CT3258 Application Notes

Analog Interface Setup

Version: 1.0

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Change History

Version	Date	Change Descriptions	Author
1.0	2015/01/14	Initial version	Hao Ye

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1 Introduction

CT3258 is a single chip base band processor for DPMR / DMR and other narrow band FDMA digital radio. It is also backward compatible with traditional analog radio with support for CTCSS and DCS signaling.

DPMR / DMR uses 4FSK modulation with a symbol rate of 2400 or 4800. As 4FSK modulation has DC components in its signal, it is required to use two-point modulation scheme for connection with RF transmitter. One of the paths is used to modulate the VCO, the other path is used to modulate the VCTCXO.

In addition, the analog DCS signal also has DC components and requires two-point modulation as well. However, the settings for DCS and for 4FSK may not always to be the same for non-ideal transmitter.

Correct set up of two point modulation is crucial for the 4 FSK and DCS operation. CT3258 provides flexible controls and test signal to facilitate the configuration and tuning for the two point modulation setup.

This document describes tools and procedures for configuring and fine tuning CT3258 for best performance in two-point modulation and other aspect of analog setup.

2 Test Signals

CT3258 can be configured to send out a fixed pattern signal. The test pattern can be programmable. By varying the test patterns, different test signal can be generated. The most useful signals are described in this section.

Note that the symbol rate is 2400 Hz in DPMR mode, and 4800Hz in DMR mode. With the same command, CT3258 generate the same test signals, with the frequency doubled in DMR mode.

Also note that all DMR test signals are transmitted in continuous mode, with slot 1 and slot 2 has the same contents, even though real-life DPMR signals are transmitted in slot mode.

2.1 1200 Hz / 2400 Hz 4FSK Signal

This signal is generated by alternately sending out +3 and -3 4FSK symbols. It is used to set the correct frequency deviation level. The test signal can be generated with the following command:

The frequency of the signal is 1200 Hz in DPMR mode and 2400 Hz in DMR mode

```
Command ID:   DEBUG_FS1
Send   Command: 84 A9 61 00 04 00 18 02 00 02
Receive    Command: 84 A9 61 00 02 00 18 00
Command ID:   DMPR_FS_TR2
Send   Command: 84 A9 61 00 07 03 4C 77 77 77 77 77 77 00
Receive    Command: 84 A9 61 00 02 03 4C 00
```

2.2 100 Hz / 200 Hz Square Wave Signal

This is a square wave signal with 33% duty cycle, used for coarse tuning of two-point modulation.

The frequency of the signal is 100 Hz in DPMR mode and 200 Hz in DMR mode

The signal can be generated with the following command.

```
Command ID:   DEBUG_FS1
Send   Command: 84 A9 61 00 04 00 18 02 00 02
Receive    Command: 84 A9 61 00 02 00 18 00
Command ID:   DMPR_FS_TR2
Send   Command: 84 A9 61 00 07 03 4C 55 55 55 55 FF FF 00
Receive    Command: 84 A9 61 00 02 03 4C 00
```

2.3 400 Hz / 800 Hz Triangular Wave Signal

This is a triangular wave signal, used for fine tuning for two-point modulation.

The frequency of the signal is 400 Hz in DPMR mode and 800 Hz in DMR mode

The signal can be generated with the following command.

```
Command ID:   DEBUG_FS1
Send   Command: 84 A9 61 00 04 00 18 02 00 02
Receive    Command: 84 A9 61 00 02 00 18 00
Command ID:   DMPR_FS_TR2
Send   Command: 84 A9 61 00 07 03 4C 4b 84 b8 4b 84 b8 00
Receive    Command: 84 A9 61 00 02 03 4C 00
```

2.4 Analog Single Tone

This is the single frequency analog tone, with configurable frequency from 1Hz to 4 kHz. It can be used to fine tune to frequency response of the 2-point modulator.

The analog single tone can be generated by first setting CT3258 in TX analog call mode, and then send analog tone to the remote end.

The generated tone should be observable at DAC left and DAC right channel.

```
Command ID:   PROCESS_MODE
Send   Command: 84 A9 61 00 02 00 1A 80
Receive    Command: 84 A9 61 00 02 00 1A 00

Command ID:   WORK_MODE_TX
Send   Command: 84 A9 61 00 04 00 18 02 00 00
Receive    Command: 84 A9 61 00 02 00 18 00

Command ID:   ANALOG_TONE
Send   Command: 84 A9 61 00 12 00 1F FF {VAR1_MSB} {VAR1_LSB} 00 00 00
00 00 00 {VAR2} 00 00 00 03 E8 00 00
Receive    Command: 84 A9 61 00 02 00 1F 00
```

VAR1 is the frequency of the generated tone. For example, VAR1 = 03 E8, the frequency is 1 kHz

VAR2 is the amplitude of the tone, in 8 bit linear scale and 6 bit fraction. The max of VAR2 is 0xFF, corresponding to 12 dB gain.

2.5 DCS Signal

This is regular DCS signals, which can be generated by starting an analog voice call with DCS enabled.

3 Test Tools

Test tools involved in testing include audio signal generator, scope, HP8920 tester.

CT3258 has built in a BER tester, especially useful for fine tuning performance.

3.1 Test Equipments

Test equipment involved in configuration and calibration includes the following:

1. HP8920 RF Tester
2. Signal Generator capable of generating 1000 Hz, 1 mVpp sine wave signal
3. Oscilloscope
4. Test RF transceiver with at the frequency band of interest.
5. Audio Analyzer (optional)

Optionally, the user can use Aeroflex 3920 digital tester. With Aeroflex 3920, the calibration task can be simplified. This application note assumes no Aeroflex 3920 is used.

3.2 CT3258 Built in DPMR BER Tester

To set up for BER Test, the user configures the transmitter and receivers exactly the same way as a normal voice call except the following commands:

1. At the transmitter, instead of setting the CT3258 WORK MODE to TX mode, set CT3258 WORK MODE to TX mode with BER with command

```
Command ID: WORK_MODE_TX_BER
Send command: 84 A9 61 00 04 00 18 02 00 05
Receive Data: 84 A9 61 00 02 00 18 00
Command ID: PROCESS_MODE
Send command: 84 A9 61 00 02 00 1A 03
Receive Data: 84 A9 61 00 02 00 1A 00
Command ID:   ADDRESSING_MODE
Send   Command: 84 A9 61 00 02 03 28 01
Receive    Command:84 A9 61 00 02 03 28 00
Command ID: DPMR_CALLED_ID
Send command: 84 A9 61 00 04 03 50 12 34 56
Receive Data: 84 A9 61 00 02 03 50 00
```

