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1 Introduction

The CMX882 is a sophisticated modem + baseband processor targeted at “family radio” applications (e.g. FRS/GMRS/MURS/PMR446 radios). It is particularly well suited to family radios that include facilities for text messaging and GPS location data exchange.

The purpose of this application note is to illustrate how the CMX882 can be configured for a feature-rich “family radio” product. The CMX882 facilitates the following features:

- Voice communications
- Text Messaging (both open and private messages)
- GPS location data
- Unique ‘ring tones’
- Audible alerting tones, for example indicating when a button has been pressed
- ‘All Call’ (urgent) call capability

The CMX882 datasheet should be consulted while reviewing the information in this document.

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2 Description of Scenario

This document will use a combination of a state diagram and routines associated with these states to provide an overview of how the host microcontroller should control the CMX882 to perform the necessary tasks.

In our system we will assume that two hand held FRS radios are being used both of which are equipped with the CMX882. The following functions are required:

- Half duplex voice communications
- Text Messaging (both 'open' and 'private' messages)
- GPS location data
- Unique 'ring tones' (single tones and simple melodies)
- 'All Call' (urgent) call capability

Clearly the CMX882 could be used to implement many more radio designs, however this document is not intended to describe all options but to provide a detailed overview of what is required in software to control the CMX882.

For engineers who have other requirements and wish to discuss them further or who wish to receive further clarification on the information in this document, please contact the CML Help Desk for your respective geographic area:

| | |
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2.1 Transmit Functions

The user of one of our FRS radios will be able to press the “Push To Talk” (PTT) radio button to begin a voice transmission to the second remote radio. When the PTT button is pressed:

1. An audible alerting tone should be generated by the CMX882 so the user knows a button was pressed.
2. If the user has previously configured a “buddy list” in software look up table, they can scroll through the list and highlight the person(s) they wish to call before pressing the PTT button.
3. The radio will create a message header, using the CMX882’s XTCSS functions, to indicate to the remote user that a voice message is about to be received.
4. After the audible alerting tone is generated and the XTCSS header is transmitted, the CMX882 can process the transmitted speech (e.g. pre-emphasis). The CMX882 can also generate a sub-audio tone (i.e. CTCSS tone) that may be transmitted with the voice signal.

The user can press the “Poll” button to manually request the location data of the remote user. When the “Poll” button is pressed:

1. An audible alerting tone will be generated by the CMX882 so the user knows a button was pressed.
2. The CMX882 can be instructed to automatically transmit an XTCSS tone burst to the remote user. This XTCSS burst will contain a special tone that instructs the remote user to transmit its location data back to the calling radio.

The user can send a text message to a remote user by entering text on the FRS radio and pressing the “Send” button.

1. The user will select the ‘text message’ function (the activation of the ‘text message’ function is not described in this document).
2. The user selects the intended recipient of the message and indicates whether the message is ‘open’ or ‘private’.
 - If the user has previously configured a “buddy list”, the user can scroll through this list and highlight the desired message recipient(s).
3. The user can compose the text message by one of the two following methods:
 - Preset text messages. The user can scroll through a list of pre-programmed text messages stored on the host microcontroller and highlight the desired message.
 - User-typed text messages. The user enters the desired text through the radio’s keypad.
4. Once these steps are done and the “Send” button is pressed, the host microcontroller and CMX882 can:
 - Generate an XTCSS transmission that contains:
 - The address of the recipient.
 - A code to indicate that the message is data.
 - Process the raw text message data from the microcontroller, create a properly formatted FFSK/MSK data frame, and present this frame to an external RF transceiver for transmission.

If the received message is corrupt, the remote radio can use its CMX882 to transmit a “retransmission request” via an XTCSS tone burst.

The CMX882 enabled FRS radio in this application will also regularly transmit its location data to other users. The XTCSS and FFSK/MSK capabilities of the CMX882 power this feature.

Note 1: XTCSS is a state-of-the art (squellch) signaling format, employing both sub-audio (CTCSS) and in-band (XTC) signaling concurrently, which offers more than twice as many privacy codes as standard CTCSS operation and completely eliminates interference caused by other traffic on the channel (quiet operation). Additionally the XTCSS signaling can be employed as an over-air control for such features as voice scrambling and voice-compression. XTCSS is fully compatible with both conventional and enhanced CTCSS signalling operations and will implement the ‘All Call Code’ and ‘All Codes Monitor’ functions.

2.2 Receive Functions

The FRS radio will normally be in “sleep” mode waiting to receive a call. When an incoming transmission is detected, the CMX882 can be instructed to “wake up” and enter a special mode that allows it to simultaneously search for multiple pre-programmed signaling schemes, such as XTCSS, CTCSS and FFSK/MSK.

