PHILIPS

Philips Consumer Communications

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CRUSH 9301 Theory of Operation

i). Radio Architecture

The EUT utilizes analog FM system radio communication link in both the handset and base. This telephone uses a Frequency Division Duplex (FDD) in which the transmit signal is at different carrier frequency from the desired receive signal. Since a single antenna is used, the received path needs to be isolated from the transmit path. To achieve this a RF filter duplexer for cordless telephone is used. These radios are designed to comply with FCC Part 15 requirements.

Transmitter

The RF includes a FM modulator circuit, buffer, matching filter, power amplifier, duplexer, antenna matching circuit and antenna. The modulator or transmitter's frequency source consists of a Colpitts Voltage Controlled Oscillator (VCO) controlled by the transmitter Phase Locked Loop (PLL) frequency synthesizer; the Phase Noise for this VCO is -92dBc/Hz at 10 kHz frequency offest. Follow the Tx VCO is a buffer used to provide isolation of the transmit power amplifier from the VCO. After the buffer circuit, there is a matching filter for the transmit bandwidth frequencies followed by a Power Amplifier (PA) with a output power of 0.25mWatt. The output of the PA is then connected to the Tx port of the Duplexer and the output port of the Duplexer is followed by the antenna matching circuit which is connected to the Antenna. The baseband signal (audio) is applied to the Tx VCO in order to modulate the transmitter.

Receiver

In a FM radio a receiver subsystem is used to provide the interface between the antenna and the baseband processing circuit. The receiver is a double conversion superhetrodyne down converter design with IF processing and demodulation. The RF includes a Low Noise Amplifier (LNA), first local oscillator and a first down conversion mixer to 1st IF of 70.016 MHz, a second down conversion mixer to convert 1st IF to final 2nd IF of 10.688 MHz, and an IF processing block which includes an IF amplifier, limiter, RSSI (Receive Signal Strength Indicator) and coilless demodulator. The first local oscillator frequencies are generated by a Colpitts Voltage Controlled Oscillator (VCO) controlled by the receive Phase Locked Loop (PLL) frequency synthesizer; the Phase Noise for this VCO is -92dBc/Hz at 10 kHz frequency offset. The first local oscillator operates at a frequency to produce a 1st IF signal of 70.016 MHz. The second local oscillator operates at 59.328 MHz producing a 2nd IF signal of 10.688 MHz. The 2nd IF filter has a bandwidth of 150 kHz. The receiver system uses a coilless demodulator which eliminates the conventional tunable quadrature coil in FM systems; it is self tuning and the frequency demodulator uses a phase locked loop with a fully integrated on chip relaxation oscillator which reproduce the baseband signal.

ii). Frequency Plan and Sources

1. The source for the system reference clock is derived from a quartz crystal of 16.384 MHz with a +/- 10 ppm accuracy. The reference clock provides the basis for the transmitter PLL, receiver PLL, 2nd LO PLL and MCU clock output. This reference clock is divided by 256 to produce a frequency of 64 kHz which is used as the reference frequency for the transmitter, receiver and 2nd LO Phase Locked Loops

(PLL's) frequency synthesizers. Also the reference clock is divided by 4 to produce a 4.096 MHz MCU clock output frequency used by the microprocessor.

2. There are 20 available channels for transmit and receive frequencies with a channel spacing of 128 kHz Following are the frequency bandwidths allocated for these 20 channels:

   a). Handset Transmit / Base Receive: **902.400** to **904.832** MHz spacing of 128 kHz.
   b). Handset Receive / Base Transmit : **924.928** to **927.360** MHz spacing of 128 kHz.

3. There are 20 1st LO (local oscillator) frequencies:

   a). Handset Transmit / Base Receive: **832.384** to **834.816** MHz spacing of 128 kHz.
   b). Handset Receive / Base Transmit : **854.912** to **857.344** MHz spacing of 128 kHz.