2. At the receiver, instead of setting the CT3258 WORK MODE to RX mode, set CT3258 WORK MODE to RX mode with BER with command:

```
Command ID: WORK_MODE_RX_BER
Send command: 84 A9 61 00 04 00 18 01 00 05
Receive Data: 84 A9 61 00 02 00 18 00
Command ID:   CARRIER_LOST
```



```
Send   Command: 84 A9 61 00 02 00 19 00
Receive    Command:84 A9 61 00 02 00 19 00
Command ID:   CARRIER_READY
Send   Command: 84 A9 61 00 02 00 19 {READY_VAR}
Receive    Command:84 A9 61 00 02 00 19 00
```

3. The user then start the call normally with

```
Command ID:   CALL_START
Send   Command: 84 A9 61 00 02 00 20 02
Receive    Command:84 A9 61 00 02 00 20 00
```

4. Also enable the RF transmitter and receiver the same way as voice call.
5. The user can check the BER test result with command:

```
Command ID:   Q_BER
Send command: 84 A9 61 00 02 23 1E 08
```

6. The response will indicate the time duration of the BER test (in seconds), the total error numbers and the corresponding error rate in ppm (number of errors in a million unit)
7. By default, CT3258 count all bit errors in ppm error rate calculation. Optionally, the user can specify a duration parameter for BER calculation. When duration parameter is none zeros, error before the duration are not counted in ppm calculation. This allows for real time ppm updating. Duration parameter is specified in unit of second. If the duration parameter is none, all bit errors are counted in ppm calculation.

3.3 CT3258 Built in DMR BER Tester

To set up for BER Test, the user configures the transmitter and receivers exactly the same way as a normal voice call except the following commands:

1. At the transmitter, instead of setting the CT3258 WORK MODE to TX mode, set CT3258 WORK MODE to TX mode with BER with command

```
Command ID:   PROCESS_MODE
Send   Command: 84 A9 61 00 02 00 1A 03
Receive    Data:84 A9 61 00 02 00 1A 00

Command ID: DMR_CALLED_ID
Send command: 84 A9 61 00 05 05 7d 01 23 45 67
Receive Data: 84 A9 61 00 02 05 7d 00
Command ID:   OWNID_BCD
Send   Command: 84 A9 61 00 05 05 7e 01 23 45 67
Receive    Data: 84 A9 61 00 02 05 7e 00

Command ID:   WORK_MODE_TX
Send   Command: 84 A9 61 00 04 00 18 02 00 0B
Receive    Data:84 A9 61 00 02 00 18 00
```



```
Command ID:    DMR_CALL_OPTION
Send   Command: 84 A9 61 00 06 05 79 81 00 00 00 00
Receive    Data:84 A9 61 00 02 05 79 00
Pause 1500
```

2. At the receiver, instead of setting the CT3258 WORK MODE to RX mode, set CT3258 WORK MODE to RX mode with BER with command:

```
Command ID:    PROCESS_MODE
Send   Command: 84 A9 61 00 02 00 1A 03
Receive    Data:84 A9 61 00 02 00 1A 00
Command ID:    DMR_CALL_OPTION
Send   Command: 84 A9 61 00 06 05 79 81 00 00 00 00
Receive    Data:84 A9 61 00 02 05 79 00
Pause 1500
Command ID:    DMR_CC
Send   Command: 84 A9 61 00 02 05 77 0d
Receive    Data:84 A9 61 00 02 05 77 00

Command ID:    OWNID_BCD
Send   Command: 84 A9 61 00 05 05 7e 01 23 45 67
Receive    Data:84 A9 61 00 02 05 7e 00

Command ID: REPORT_FIELD
Send command: 84 A9 61 00 02 00 1D ff
Receive Data: 84 A9 61 00 02 00 1D 00
Command ID:    WORK_MODE_RX
Send   Command: 84 A9 61 00 04 00 18 01 00 0b
Receive    Data:84 A9 61 00 02 00 18 00
Command ID:    CARRIER_LOST
Send   Command: 84 A9 61 00 02 03 19 00
Receive    Data:84 A9 61 00 02 03 19 00
Command ID:    CARRIER_READY
Send   Command: 84 A9 61 00 02 03 19 01
Receive    Data:84 A9 61 00 02 03 19 00
```

3. The user then start the call normally with

```
Command ID:    DMR_CALL_START
Send   Command: 84 A9 61 00 01 05 78
Receive    Data: 84 A9 61 00 02 05 78 00
```

4. Also enable the RF transmitter and receiver the same way as voice call.
5. The user can check the BER test result with command:


```
Command ID:   Q_BER
Send command: 84 A9 61 00 02 23 1E 08
```

6. The response will indicate the time duration of the BER test (in seconds), the total error numbers and the corresponding error rate in ppm (number of errors in a million unit)
7. By default, CT3258 count all bit errors in ppm error rate calculation. Optionally, the user can specify a duration parameter for BER calculation. When duration parameter is none zeros, error before the duration are not counted in ppm calculation. This allows for real time ppm updating. Duration parameter is specified in unit of second. If the duration parameter is none, all bit errors are counted in ppm calculation.

4 Parameters used in Analog Configuration

The data flow for the DPMR / DMR /Analog transmitter and receiver are shown in the diagrams below.