1. If the incoming transmission is a request for location data, the host microcontroller should instruct the CMX882 to:
 - Switch to transmit mode.
 - Generate an XTCSS tone burst.
 - Transmit its location data in an FFSK/MSK data frame to the remote radio.
2. If the incoming transmission is a “retransmission request” (in other words, the remote radio received a corrupted data packet and is asking for a retransmission) the CMX882 will:
 - Switch to transmit mode.
 - Generate an XTCSS tone burst.
 - Retransmit the previous FFSK/MSK data frame to the remote radio.
3. If the incoming transmission is a data message (e.g. location data from remote user), the CMX882 will interpret the data message and present the data to the microcontroller for display.
4. If the incoming transmission is a voice call, the CMX882 will:
 - Generate a ring tone to alert the user that a call is about to be heard.
 - Process the recovered voice signal for presentation to the external speaker driver.

The user can press the radio’s “Monitor” button to listen for all activity on a channel. When this happens:

1. An audible alerting tone will be generated by the CMX882 so the user knows a button was pressed.
2. The CMX882 will be instructed to activate its audio output amplifier to allow any received signal to be passed to the radio’s speaker or headset.

2.3 Assumptions

The following assumptions were used in the development of this application note:

- Supply Voltage, $V_{dd}=3.0V$.
- External components configured in accordance with CMX882 datasheet.
- External 18.432MHz crystal oscillator circuit is used.
 - “CLOCK_OUT” pin is disabled in this scenario.
- FRS service with 25kHz channel spacing.
- Voice Information:
 - Transmitted on MOD_1.
 - Pre/de-emphasis enabled.
 - Voice level required for +/-3kHz deviation = 308mVrms.
 - No voice inversion.
- CTCSS Information:
 - Transmitted on MOD_2 during voice transmissions for squelch control.
 - Not used for FFSK/MSK transmissions.
 - CTCSS tone amplitude required for +/-300Hz deviation = 31mVrms.
 - 31mVrms is approximately 20dB down from assumed 308mVrms voice level (10:1 ratio for voice-to-subaudible tone).
 - No sub-audio tone inversion.
 - **Note:** Actual voice and sub-audible tone levels depend on VCO gain and desired deviation; these specifications are application dependent.
- XTCSS Information:
 - Performed at beginning of all transmissions.
 - Not used to signal end of transmissions.
 - Transmitted on MOD_1.
 - Four XTCSS tones used in burst.
 - Individual tone lengths=60ms.
 - 60ms “silence suffix” follows 4-tone burst.
- FFSK/MSK Information:
 - Transmitted on MOD_1.
 - FFSK/MSK Transmit Address = 30d = 0x1E (arbitrarily chosen).
 - FFSK/MSK Receive Address = 79d = 0x4F (arbitrarily chosen).
 - 2400bps, Type 5 message format.
 - Frame length = 80 bytes (arbitrarily chosen).
 - Standard scrambling seed.
 - Default bit sync (0x5555) and frame sync (0xCB23) patterns are used.
- Alerting (Ring) Tones
 - Single 1250Hz ring tone is used in this scenario, but the user can select different ring tones or combinations of tones.
 - Ring tone level = 308mVrms.
- RSSI signal monitored with Aux ADC via SIG MONITOR pin during Rx mode.
 - High threshold (good carrier signal) = 1.85V for -60dBm received signal strength.
 - Low threshold (indicates weak signal) = 0.9V for -100dBm received signal strength.
 - The received signal strength values used for this document include no “noise margin”. The user must evaluate their application and determine the optimal RSSI threshold and hysteresis settings.
- RF discriminator output is applied to CMX882 DISC pin.
- CMX882 Audio pin delivers ring/alerting tones and recovered voice to an external speaker driver amplifier for presentation to the radio speaker.

The normal operating mode for the CMX882 in this application is powered down, monitoring RSSI on SIG MONITOR pin with its ADC, with Rx Auto Startup enabled (STATE 2).

Note 2: The address held in the Audio and Device Address register (\$C2) is used when decoding CTCSS, XTCSS or FFSK/MSK data.

Note 3: Both CTCSS (where CTCSS is used as the “special” sub audio maintenance tone) and XTCSS can be used consecutively without affecting the address in \$C2. However simultaneous transmission or reception of CTCSS and XTCSS will limit the maximum address size in \$C2 to 1 to 51 for both signals. Similarly if XTCSS and FFSK/MSK are used together then the address range must not exceed 99; FFSK/MSK alone (no XTCSS) can have an address of up to 255.

3 General Comments

The following comments concern specific operating conditions of the CMX882. All of these points are described in the CMX882 datasheet but are provided here for ease of reference:

3.1 Transmit Operation

In this application, FFSK/MSK data is transmitted without an accompanying sub-audio tone. If it is desired for a sub-audio tone to accompany the FFSK/MSK transmission:

- Transmit an XTCSS 4-tone burst at the beginning of the transmission.
- Select a CTCSS tone from Table 3 in the CMX882 datasheet.
 - This tone should be loaded into b7-0 of Audio and Device Address Control (\$C2) register.
- When the XTCSS burst is complete, deselect XTCSS and select CTCSS + FFSK/MSK transmission in the Mode Control (\$C1) register.