BASE Receive / HS Transmit (MHz)

Ch #	RF	1LO	1IF	2LO	2IF
1	902.400	832.384	70.016	59.328	10.688
2	902.528	832.512	"	"	"
3	902.656	832.640	"	"	"
4	902.784	832.768	"	"	"
5	902.912	832.896	"	"	"
6	903.040	833.024	"	"	"
7	903.168	833.152	"	"	"
8	903.296	833.280	"	"	"
9	903.424	833.408	"	"	"
10	903.552	833.536	"	"	"
11	903.680	833.664	"	"	"
12	903.808	833.792	"	"	"
13	903.936	833.920	"	"	"
14	904.064	834.048	"	"	"
15	904.192	834.176	"	"	"
16	904.320	834.304	"	"	"
17	904.448	834.432	"	"	"
18	904.576	834.560	"	"	"
19	904.704	834.688	"	"	"
20	904.832	834.816	"	"	"

HANDSET Receive / BASE Transmit (MHz)

Ch #	RF	1LO	1IF	2LO	2IF
1	924.928	854.912	70.016	59.328	10.688
2	925.056	855.040	"	"	"
3	925.184	855.168	"	"	"
4	925.312	855.296	"	"	"
5	925.440	855.424	"	"	"
6	925.568	855.552	"	"	"
7	925.696	855.680	"	"	"
8	925.824	855.808	"	"	"
9	925.952	855.936	"	"	"
10	926.080	856.064	"	"	"
11	926.208	856.192	"	"	"
12	926.336	856.320	"	"	"
13	926.464	856.448	"	"	"
14	926.592	856.576	"	"	"
15	926.720	856.704	"	"	"
16	926.848	856.832	"	"	"
17	926.976	856.960	"	"	"
18	927.104	857.088	"	"	"
19	927.232	857.216	"	"	"
20	927.360	857.344	"	"	"

iii). Baseband Signal Processing

Transmit Path

This subsystem consist of a microphone amplifier, compressor circuit, limiter, low pass filter, variable gain stage adjusted during the tuning procedure, a mute switch and a pre-emphasis filter. The audio signal from the microphone (in the handset) or the telephone hybrid (in the base) is input to the microphone amplifier then goes into the compressor. The output of the compressor is input to the limiter which then passes trough a low pass filter. The next stage is the gain stage which is set for the proper audio frequency deviation. The final stage is the pre-emphasis circuit in which the resulting signal is then applied to the transmit modulation circuit.

Receive Path

The receive audio path consist of a de-emphasis filter, anti-aliasing filter, a low pass filter, side tone attenuator, variable receive gain stage adjusted during tuning procedure, a mute switch, expander and volume control. The output of the FM demodulator goes trough the de-emphasis filter then goes to the anti-aliasing filter. The output goes through the low pass filter, the output of the low pass filter then goes to the side tone attenuation network then to the receive gain stage set for nominal audio level. The signal passes trough the expander and finally to the volume control amplifier; the output of this amplifier is connected to the speaker (in the handset) or to the telephone hybrid (in the base).

Also, the demodulator output signal goes trough a data filter which then inputs to the data slicer, the output signal of the data slicer is then applied to the Rx data pin in the microprocessor for the receive data communication.

iv). Channel Selection Algorithm

Before the 9301 cordless telephone establishes a RF link, it tries to find a free channel. The handset tests its receive frequency to determine if a channel is free and, when it finds a free channel, suggests the channel number to the base. The base tests the receive frequency of that channel to determine if the channel is free and returns OK or NOT OK to the handset. When the base rejects the suggested channel it sends a NOT OK message to the handset and the handset continuous to search for another free channel.

The handset has up to ten tries to find a free channel; if after ten tries it has not found a free channel, the handset will force the base to go to the last successful channel used in the last off-hook condition. When the handset does find a free channel, it sends the channel number as part of its message to the base as described above.

v). RF Semiconductors IC's

Three Motorola RF/Linear IC's are used in the 9301 RF platform design:

Product	**IC Description**	**Manufacturers Part Number**
9301	Low Power Transmitter for ISM Band	MC13146, MOTOROLA
9301	Low Power Receiver for ISM Band	MC13145, MOTOROLA
9301	900 MHz Analog Cordless Baseband	MC33411B, MOTOROLA

vi). Tuning Procedure

BASE BOARD REQUIREMENT

This section defines the tuning procedure and verification testing to be performed during the board level manufacturing of the Base PWB.