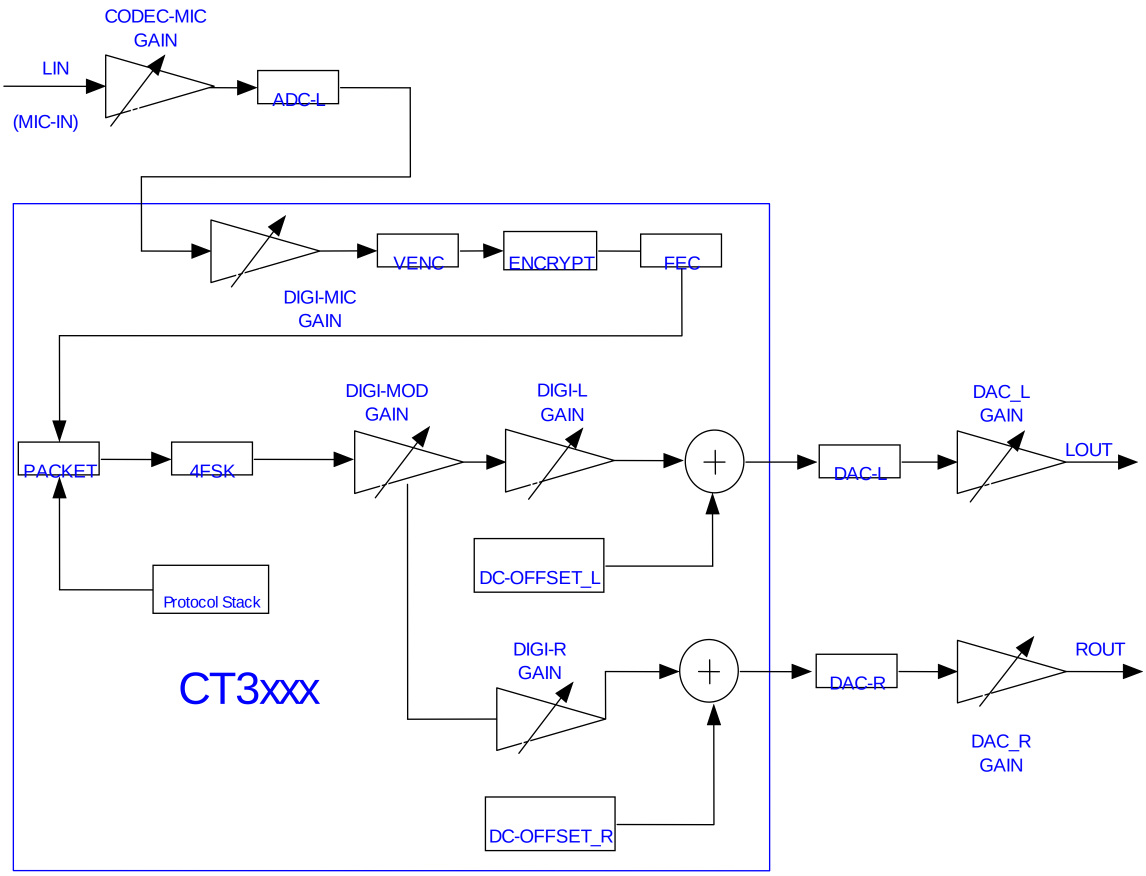

Figure 4-1 Signal Flow for DPMR / DMR Transmitter

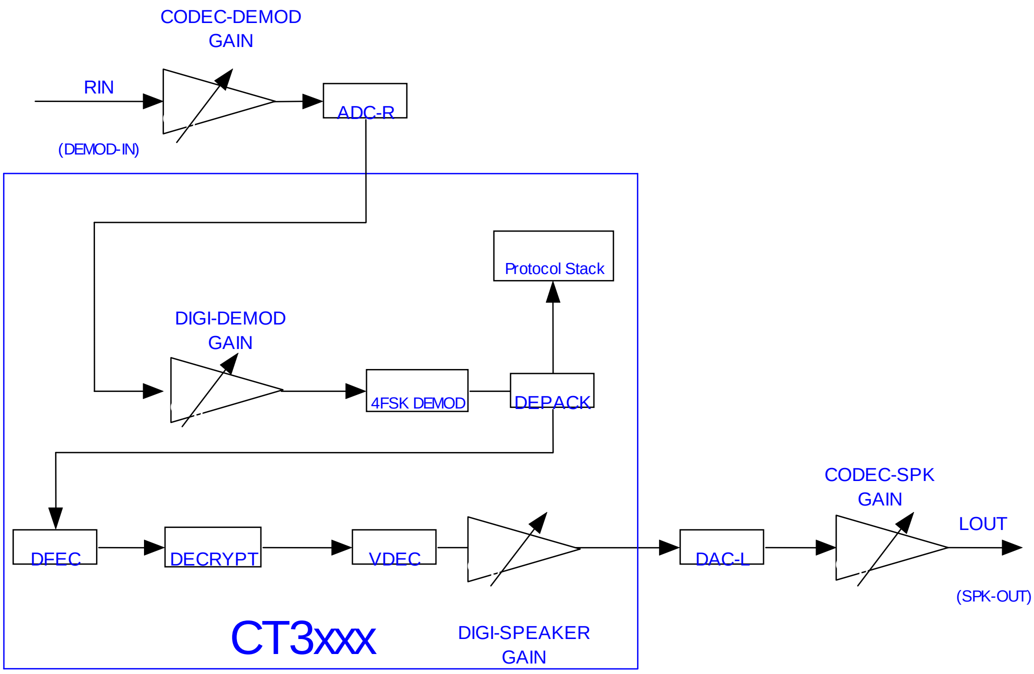

Figure 4-2 Signal Flow for DPMR / DMR Receiver

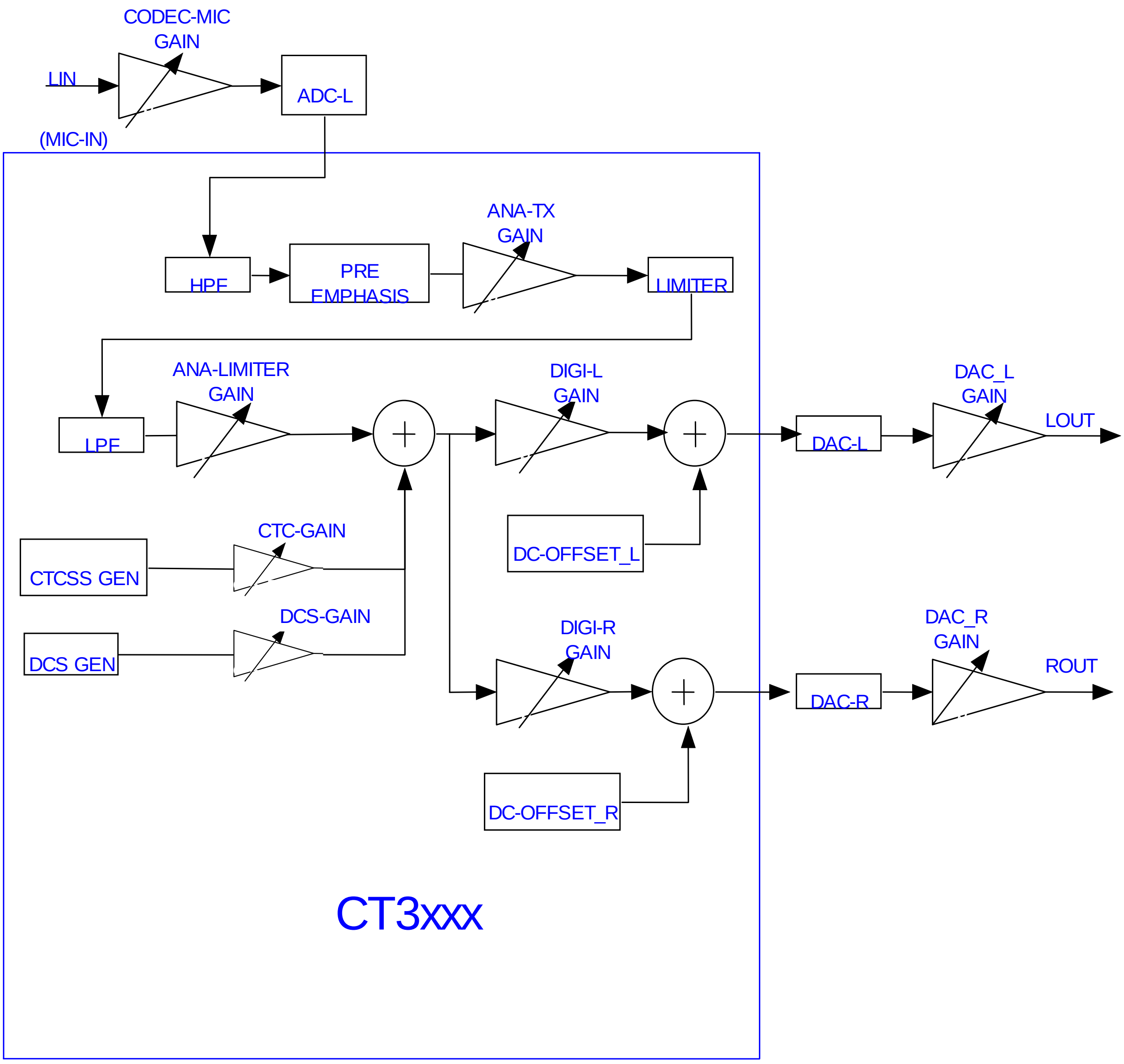

Figure 4-3 Signal Flow for Analog Transmitter

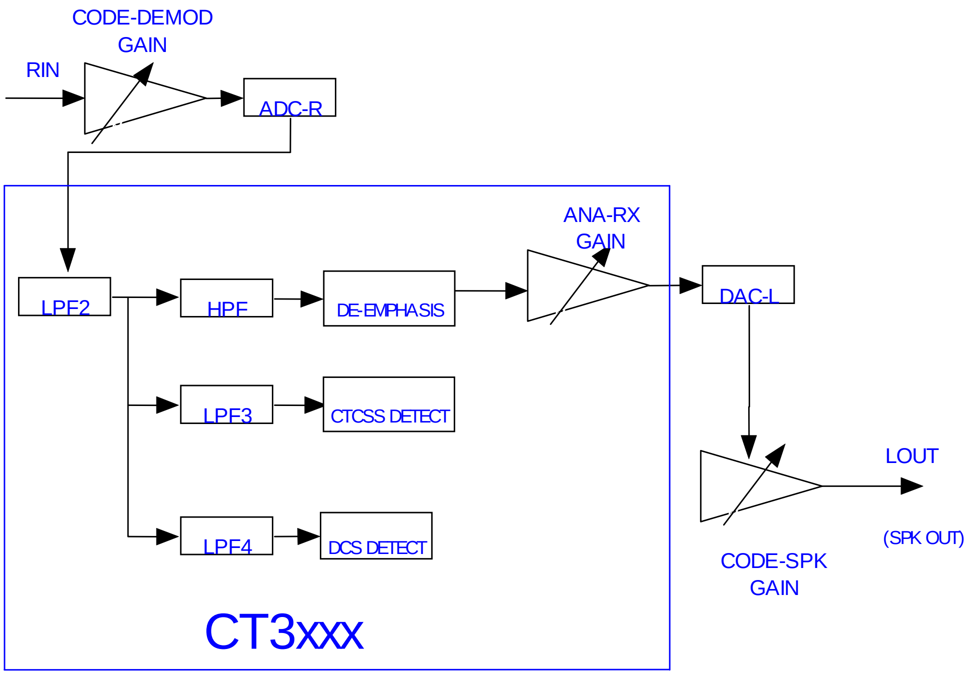

Figure 4-4 Signal Flow for Analog Receiver

The parameters are described below. Some of the gains are provided by the codec. In those cases, the codec commands are sent to CT3258 through HPI. CT3258 formats it into I2C control words and send to the codec. WM8758B from Wolfson and TLV320AIC3204 from TI are used as examples in this document.

4.1 CODEC_MIC_GAIN

This is the analog gain codec gain before the left channel ADC for the microphone signal amplification. This is a codec dependent command.

4.1.1 Wolfson WM8758B

The Codec Mic Gain is set with I2C command to the codec:

```
84 a9 61 00 02 40 5B {VAR1}
```

The gain value is in dB scale, as described in the following table.

VAR1	CODEC_MIC_GAIN (dB)
0x00	-12
0x01	-11.25
…	
0x10	0
…	
0x3f	+35.25 dB

Note that an additional 20dB gain of the codec is not used by CT3258, as ALC is enabled, and that 20 dB microphone gain is not controlled by ALC.

As ALC Limiter mode of WM8758B is enabled by default, the user needs to disable it before microphone gain adjustment, and re-enable it after the adjustment.

The ALC Limiter mode can be disabled with
`84 a9 61 00 02 40 40 38`
and enabled with
