps (e) of section 3.1
- d) Increase the PA bias D2A (D2A#3) until the dc current exceeds the “VL B0 CURRENT“ as specified in table 1.3 “B CURRENT”. This relates to steps (f) of section 3.1
- e) Store the PA bias D2A value in the PA bias softpot.

	<b>VL Current</b>	<b>B Current</b>
136-174	100mA +/- 10%	100mA +/- 10%
403-470	peak 10mA-17mA	peak 400mA-440mA

Table 1.3

**3.2 Transmitter Power Adjustment**

(Important: Section 3.2 must be completed before power adjustment can be carried out)

The radio power-level tuning is across the band at 7 discrete test frequencies, each at 2 discrete power levels. In addition, there are 2 nominal power setting.

- a) Set the radio to first tuning frequency
- b) Key up the radio and measure power.
- c) Adjust the high power level (4W UHF, 5W VHF) and store the data.
- d) Repeat for each tuning frequency F1-F7.
- e) Repeat a) through d) for low power level (1W).

**Power Tuning Level Specification at each test point in table 1.1:**

	<b>VHF</b>	<b>UHF BAND 1</b>		
	(136-174)	(403-470)		
Hi Power	5.2-5.5W	4.2-4.5W		
Lo Power	1.1-1.3W	1.1-1.3W		

Table 1.4

#### 4. BALANCING/LIMITING LOW AND HIGH PORT Modulation of the Synthesizer

##### 4.1 Modulation Balancing (MOD ATTN):

- a) Program the radio for low power using the settings obtained in procedure 3.3 above.
- b) Program the ASFICCMP to mute the microphone .Set ASFICcmp for FLAT\_TX\_RTN mode (Flat audio response) and default attenuator settings (Note 1).  
Program the synthesizer to the lowest transmit tune frequency as in table 1.1 and set the ADC bits 12-11 = „10,,. These bits set the fractional-N low port sensitivity to a max of 5.0 kHz. Set the Mod Attenuator enable bit to "1" to enable the high port modulation.
- d) Apply a 80 Hz tone, 100 mVrms at the external test box "Audio In " input.
- e) Measure deviation (D1)
- f) Change the input tone to 3KHz, 91mVrms and measure deviation (D2)
- g) Find the ratio in dB using  $20\log[D1/D2]$
- h) Remove the audio signal by disabling the external Tx audio path
- i) Program the Mod attenuator setting of the fractional-N using the equation below:

$$\text{Modulation attenuator setting} = (\text{current setting at step i}) + -(5 \times (\text{dB value of step i}))$$

- j) Re-enable the External Tx audio path.
- k) Repeat steps f) - l) until the ratio in dB of step i) is  $\leq \pm 0.20\text{dB}$ , store modulation attenuator setting to EEPROM.

(NOTE 1: The attenuator settings of the ASFICcmp are defaulted for minimum attenuation (MOD6 - MOD0 = \$FF) before start of balancing. The fractional-N modulation attenuator should be set to 6.4dB, ie \$20 (32 decimal)).

#### 5. MODULATION LIMITING

- a) Disable the FLAT\_TX\_RTN mode. Select the Ext Mic and unmute it.
- b) Inject at the Ext Mix Input a 1KHz tone, 80mVrms with the pre-emphasis enabled and adjust the Mod attenuator of the ASFICcmp to obtain the deviation in table 1.5.
- c) Dekey the radio
- d) Store the attenuator setting in the codeplug.
- e) Repeat the steps (a) to (d) for other frequencies as per the tuning matrix.

(Note 2: For 20 kHz channel spacing, increase the Mod attenuator of ASFICcmp by 1.95db. Verify the deviation reduces to the range of 3.4 to 3.6KHz. If tuning is required, adjust only the Mod attenuator of ASFICcmp to ensure the deviation is reduced within this range. This should be carried out at the highest frequency.)

**12.5 kHz channel spacing.**

Program the synthesizer ADC bit 12..11 to 11(Reduce deviation sensitivity of the synthesizer).

Verify the deviation reduces to the range of 2.2 to 2.3 kHz. If tuning is required, adjust only the Mod attenuator of ASFICcmp to ensure the deviation is reduced within this range. This should be carried out at the highest frequency.

**5.1 DTMF DEVIATION**

- a) Set radio to the first tuning frequency.
- b) Key up the radio.
- c) Program the PCIC for Low Power.
- d) Program the Mod Attenuator of the ASFICcmp and the Mod Attenuator of the synthesizer to the values determined for balancing/limiting.
- e) Set the ADC bits 12-11 of the synthesizer to "10". These bits set the fractional-N low port sensitivity to a max of 5.0 kHz. Set the Mod Attenuator enable bit to "1" to enable the high port modulation.
- f) Enable DTMF pre-emphasis in ASFICcmp and generate DTMF # digit.
- g) Program the ASFICcmp TX High Speed Attenuator with default value (from default codeplug).
- h) Adjust the ASFICcmp TX High Speed Attenuator if necessary to obtain deviation per table 1.6.
- i) Dekey the radio
- j) Store the attenuator setting in the codeplug.

Reference Voice Deviation

Channel Spacing (kHz)	Deviation (kHz)
25	4.30 - 4.60
20	3.40 – 3.60
12.5	2.20 – 2.30

Table 1.5

PL & DPL Reference Deviation

Channel Spacing (kHz)	Deviation (kHz)
25	0.50 – 1.00
20	0.40 – 0.80
12.5	0.25 – 0.50

Table 1.6