Test Point #	**Signal**
TAP501	VBB
TAP502	TAP_REQ_B
TAP503	SPI_CLK_B
TAP504	SPI_MOSI_B
TAP505	SPI_MISO_B
TAP506	TAP_SEL_B
TAP507	SGND
TAP508	BBIC_CS_B

Table 0-1 Base TAP definition

SETUP CONDITIONS

The base shall be initialized in phone OFF HOOK mode with receiver and transmitter enabled and default settings for all registers (for all tests and tunes but CID) or in ON HOOK idle mode (for CID testing). The IF bandwidth shall be 230kHz, and default condition for the HPF and LPF are 300Hz and 15kHz respectively. De-emphasis shall be OFF.

Power Supply

The base circuit supply voltage shall be 12 +/- 0.05 VDC, the measured current in the phone mode shall be 100 +/- 10 mA.

EEPROM Parameter Table Initialization (Model 9301 only)

1. In order to improve test and tune time, a direct access to EEPROM is conceived as means of downloading all default parameters.
2. The following sequence is required:
    - Before power-up, set UUT’s uP in RESET mode
    - Power UUT up
    - Send PREN command to EEPROM
    - Send PRCLEAR command
    - Send WEN command
    - Clear address EECLR_FLAG (WRITE command)
    - Release UUT’s uP from RESET mode
    - Wait 2 seconds to allow UUT to initialize itself

BASE CIRCUIT TEST AND TUNES

All base circuit tunes and verifications are performed on channel 10 only. Use TAP commands to initialize base and operate in this channel. Adjust RF generator carrier frequency to 903.552 MHz and 1kHz modulation tone.

- NOTE 1: Every time a parameter in the MC33411 base band IC is modified, execute TAP command WR_RFIC to reflect this change.
- NOTE 2: If an SPI error is detected, further SPI commands will be ignored. To recover, UUT power shall be turned OFF and then back to ON.
- NOTE 3: All tunes require the RF shield to be properly placed.

Transmit PLL error voltage (TX local oscillator)

1. Send TAP command to go OFF-HOOK, TX muted.
2. Apply -50dBm, 0 kHz deviation signal at the antenna port.
3. Measure DC voltage at TT406. It shall be between 1.0 and 3.5 VDC.

   NOTE: Add a 10k ohm resistor connected to TT406 to avoid noise interference.

Reference Oscillator (manual adjustment)

1. Tune C4044 to achieve a frequency at the antenna port of 926.080 MHz +/- 1000 Hz.

RX first local oscillator error voltage

1. Measure DC voltage at TT407. It shall be between 1.0 and 3.5 VDC.

   NOTE: Add a 10k ohm resistor connected to TT407 to avoid noise interference.

RX second local oscillator error voltage

1. Program RAM location LO2_cap_sel to achieve a DC voltage at TT405 between 0.6 and 2.2 VDC.
2. Write new value in EEPROM location LOCAP_ADDR.

   NOTE: Add a 10k ohm resistor connected to TT405 to avoid noise interference.

Transmit Power

1. Measure power at the antenna port. The reading shall be 0 +/- 3 dBm.

VREF programming

1. Program RAM location Vb_ref_ctrl to achieve a DC voltage at TT402 of 1.5 +/- 0.01 VDC.
2. Write new value in EEPROM location VBREFADJ_ADDR.

Maximum RSSI level (manual adjustment)

1. Apply -50dBm, 0 kHz deviation signal at the antenna port.
2. Measure DC voltage at TT403.
3. Adjust C4080 for maximum value. The reading shall be >=2.7 VDC.