`84 a9 61 00 02 40 41 38`

4.1.2 TI TLV320AIC3204

The Codec Mic Gain is set with I2C command to the codec:

`84 a9 61 00 06 40 00 01 3B {VAR1} 00 00`

The gain value is in dB scale, as described in the following table.

VAR1	CODEC_MIC_GAIN (dB)
0x00	-6
0x01	-5.5
…	
0x0c	0
…	
0x5f	+41.5 Db

The user needs to disable the AGC before microphone gain adjustment, and re-enable it after the adjustment.

The AGC mode can be disabled with
`84 a9 61 00 02 40 56 00`
and enabled with
`84 a9 61 00 02 40 56 C1`

4.2 CODEC_DEMOD_GAIN

This is the analog gain codec gain before the right channel ADC for FM demodulated signal amplification.

This is a codec dependent command.

4.2.1 Wolfson WM8758B

The Codec Demod Gain is set with I2C command to the codec:


```
84 a9 61 00 02 40 5D{VAR}
```

The gain value is in dB scale, as described in the following table.

VAR	CODEC_MIC_GAIN (dB)
0x00	-12
0x01	-11.25
…	
0x10	0
…	
0x3f	+35.25

4.2.2 TI TLV320AIC3204

The Codec Demod Gain is set with I2C command to the codec:

```
84 a9 61 00 06 40 00 01 3C {VAR} 00 00.
```

The gain value is in dB scale, as described in the following table.

VAR	CODEC_DEMOD_GAIN (dB)
0x00	-6
0x01	-5.5
…	
0x0c	0
…	
0x5f	+41.5 Db

4.3 DAC_L_GAIN

This is the analog gain codec gain after the left channel DAC.

This is a codec dependent command.

4.3.1 Wolfson WM8758B

It is set with I2C command to the codec:

```
84 a9 61 00 02 40 6D {VAR}
```

The gain value is in dB scale, as described in the following table.

