

FUNCTION OF RF SEMICONDUCTORS AND OTHER ACTIVE DEVICES

SCHEMATIC KEY	PART NUMBER	CIRCUIT APPLICATION	OPERATING FREQUENCY	INDUSTRY EQUIVALENT
CR3301	4802245J42	Mixer	136-174 MHz	HPSMZ827
CR3302	4805129M96	Diode	136-174 MHz	SMBV1032LT1
CR3303	4880154K03	Limiter	136-174 MHz	MMBD353LT1
CR412	4802245J47	Protection Diode	DC	RB471E
CR413	4802245J47	Protection Diode	DC	RB471E
CR414	4802245J47	Protection Diode	DC	RB471E
CR440	4813833C02	Switching	DC	MMBD6100LT1
CR501	4880107R01	Switching	DC	BYD17D
CR503	4805729G49	Operator Interface	DC	BRPY1204W
D3270	4862824C01	Oscillator Tuning	136-174 MHz	1SV229
D3301	4802081B58	Filter Tuning	136-174 MHz	BB814
D3302	4802081B58	Filter Tuning	136-174 MHz	BB814
D3521	4880973Z02	RX/TX Switching	DC	MA4PH261
D3551	4880973Z02	RX/TX Switching	DC	4880973Z02
D3701	4802233J09	Voltage Multiplier	DC	1MN10
D3702	4802233J09	Voltage Multiplier	DC	1MN10
D3761	4862824C03	Oscillator Tuning	136-174 MHz	1SV232
D3821	4805649Q13	Oscillator Tuning	136-174 MHz	4805649Q13
D3831	4805649Q13	Oscillator Tuning	136-174 MHz	4805649Q13
D3832	4862824C01	Oscillator Tuning	136-174 MHz	4805649Q13
Q3200	4813827A07	IF Amplifier	45.1 MHz	MMBR941LT1
Q3201	4880214G02	AGC	DC	MMBT3904
Q3202	4880214G02	DC Switching	DC	MMBT3904
Q3270	4805218N63	2nd IF Oscillator	45 MHz	BFQ67W
Q3301	4880214G02	AGC	DC	MMBT3904
Q3302	4813827A07	Preamplifier	136-174 MHz	MMBR941LT1
Q3501	4802245J55	RF Final Amplifier	136-174 MHz	PRF1507
Q3721	4802245J50	DC Switching	DC	UMC5N
Q3801	4813827A07	LO Buffer	181-219 MHz	MMBR941
Q400	4809579E18	DC Switching	DC	TP010IT
Q403	4880214G02	DC Switching	DC	MMBT3904
Q405	4802245J54	DC Switching	DC	UMG5N
Q410	4802245J54	DC Switching	DC	UMG5N
Q417	4802245J50	DC Switching	DC	UMC5N
Q418	4802245J50	DC Switching	DC	UMC5N
Q419	5180159R01	DC Switching	DC	1MX1
Q420	4805128M67	DC Switching	DC	MMBT3906
Q421	4880214G02	DC Switching	DC	MMBT39041
Q431	5180159R01	DC Switching	DC	1MX1
Q433	4880214G02	DC Switching	DC	MMBT39041
Q502	5180159R01	LED Driver	DC	1MX1
Q505	4880214G02	DC Switching	DC	MMBT3904
U3201	5102463J58	3.3V Regulator VDDA	DC	LP2980A1M5
U3220	5109632D83	Receiver backend IC	45.1 MHz	48TQFP
U3501	5105109Z67	RF Driver Amplifier	136-174 MHz	TBD
U3502	5185765B01	RF Power Control IC	DC	H99S-4
U3503	5185963A15	Temperature Sensor	DC	LM50CIM3X
U3701	5185963A27	Freq.Synthesizer IC	136-174 MHz	63A27

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SCHEMATIC KEY	PART NUMBER	CIRCUIT APPLICATION	OPERATING FREQUENCY	INDUSTRY EQUIVALENT
U3711	5105739X05	Voltage Regulator 5V	DC	ADP3300
U3801	5105750U54	VCO Buffer IC	DC	50454
U400	5102463J40	V. Regulator VDDD	DC	LP2951CMM
U404	5185963A53	Audio Processing	Audio	CUSTOM
U406	5102463J59	Flash ROM	1.83 MHz	AT49LV010
U407	5102463J64	EEPROM	1.83 MHz	16KX8
U409	5102226J56	Microprocessor	1.83 MHz	68HC11FLO
U410	5102463J57	Voltage Regulator	DC	ILC7062CM
U420	5102463J44	Audio Power Amplifier	Audio	TDA8547TS
VR431	4802245J51	ESD Protection	DC	BZX284-C6V8
VR432	4880140L15	ESD Protection	DC	MMBZ5240B
VR433	4880140L15	ESD Protection	DC	MMBZ5240B
VR439	4880140L15	ESD Protection	DC	MMBZ5240B
VR440	4802245J51	ESD Protection	DC	BYY284
VR441	4802245J51	ESD Protection	DC	BYY284
VR444	4802245J51	ESD Protection	DC	BYY284
VR450	4802245J53	ESD Protection	DC	BZX284-C10
VR451	4802245J53	ESD Protection	DC	BZX284-C10
VR501	4813830A18	ESD Protection	DC	225MWMMBZ5235B
VR506	4802245J51	ESD Protection	DC	BZX284-C6V8
Y3200	4802245J43	IF Filter Motorola	IF	TBD
Y3761	4802245J49	Reference Oscillator	16.8 MHz	TBD

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 Source, 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

1. Tuning frequencies

These frequencies should be used for transmitter tuning. To avoid interference, the factory should use a frequency offset of 100KHz 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_H
- g) Use frequency counter to get frequency reading. Store it in F_H
- h) Use SBEP command to program the radio to warp_dac_low
- i) Use DMM to get voltage reading. Store it in V_L
- j) Use frequency counter to get frequency reading. Store it in F_L
- 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

$$\text{osc_sens} = \text{The sensitivity of the oscillator's frequency to the voltage applied to the varactor}$$

$$\text{constants: osc_sens_offset} = 0$$

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;

$$V(t) = [(\text{xtal_curve} - \text{ppm}(t)) + \text{osc_contrib}(t)] / \text{osc_sens}$$
 where

$$V(t) = \text{voltage at given temperature}$$

$$\text{osc_contrib}(t) = \text{determined by hardware team ! Currently equal to zero}$$

$$\text{osc_sens} = \text{determined in m}$$
- 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

$$\text{comp_curve_v}(t) = \text{inverted voltage at given temperature}$$

$$\text{comp_curve_vref} = 1/2 \text{ of VRO} = \mathbf{2.500V}$$

$$\text{reg_contrib}(t) = \text{determined by hardware team}$$

$$V(t) = \text{voltage at given temperature calculated in 2.4.1(a)}$$

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.

	VL Current	B Current
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 settings.

- 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:

	VHF	UHF BAND 1		
	(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 ASFICMP to mute the microphone .Set ASFICcmp for FLAT_TX_RTN mode (Flat audio response) and default attenuator settings (Note 1).
- c) 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 an 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