Carrier Detect Threshold - RSSI level

1. Apply -85 dBm, 0 kHz deviation signal at the antenna port.

2. Read register 5 (bits 12 to 17) of IC403 (Base band IC) and store value in EEPROM location CD_ADDR.

Receiver Audio Gain

1. Apply -50dBm, +/- 18 kHz p-p deviation signal at the antenna port.
2. Measure output voltage D at the 900 Ohm +/-1% CO Simulator load resistor connected between TT420 (TIP) and TT421 (RING) through a CO simulator. Refer to table 4-1. Calculate new gain value N=ROUND[(-20-D)/2]+OLD_GAIN. Write new value for RX gain (high-order byte) to EEPROM location GAIN_ADDR9 (channel 10), high order byte.
3. New measured voltage between TT420 (TIP) and TT421 (RING) shall be -20 dBV +/- 2.5 dB.
4. Measure DISTORTION. The obtained reading shall be <= 3%.
5. Copy RX gain value for all channels, GAIN_ADDR0 to GAIN_ADDR19.

SINAD

1. Apply -110dBm, +/- 18 kHz p-p deviation signal at the antenna port.
2. Measure SINAD at 900 Ohm +/-1% load resistor, connected between TT420 (TIP) and TT421 (RING) through a CO simulator. Refer to table 4-1.
3. The reading shall be >=12 dB using CCITT or C-message filter.

Data Slicer

1. Apply -50dBm, +/- 40 kHz p-p deviation signal at the antenna port. A 1kHz +/- 10Hz signal with 2.5 Vrms +/- 20% shall be observed at TT501 (RXDAT). Use <20 Hz HPF and >99 kHz LPF.

Transmitter Audio Gain

1. Apply -50dBm, 0 kHz deviation signal at the antenna port. Apply a 100 mVrms, 1 kHz tone from a low source impedance generator connected between TT420 (TIP) and TT421 (RING) through a CO simulator circuit. Refer to Table 4-2.
2. Measure RF carrier deviation D at the antenna port. Use 230 kHz IF bandwidth, de-emphasis off, detector Pk +-/2, 300 Hz HPF and 3 kHz LPF filter. Calculate new gain value N=ROUND[20*LOG10(18/D)]+OLD_GAIN. Write new value for TX gain to EEPROM location GAIN_ADDR9 (channel 10), low order byte.
3. New measured deviation shall be within 18 +/- 1.3 kHz.
4. Copy TX gain value for all channels, GAIN_ADDR0 to GAIN_ADDR19.

Transmit RF Data

1. Apply -50dBm, 0 kHz deviation signal at the antenna port.
2. Apply 1 kHz square wave (meander) signal 5.0 Vp-p and 2.5 VDC offset to TT502.
3. Measure RF carrier deviation D at the antenna port. Use 230 kHz IF bandwidth, de-emphasis off, detector RMS, <20 Hz HPF and >99 kHz LPF. Measured deviation shall be 40 +/- 10 kHz.

Charging and Cradle Detector

1. Measure logic level at TT527. It shall be logic 1.
2. Connect 30 Ohm +/- 1% 5W resistor between TT517 and TT518.

3. Measure logic level at TT527. It shall be logic 0.
4. Measure DC current through the resistor. It shall be 140 +/- 15 mA.

AC Power Loss Detector

1. Place a 47k Ohm +/- 1% resistor between TP54 and GND.
2. Measure logic level at TT528. It shall be logic 0.
3. Remove load from TP54.
4. Measure logic level at TT528. It shall be logic 1.

CO Interface International Parameters Programming

1. Store in EEPROM parameters defined in table 2-2 for the specified country.

NOTE: USA version does not require these parameters to be stored.

EEPROM	MEX		ARG		BRZ/CHL	
ADDRESS	H Byte	L Byte	H Byte	L Byte	H Byte	L Byte
	EE[0]	EE[1]	EE[0]	EE[1]	EE[0]	EE[1]
MakeLen+BreakLen	0x08	0x11	0x08	0x11	0x09	0x10
DTMFLen+DTMFInter	0x1B	0x10	0x12	0x10	0x1B	0x10
PulInter+SWFlash	0xAA	0x19	0xC9	0x5E	0xC9	0x44
Inter_CHKSUM	0XA1	0xFF	0x8C	0xFF	0x9F	0xFF

Table 0-2 International Parameters for Network Compatibility

EEPROM Protect Register (Model 9301 only)

1. Last step in the tuning process is to set the protection register in the EEPROM and prevent alteration of tuning parameters.
2. The following sequence has to be executed:
   - Set UUT's uP in RESET mode
   - Send WEN command to EEPROM
   - Send PREN command to EEPROM
   - Send PRWRITE command with address of register LOCAP_ADDR
   - Verify address with a PRREAD command
   - Release UUT's uP from RESET mode

HANDSET BOARD REQUIREMENT

This section defines the tuning procedure and verification testing to be performed during the board level manufacturing of the Handset PWB.