VAR	DAC_L_GAIN (dB)
0x00	-57
0x01	-56
…	
0x39	0
0x3f	+6
0x40	Mute

4.3.2 TI TLV320AIC3204

It is set with I2C command to the codec:

```
84 a9 61 00 06 40 00 01 12 {VAR} 00 00
```

The gain value is in dB scale, as described in the following table.

VAR	DAC_L_GAIN (dB)
0x3A	-6
0x3B	-5
…	
0x00	0
0x1D	+29

4.4 DAC_R_GAIN

This is the analog gain codec gain after the right channel DAC.

This is a codec dependent command.

4.4.1 Wolfson WM8758B

It is set with I2C command to the codec:

```
84 a9 61 00 02 40 6F {VAR}.
```

The gain value is in dB scale, as described in the following table.

VAR	DAC_R_GAIN (dB)
0x00	-57
0x01	-56

…	
0x39	0
0x3f	+6
0x40	Mute

4.4.2 TI TLV320AIC3204

It is set with I2C command to the codec:

```
84 a9 61 00 06 40 00 01 13 {VAR} 00 00
```

The gain value is in dB scale, as described in the following table.

VAR	DAC_R_GAIN (dB)
0x3A	-6
0x3B	-5
…	
0x00	0
0x1D	+29

4.5 CODEC_SPK_GAIN

This is the analog codec gain after the left channel DAC for the audio signal to the speaker.

This is a codec dependent command.

4.5.1 Wolfson WM8758B

It is set with I2C command to the codec:

```
84 a9 61 00 02 40 69 {VAR}
```

The gain value is in dB scale, as described in the following table.

VAR	CODEC_SPK_GAIN (dB)
0x00	-57
0x01	-56
…	
0x39	0

0x3f	+6
0x40	Mute

4.5.2 TI TLV320AIC3204

It is set with I2C command to the codec:

```
84 a9 61 00 06 40 00 01 10 {VAR} 00 00
```

The gain value is in dB scale, as described in the following table.

VAR	CODEC_SPK_GAIN (dB)
0x3A	-6
0x3B	-5
…	
0x00	0
0x1D	+29

4.6 DIGI_MOD_GAIN

This is the CT3258 digital gain for fine tuning the modulation index. It is set with the following command to CT3258.

```
84 a9 61 00 03 2C {VAR-MSB} {VAR-LSB}
```

VAR is a sixteen bit number sent in two bytes, with MSB first.

The gain is expressed in linear scale as 16 bit 2’s complement, with 2048 being the 0 dB reference.

The real gain value is thus

DIGI_MOD_GAIN = VAR / 2048.

A minus gain value provides a phase reversal to the input signal.

4.7 DIGI_L_GAIN, DIGI_R_GAIN

This is the CT3258 digital gain for fine tuning the amplitude of the signal to the left and right channel DAC. It is set with the following command to CT3258.

```
84 a9 61 00 0d 39 00 {VAR1-MSB} {VAR1-LSB} {VAR2-MSB} {VAR2-LSB} {VAR3-MSB}
{VAR3-LSB} {VAR4-MSB} {VAR4-LSB} {VAR5-MSB} {VAR5-LSB} {VAR6-MSB}
```


{VAR6-LSB}

VAR1 and VAR2 are DC OFFSET values applied at the left and right channel ADC.

The right channel ADC is connected to the demodulated FM signal.

VAR3 and VAR4 are DC OFFSET values applied at the left and right channel DAC.

VAR5 (DIGI_L_GAIN) and VAR6 (DIGI_R_GAIN) are digital gains for fine tuning the signal level to the DAC.

The gain is expressed in linear scale as 16 bit 2's complement, with 2048 being the 0 dB reference.

The real gain value is thus

DIGI_L_GAIN = VAR5 / 2048.

DIGI_R_GAIN = VAR6 / 2048.

A minus gain value provides a phase reversal to the input signal.

4.8 DIGI_DEMOD_GAIN

This is the CT3258 digital gain for fine tuning the amplitude of the FM demodulated signal. It is set with the following command to CT3258.

```
84 a9 61 00 03 1C {VAR-MSB} {VAR-LSB}
```

VAR is a sixteen bit number sent in two bytes, with MSB first.

The gain is expressed in linear scale as 16 bit 2's complement, with 2048 being the 0 dB reference.

The real gain value is thus

DIGI_DEMOD_GAIN = VAR / 2048.

A minus gain value provides a phase reversal to the input signal.

If VAR = 0, automatic gain match is enabled and DIGI_DEMOD_GAIN are set by CT3258 automatically based on the level of the incoming FM demodulated signal.

4.9 ANA_TX_GAIN

This is the CT3258 gain for adjust the amplitude of the TX signal before the limiter in analog call mode. It is mostly used to fine tuning the microphone sensitivity. ANA_TX_GAIN is set with the following command to CT3258.

```
84 a9 61 00 0C 3C {CONFIG} {VAR1-MSB} {VAR1-LSB} {VAR2-MSB} {VAR2-LSB}
{VAR3-MSB} {VAR3-LSB} {VAR4-MSB} {VAR4-LSB} {VAR5-MSB} {VAR5-LSB}
```

VAR1 is for ANA_TX_GAIN.

Other variables are described in other sections of this document and in “Packet Interface of CT3258”.

VAR1 is a sixteen bit number sent in two bytes, with MSB first.

The gain is expressed in linear scale as 16 bit 2’s complement, with 2048 being the 0 dB reference.

The real gain value is thus

ANA_TX_GAIN = VAR1 / 2048.

A minus gain value provides a phase reversal to the input signal.

Note that ANA_TX_GAIN should have a minimum value of 4096 (+6 dB gain). If this value is below 4096, the user can reduce CODEC_MIC_GAIN and increase ANA_TX_GAIN.

4.10 ANA_LIMITER_GAIN

This is the CT3258 gain for adjust the amplitude of the TX signal after the limiter in analog call mode. It is mostly used for fine tuning the modulation index in analog mode. ANA_LIMITER_GAIN is set with the following command to CT3258.

```
84 a9 61 00 0C 3C {CONFIG} {VAR1-MSB} {VAR1-LSB} {VAR2-MSB} {VAR2-LSB}
{VAR3-MSB} {VAR3-LSB} {VAR4-MSB} {VAR4-LSB} {VAR5-MSB} {VAR5-LSB}
```

VAR2 is for ANA_LIMITER_GAIN.

Other variables are described in other sections of this document and in “Packet Interface of CT3258”.

VAR2 is a sixteen bit number sent in two bytes, with MSB first.

The gain is expressed in linear scale as 16 bit 2’s complement, with 4096 being the 0 dB reference.

The real gain value is thus

ANA_LIMITER_GAIN = VAR2 / 4096.

A minus gain value provides a phase reversal to the input signal.

4.11 ANA_RX_GAIN

This is the CT3258 gain for adjust the amplitude of the RX signal in analog call mode. It is mostly used for volume control. ANA_RX_GAIN is set with the following command to CT3258.

```
84 a9 61 00 0C 3C {CONFIG} {VAR1-MSB} {VAR1-LSB} {VAR2-MSB} {VAR2-LSB}
{VAR3-MSB} {VAR3-LSB} {VAR4-MSB} {VAR4-LSB} {VAR5-MSB} {VAR5-LSB}
```

VAR5 is for ANA_RX_GAIN.

Other variables are described in other sections of this document and in “Packet Interface of CT3258”.

VAR5 is a sixteen bit number sent in two bytes, with MSB first.

The gain is expressed in linear scale as 16 bit 2’s complement, with 2048 being the 0 dB reference.

The real gain value is thus

ANA_RX_GAIN = VAR5 / 2048.

A minus gain value provides a phase reversal to the input signal.

4.12 CTC_GAIN

This is the CT3258 gain for adjust the TX amplitude of the CTCSS sub-audio signal in analog call mode. It is set with the following command to CT3258.

```
84 a9 61 00 0C 3C {CONFIG} {VAR1-MSB} {VAR1-LSB} {VAR2-MSB} {VAR2-LSB}
{VAR3-MSB} {VAR3-LSB} {VAR4-MSB} {VAR4-LSB} {VAR5-MSB} {VAR5-LSB}
```

VAR3 is for CTC_GAIN.

Other variables are described in other sections of this document and in “Packet Interface of CT3258”.

VAR3 is a sixteen bit number sent in two bytes, with MSB first.

The gain is expressed in linear scale as 16 bit 2’s complement, with 4096 being the 0 dB reference.

The real gain value is thus

CTC_GAIN = VAR3 / 4096.

A minus gain value provides a phase reversal to the input signal.

4.13DCS_GAIN

This is the CT3258 gain for adjust the TX amplitude of the DCS sub-audio signal in analog call mode. It is set with the following command to CT3258.

```
84 a9 61 00 0C 3C {CONFIG} {VAR1-MSB} {VAR1-LSB} {VAR2-MSB} {VAR2-LSB}
{VAR3-MSB} {VAR3-LSB} {VAR4-MSB} {VAR4-LSB} {VAR5-MSB} {VAR5-LSB}
```

VAR4 is for DCS_GAIN.

Other variables are described in other sections of this document and in “Packet Interface of CT3258”.

VAR4 is a sixteen bit number sent in two bytes, with MSB first.

The gain is expressed in linear scale as 16 bit 2’s complement, with 4096 being the 0 dB reference.

The real gain value is thus

DCS_GAIN = VAR4 / 4096.

A minus gain value provides a phase reversal to the input signal.

4.14DIGI_MIC_GAIN

This is the digital MIC gain for vocoders in digital mode. It is set with the following command to CT3258.

```
84 a9 61 00 03 68 {VAR-MSB} {VAR-LSB}
```

VAR is a sixteen bit number sent in two bytes, with MSB first.

The gain is expressed in linear scale as 16 bit 2’s complement, with 2048 being the 0 dB reference.

The real gain value is thus

DIGI_MIC_GAIN = VAR / 2048.

A minus gain value provides a phase reversal to the input signal.

4.15 DIGI_SPEAKER_GAIN

This is the digital speaker gain for vocoders in digital mode. It is set with the following command to CT3258.

```
84 a9 61 00 03 69 {VAR-MSB} {VAR-LSB}
```

VAR is a sixteen bit number sent in two bytes, with MSB first.

The gain is expressed in linear scale as 16 bit 2’s complement, with 2048 being the 0 dB reference.

The real gain value is thus

DIGI_SPEAKER_GAIN = VAR / 2048.

A minus gain value provides a phase reversal to the input signal.

4.16 DC_OFFSET

To enable DC coupling of FM demodulated input from FM discriminator (e.g. 31136), and output signal to the VCTCXO and VCO, CT3258 provide command to set DC offset for matching of the common mode of the codec to the components connecting to the codec.

DC offsets are set with the following command to CT3258.

```
84 a9 61 00 0d 39 00 {VAR1-MSB} {VAR1-LSB} {VAR2-MSB} {VAR2-LSB} {VAR3-MSB}
{VAR3-LSB} {VAR4-MSB} {VAR4-LSB} {VAR5-MSB} {VAR5-LSB} {VAR6-MSB}
{VAR6-LSB}
```

VAR1 and VAR2 are DC OFFSET values applied at the left and right channel ADC. The right channel ADC is connected to the demodulated FM signal.

VAR3 and VAR4 are DC OFFSET values applied at the left and right channel DAC.

VAR5 (DIGI_L_GAIN) and VAR6 (DIGI_R_GAIN) are digital gains for fine tuning the signal level to the DAC.

VAR1 – VAR4 are a linear sixteen bit number sent in two bytes, with MSB first.

The value of the DC offsets are in 2’s complements, with 0x7fff corresponds to the maximum positive DC offset, and 0x8000 corresponds to the maximum negative DC offsets. The electrical voltage of the DC offset depends on the codec types and the analog gain that is applied to the codec.

The maximum offset is capped by the supply voltage of the codec, and the minimum is capped by zero.

For example, for WM8758B codec, and with zero analog gain and AVDD=3.3v, the common mode is at 1.65 V, and the low and high cap are about 0.1 V and 3.2 V. Applying 0x7fff to DC offset moves the common mode to around 3.2V; while applying 0x8000 to DC offset moves the common mode to 0.1 V

5 Initial and Default Parameter Setting

The following tables describe the initial settings for each parameter.