The handset TAP connector consists of 8 land areas as shown in Table 0-1 Handset TAP Port

Test Point #	Signal
TAP201	VCC
TAP202	TAP_REQ
TAP203	SPI_CLK
TAP204	SPI_MOSI
TAP205	SPI_MISO
TAP206	TAP_SEL
TAP207	GND
TAP208	BBIC_CS

Table 0-1 Handset TAP Port

SETUP CONDITIONS

Connect a 150 Ohm resistor across the speaker terminals (TT108 and TT109) to simulate the load of the speaker. The IF bandwidth shall be 230kHz, and the normal condition for the HPF and LPF are 300Hz and 15kHz respectively. De-emphasis shall be OFF.

Power Supply

The handset shall be powered with 4 +/- 0.05 V, the measured current in the transmit mode shall be 65 +/- 5 mA.

EEPROM Parameter Table Initialization

1. In order to improve test and tune time, a direct access to EEPROM is conceived as means of downloading all default parameters.
2. The following sequence is required:
    - Before power-up, set UUT’s uP in RESET mode
    - Power UUT up
    - Send PREN command to EEPROM
    - Send PRCLEAR command
    - Send WEN command
    - Clear address EE_CRL_FLAG (WRITE command)
    - Release UUT’s uP from RESET mode
    - Wait 2 seconds to allow UUT to initialize itself. A happy tone is generated.

HANDSET CIRCUIT TEST AND TUNES

All handset tunes are performed on channel 10 only. Use TAP commands to initialize handset and operate in this channel. Adjust RF generator carrier frequency to 926.080 MHz and 1kHz modulation tone. Handset shall be initialized in phone mode with all default settings of RF IC registers and nominal volume level. A TAP sequence to enter test mode shall be sent within 10 seconds after power-up, otherwise UUT will enter in sleep mode and further TAP commands will be ignored.

- NOTE 1: Every time a parameter in the MC33411 base band IC is modified, execute TAP command WR_RFIC to reflect this change.
- NOTE 2: If an SPI error is detected, further SPI commands will be ignored. To recover, UUT power shall be turned OFF and then back to ON.
- NOTE 3: All tunes require the RF shield to be properly placed and soldered.

Transmit PLL error voltage (TX local oscillator)

1. Send TAP command to go into PHONE mode, TX muted.
2. Apply -50dBm, 0 kHz deviation signal at the antenna port.
3. Measure DC voltage at TT106. It shall be between 1.0 and 2.5 VDC.

   NOTE: Add a 10k ohm resistor connected to TT106 to avoid noise interference.

Reference Oscillator (manual adjustment)

1. Tune C1044 to achieve a frequency of 903.552 MHz +/- 1000 Hz at the antenna port.

RX First Local Oscillator error voltage

1. Measure DC voltage at TT107. It shall be between 1.0 and 2.5 VDC.

   NOTE: Add a 10k ohm resistor connected to TT107 to avoid noise interference.

RX Second Local Oscillator error voltage

1. Program RAM location LO2_cap_sel to achieve a DC voltage at TT105 between 0.6 and 1.3 VDC.
2. Write new value in EEPROM location LOCAP_ADDR.

   NOTE: Add a 10k ohm resistor connected to TT105 to avoid noise interference.

Transmit Power

1. Measure the transmit power at the antenna port. It shall be 0 +/- 3 dBm.

VREF programming

1. Program RAM location Vb_ref_ctrl to achieve a DC voltage at TT102 of 1.5 +/- 0.01 VDC.
2. Write new value in EEPROM location VBREFADJ_ADDR.

Maximum RSSI level (manual adjustment)

1. Apply -50dBm, 0 kHz deviation signal at the antenna port.
2. Measure DC voltage at TT103.
3. Adjust C1080 for maximum value. The reading shall be >=2.5 VDC.