5.1 Wolfson WM8758B

Gain Block	Initial Gain (dB)	Initial settings	Notes
CODEC_MIC_GAIN	35.25	0x3f	
CODEC_DEMOD_GAIN	0	0x10	
DAC_L_GAIN	0	0x39	
DAC_R_GAIN	0	0x39	
CODEC_SPK_GAIN	0	0x39	
DIG_L_GAIN	0	0x08 0x00	
DIG_R_GAIN	0	0x08 0x00	
DIG_DEMOD_GAIN	0	0x00 0x00	Automatic DEMOD Gain match enabled
DIG_MOD_GAIN	0	0x08 0x00	
DIG_MIC_GAIN	-6	0x04 0x00	
DIG_SPEAKER_GAIN	+6	0x10 0x00	
ANA_TX_GAIN	+6	0x10 0x00	
ANA_LIMITER_GAIN	0	0x10 0x00	
CTC_GAIN	0	0x10 0x00	
DCS_GAIN	0	0x10 0x00	
ANA_RX_GAIN	0	0x08 0x00	
DC_OFFSET_L	0	0x00 0x00	No DC offset applied
DC_OFFSET_R	0	0x00 0x00	No DC offset applied
WM8758 Limiter ALC	Enabled	0x41	

5.2 TI TLV320AIC3204

Gain Block	Initial Gain (dB)	Initial settings	Notes
CODEC_MIC_GAIN	44	0x50	
CODEC_DEMOD_GAIN	0	0x0C	
DAC_L_GAIN	0	0x00	
DAC_R_GAIN	0	0x00	
CODEC_SPK_GAIN	0	0x00	
DIG_L_GAIN	0	0x08 0x00	
DIG_R_GAIN	0	0x08 0x00	
DIG_DEMOD_GAIN	0	0x00 0x00	Automatic DEMOD Gain match enabled

DIG_MOD_GAIN	0	0x08 0x00	
DIG_MIC_GAIN	-6	0x04 0x00	
DIG_SPEAKER_GAIN	+6	0x10 0x00	
ANA_TX_GAIN	+6	0x10 0x00	
ANA_LIMITER_GAIN	0	0x10 0x00	
CTC_GAIN	0	0x10 0x00	
DCS_GAIN	0	0x10 0x00	
ANA_RX_GAIN	0	0x08 0x00	
DC_OFFSET_L	0	0x00 0x00	No DC offset applied
DC_OFFSET_R	0	0x00 0x00	No DC offset applied

6 Analog Connections

Even though the left channels and the right channels of the codec ADC's and DAC's are identical, certain limitation are placed on the connection between CT3258 and the codec.

For input, the microphone input is always connected to the left channel ADC; while the FM demodulated signal from the FM demodulator (e.g. 31136) is always connected to the right channel ADC.

At the output side, the speaker line is always connected to the left channel DAC in RX mode. For TX mode, the left channel control and the right channel control are identical, except that the left channel is multiplexed as speaker output in the RX mode. If DC coupling is used for VCTCXO, the right channel is to be connected to VCTCXO input, while the left channel is connected to VCO. If AC coupling is used for VCTCXO control, either left or right channel can be connected to TCXO or VCO.

The analog connections are summarized in the table below.

Analog Signals	Using DC Coupling	Not using DC coupling
Microphone	Left Channel ADC	
FM demod input	Right Channel ADC	
Speaker output	Left Channel DAC	
VCO	Left Channel DAC	Left or Right Channel DAC
VCTCXO	Right Channel DAC	Right or Left Channel DAC

The document below assumes the VCO is connected to the left channel DAC, while the VCTCXO is connected the right channel DAC.

7 Analog Configuration Procedures

Follow these steps for analog configurations. The details are describes in each sections. AC coupling are assume in this section. For DC coupling, refer to the next section for DC offset adjustments. The vocoder in analog configurations should be analog vocoder as 0x10 0x10.

1. Digital frequency deviation
2. Two point modulation for 4FSK
3. Fine tune of frequency response
4. Digital receiver levels
5. BER Test
6. Analog audio frequency deviation
7. Analog Microphone Gain
8. CTCSS frequency deviation
9. Two point modulation for DCS
10. Analog receiver levels
11. Vocoder digital microphone gain
12. Vocoder digital speaker gain

7.1 Digital Frequency Deviation

1. Connect the RF of DUT (device under test, or the radio under configuration) to HP8920.
2. Configure HP8920 in TX testing mode
3. Configure CT3258 to send out 1200/2400 Hz 4 FSK test signal (Section 2.1)
4. Check the frequency deviation level on HP8920, and make sure that it is around 1150 Hz in DPMR mode or 2138 Hz in DMR mode.
5. If not, adjust parameter DAC_L_GAIN to achieve that.
6. Adjust DIG_MOD_GAIN for fine adjustment
7. Continue to the next section

7.2 Two Point Modulation for 4FSK

1. Configure HP8920 to use < 20 Hz low pass filter, set it into scope mode to display the demodulation result
2. The user can replace the HP8292 by using the another RF receiver with a scope to display demodulation result
3. Configure CT3258 to send out 100/200 Hz square wave signal
4. Check the output signals of CT3258 on the LOR port (to VCTCXO) and demodulation result. Both should show a good square wave signal, with slightly or none tilting on the horizontal lines.
5. Adjust parameter DAC_R_GAIN to achieve the best square wave.
6. If the adjustment is out of the range of DAC_R_GAIN, the user can adjust parameter DIGI_R_GAIN as well.
7. Check the output level of LOR (to VCTCXO), make sure that it correctly reflects the

configuration. If the desired LOR level exceeds what is allowed for the codec, hardware adjustment is needed. The user can also try DC coupling, as described in Section 8.

8. When the best demodulated square wave is achieved, configure CT3258 to send out 400 Hz triangular signals.
9. Compare the triangular signals at the transmitter and at the receiver, they should be identical except for amplitude.
10. When both the best square wave and triangular signals are achieved, go back to Section 7.1 to verify frequency deviation is unchanged. Adjust DAC_L_GAIN, DAC_R_GAIN and DIG_L_GAIN and DIG_R_GAIN if necessary.
11. Continue to the next section

7.3 Fine Tuning of Frequency Response

1. Generate a 1200 Hz analog tone as described in Section 2.4. Adjust the amplitude of the analog tone (by changing Tone Amp parameter) so that the frequency deviation is 1050 Hz.
2. Using a scope or an audio analyzer to check the demodulated signal at the receiver, and note its amplitude as A0. Make sure the check point is right after the FM discriminator out and before any coupling capacitor and other audio processing.
3. Vary the frequency of the analog tone between 1 Hz to 3000 Hz, and note the amplitude of the demodulated signal A1. The difference of A1 to A0 should be less than 0.5 dB from 10 Hz to 3000 Hz, and ideally from 1 Hz to 3000 Hz. Adjust DIG_L_GAIN and DIG_R_GAIN to best achieve that.

7.4 Digital Receiver Level

1. With the RF transmitter adjusted for 4 FSK modulation, allow it the transmit RF signal with CT3258 configured to transmit 1200 Hz modulating signals (Section 2.1)
2. Tuning the receiver unit to the RF frequency of the transmitter and allow it to demodulate FM signals.
3. Measure the amplitude of the demodulated signals. They should be at a level of around -14.5 dBFS, where dBFS is the full scale ADC input of the codec. For WM8758B with 3.3v VDDA, 0 dBFS is at 3 V. -14.5 dBFS corresponds to a level of 560 mVpp. For TLV320AIC3204 with 1.8v VDDA, 0dBFS is at 1.5 v, -14.5 dBFS corresponds to a level of 280 mVpp.
4. If not, adjust parameter CODEC_DEMOD_GAIN to such a value that the level at the ADC after the codec gain is at -14.5 dB. (Note that the level of signal before the ADC and after the CODEC_DEMOD_GAIN block can not measured directly). For example, if the level at the demodulator is L dB, CODEC_DEMOD_GAIN = -14.5 – L (dB).

7.5 BER Test

With both transmitter and receiver tuned, perform BER test. The BER test should show a BER of close to zeros when the transmitter and receiver are close to each other (in a room). At the worst, the BER for voice communication should be less than 1 percent; while the BER for data communication should be less than 0.1 percent.

Go back the previous steps if the BER is high, or making adjustment to the RF hardware if all device configurations fail.

7.6 Analog Audio Frequency Deviation

1. Connect the signal generator to the DUT, and send out 1 mVpp and 1000 kHz
2. Connect the RF of DUT (device under test, or the radio under configuration) to HP8920.
3. Configure HP8920 in TX testing mode
4. Make sure ALC on WM8758B, or AGC on TLV320AIC3204 is enabled
5. Set the initial ANA_TX_GAIN to 4096
6. Start an analog voice call without CTCSS/DCS
7. Observe the frequency deviation level on HP8920.
8. Increase the signal level, the maximum frequency deviation level should be limited
9. Make sure the limit is around 2500 Hz.
10. If not, adjust parameter ANALOG_LIMITER_GAIN to achieve that.
11. Continue to the next section

7.7 Analog Microphone Gain

1. Continue from the last session with the same set up and settings.
2. Disable ALC of WM8758B, or AGC of TLV320AIC3204
3. Configure the signal generator to send out a 1000 Hz sine wave with nominal amplitude, e.g., 10 mVpp.
4. Check the frequency deviation level on HP8920, and make sure that it is at 1500 Hz
5. If not, adjust parameter CODEC_MIC_GAIN to make it close to 1500 Hz. Fine tune the frequency deviation with parameter ANA_TX_GAIN to get to 1500 Hz. Make sure that ANA_TX_GAIN should have a minimum value of 4096 (+6 dB gain). If this value is below 4096, the user can reduce CODEC_MIC_GAIN and increase ANA_TX_GAIN.
6.
7. Re-enable ALC of WM8758B, or AGC of TLV320AIC3204
8. Continue to the next section

7.8 CTCSS Frequency Deviation

1. Disconnect the signal generator
2. Start a call with CTCSS enabled.
3. Check the frequency deviation of the CTCSS signal. It should be around 350 Hz.
4. If not, adjust parameter CTCSS_GAIN to achieve that
5. Continue to the next sections

7.9 DCS Frequency Deviation

1. Configure HP8920 to use < 20 Hz low pass filter, set it into scope mode to display the demodulation result
2. The user can replace the HP8292 by using the another RF receiver with a scope to display

demodulation result
3. Start a call with DCS enabled
4. Check the output signals of CT3258 on the LOR port (to VCTCXO) and demodulation result. Both should show a good square wave DCS signal, with slightly or none tilting on the horizontal lines.
5. Adjust DIG_L_GAIN and DIG_R_GAIN to achieve the best DCS signals. The resulting DIG_L_GAIN and DIG_R_GAIN should be the same as in Section 7.3. If not, the user should save separate DIG_L_GAIN and DIG_R_GAIN set for analog call and for digital calls.
6. Make sure the frequency deviation of the DCS to be around 350 Hz, by adjusting DCS_GAIN.

7.10 Analog Receiver Level

1. With the RF transmitter adjusted for analog transmission, start an analog voice call.
2. Connect the signal generator to the RF transmitter, and send out a nominal level signal at 1000 Hz.
3. Connect a scope to the output of the SPK_OUT of CT3258 (LOUT1)
4. Tuning the receiver unit to the RF frequency of the transmitter and allow it to demodulate FM signals.
5. Set CODEC_DEMOD_GAIN to the same level as adjusted for the digital receiver
6. Measure the amplitude of the signals at SPK_OUT, while increase the level on the signal generator.
7. The output signal should be limited at a level around -12 dBFS. For WM8758B with 3.3v VDDA, the level should be around 750 mVpp.
8. If not at 750 mVpp, adjust CODEC_DEMOD_GAIN accordingly.

7.11 Vocoder Digital Microphone Gain

1. The vocoder digital microphone gain (DIGI_MIC_GAIN) adjustment has to be done after the analog microphone gain adjustment, see section 7.7.
2. DIGI_MIC_GAIN adjustment is mostly based on subjective listening, and is between -6 to -12 dB.
3. One user speaks to the microphone in one end; the other user listens to the speaker out at the other end. The value of DIGI_MIC_GAIN should be that the voice is loud and clear without the effect of saturation or overflow
4. Note that the optimum gain value may be vocoder dependent

7.12 Vocoder Digital Speaker Gain

1. The vocoder digital speaker gain (DIGI_SPEAKER_GAIN) adjustment has to be done after the vocoder digital microphone gain adjustment, see section 7.11.
2. DIGI_SPEAKER_GAIN adjustment is mostly based on subjective listening, and is between +6 to +12 dB.
3. One user speaks to the microphone in one end; the other user listens to the speaker out at the other end. The value of DIGI_SPEAKER_GAIN should be that the voice is loud and clear

without the effect of saturation or overflow

4. Note that the optimum gain value may be vocoder dependent

8 DC Coupling

For best performance, DC coupling between the FM discriminator (e.g. 31136) and the codec ADC input, and between the codec DAC output and the VCTCXO are recommended. CT3258 provide command to set DC offset for matching of the common mode of the codec to the components connecting to the codec.

Tuning the radio with DC coupling can start the same way as AC coupling, by keeping the coupling capacitor first and complete all adjustment in Section 7. After all tuning is done, measure the voltage difference before and after the capacitor. Use the DC_OFFSET command as described in Section 4.16 to compensate for the difference. When the voltage before and after the capacitor is the same, the user can remove the capacitor to realize DC coupling.

The following should be noted when doing DC coupling:

1. If DAC_L_GAIN and DAC_R_GAIN is none zero, the DC level is amplified or reduced by the gains as well. The user should keep this in mind when changing DAC_L_GAIN and DAC_R_GAIN. The alternative is to keep DAC_L_GAIN and DAC_R_GAIN to zero dB gain, and only adjust DIG_L_GAIN and DIG_R_GAIN.
2. With DC coupling, the maximum signal level can be compressed if the DC offset is none zero. If the maximum signal level is Lmax, and full scale of the ADC and DAC is FS, the following condition should be met for AC couple: Lmax <= FS/2. For DC couple, the condition becomes: DC_OFFSET + Lmax < FS/2. The larger the DC offset, the smaller the maximum signal level.