Carrier Detect Threshold

1. Apply -85dBm, 0 kHz deviation signal at the antenna port.
2. Read register 5 (bits 12 to 17) of IC403 (Base band IC) and store value in EEPROM location CD_ADDR.

Low and Dead Battery levels programming

1. Read register 5 (bits 18 to 23) of IC403 (Base band IC). With 4.0 v applied to the battery connector, reading (D) shall be between 0x3B and 0x3F.
2. Store in EEPROM address VREF_ADDR high byte (Low Battery Level) the value D-0x0B.
3. Store in EEPROM address VREF_ADDR low byte (Dead Battery Level) the value D-0x0F.
4. Nominal Low battery level is 3.3v, while Dead battery level is 3.0v.

Receiver Audio Gain

1. Apply a -50 dBm, +/- 18 kHz p-p deviation signal at the antenna port.
2. With a 150 Ohm load resistor connected between TT108 and TT109, measure AC RMS voltage D on either test point. Calculate new gain value N=ROUND[(-35.0-D)/2]+OLD_GAIN. Write new value for RX gain (high-order byte) to EEPROM location GAIN_ADDR9 (channel 10)
3. New measured voltage between TT108 and TT109 shall be -35.0 dBV +/- 2.5 dB.
4. Measure DISTORTION. The obtained reading shall be <= 3%.
5. Copy RX gain value for all channels, GAIN_ADDR0 to GAIN_ADDR19.

SINAD

1. Apply -110dBm, +/- 18 kHz p-p deviation signal at the antenna port.
2. Measure SINAD at either terminal of the 150 ohm speaker load (TT108 and TT109).
3. The reading shall be >=12 dB using CCITT or C-message filter.

Data Slicer

1. Apply -50dBm, +/- 40 kHz p-p deviation signal at the antenna port. A 1 kHz +/- 10Hz signal with 1.5 Vrms +/- 20% shall be observed at TT204 (RXDAT).

Transmitter Audio Gain

1. Apply -50dBm, 0 kHz deviation signal at the antenna port. Apply a 5 mVrms, 1 kHz tone from a low source impedance signal generator connected to the microphone terminals (TT101 and GND).
2. Measure RF carrier deviation D at the antenna port. Use 230 kHz IF bandwidth, de-emphasis off, detector Pk +-/2, 300 Hz HPF and 3 kHz LPF filter. Calculate new gain value N=ROUND[20*LOG10(18/D)]+OLD_GAIN. Write new value for TX gain to EEPROM location GAIN_ADDR9 (channel 10).
3. New measured deviation shall be within 18 +/- 1.3 kHz.
4. Copy TX gain value for all channels, GAIN_ADDR0 to GAIN_ADDR19.

Transmit RF Data

1. Apply -50dBm, 0 kHz deviation signal at the antenna port.
2. Apply 1 kHz square wave (meander) signal 3.0 V p-p and 1.5 VDC offset to TT203.

3. Measure RF carrier deviation D at the antenna port. Use 230 kHz IF bandwidth, de-emphasis off, detector RMS, <20 Hz HPF and >99 kHz LPF. Measured deviation shall be 40 +/- 10 kHz.

CHARGE CONTACT CIRCUITS

The handset should be in its on hook condition for all charge contact tests.

Normal Charge and Cradle Detection

1. Measure logic level at TT226. The reading shall be logic 0.
2. Connect 12.0 +/- 1.0VDC from a power supply, with a source impedance of 70 Ohms, across the positive (TT217) and negative (TT218) charge contacts.
3. Measure logic level at TT226. The reading shall be logic 1.
4. Measure current through the DC power supply. The current shall be 33 +/- 10 mA.

EEPROM Protect Register

1. Last step in the tuning process is to set the protection register in the EEPROM and prevent alteration of tuning parameters.
2. The following sequence has to be executed:
    - Set UUT’s uP in RESET mode
    - Send WEN command to EEPROM
    - Send PREN command to EEPROM
    - Send PRWRITE command with address of register LOCAP_ADDR
    - Verify address with a PRREAD command
    - Release UUT’s uP from RESET mode