3.1.1 FFSK/MSK Data Format

The FCC has recently modified the rules concerning FRS radios and data transmission. The key points of these rule changes include:

- Brief text (data) messages can now be transmitted.
- A data transmission cannot be longer than 1 second.
- A radio cannot transmit data more often than once each 30 seconds, but an exception is made to allow the radio to autonomously transmit its location data when polled to do so by another radio.

These rule changes have made text messaging on FRS radios a possibility!

Data transmission at the fastest possible rate is desired in order to maximize the opportunity provided by these rule changes. Since FRS radios have limited bandwidth, and since the data must be suitable for “voice path” transmission and reception, 2400bps is the optimal tradeoff between transmission speed and occupied bandwidth.

The CMX882 offers six different FFSK/MSK data formats that differ in error detection, error correction, and robustness to burst errors. The CMX882’s most robust FFSK/MSK message format, “Type 5”, provides maximum protection against errors and has been selected for this application.

Since the time available for transmission is limited, the amount of data available for transfer should be considered. The following table lists the ‘overhead’ requirements for the Type 5 message format and the amount of actual data available for transfer in one second.

| | | |
|--|-------|---------|
| Maximum bits in 1 second | 2400 | bits |
| Frame Head length, in bits | 80 | bits |
| Length of last CRC block + FEC, in bits | 48 | bits |
| Available bits remaining in 1 second | 2272 | bits |
| Size of a single data block = 4 data bytes + FEC (4bits x 4) | 48 | bits |
| Maximum integer number of data blocks | 47 | Blocks |
| Maximum data bytes = 4 x maximum number of data blocks | 188 | Bytes |
| Time for {Frame Head + User Data + Final CRC} | 0.993 | seconds |

Table 1: Estimation of Data Throughput for Type 5 Message Format

Each 8-bit character has 4 bits of FEC automatically added by the CMX882 in Type 5 message format. As can be seen from the table, 190 x 8-bit characters can be transmitted in one second using the robust Type 5 message format. This amount of data can easily convey multiple short sentences or phrases, and this is exactly the type of information typically communicated via text messaging.

The Type 5 message format utilizes a “frame head” that contains address and control information. The Frame Head contents are listed in the following table:

| Frame Head Byte | Comments |
|------------------------|--|
| <i>Bit Sync</i> | User-defined, value is loaded into Programming register blocks P0.6 and P0.7. Default value after C-BUS reset or power on reset is 0x5555 (i.e. 0101...) |
| <i>Frame Sync</i> | User-defined, value is loaded into Programming register blocks P0.0 and P0.1. Default value after C-BUS reset or power on reset is \$CB23. |
| <i>Address Byte</i> | User-defined, value is loaded into TX DATA register (\$CA), b15-8. Range of valid address is 1-255 (decimal). |
| <i>Format Byte</i> | Automatically generated by the CMX882; value depends on b7-5 of MODEM CONTROL (\$C7) register. |
| <i>Size/User Byte</i> | User-defined, value is loaded into TX DATA register (\$CA), b7-0. Range of valid sizes is 1-255 (decimal). |
| <i>Checksum A</i> | Automatically generated by the CMX882. |

Table 2: FFSK/MSK Type 5 Message Format Frame Head Contents

3.1.2 FFSK/MSK (Transmit) Operating Tips

- Transmitted FFSK/MSK address must be loaded into TX DATA (\$CA) register b15-8.
- Transmitted FFSK/MSK “Size/Information” byte must be loaded into TX DATA (\$CA) b7-0.

3.2 Receive Operation

3.2.1 FFSK/MSK (Receive) Operating Tips

- Receive FFSK/MSK address is loaded into Audio and Device Address Control (\$C2) register b7-0.

3.2.2 Other Receive Operating Tips

- To de-emphasize received in-band tones:
 - Mode Control (\$C1) b15=1.
 - Audio and Device Address Control (\$C2) b10=1.
 - Programming REGISTER (\$C8), P1.0 b0=1.

3.3 XTCSS Operation

XTCSS is an in-band tone signaling scheme that provides many advantages over traditional sub-audio tone signaling approaches. XTCSS uses a four-tone burst of 'in-band' tones to communicate user-defined information, such as:

- The type of incoming message (i.e. voice, data, non-voice, etc)
- The address of the intended recipient (individual, group, all call, etc.)
- Required voice-processing functions, such as whether or not pre-emphasis, etc, has been added to the signal.

The XTCSS burst should be transmitted as follows:

- Load the desired "A1/A0" address into b7-0 of the Audio and Device Address Control (\$C2) register.
- Load a value into the XTCSS Codes (\$CB) register that is consistent with the desired transmission type. Possible XTCSS code values are provided in the following table:

| XTCSS Codes (\$CB) | | Message Format Code Assignment |
|--------------------|-------|---|
| S1 | S0 | |
| b15-12 | b11-8 | |
| 0000 | 1011 | Retransmission Request |
| 0001 | 1011 | Location Data Request |
| 0001 | 1100 | Voice message; compressed, pre-emphasized and voice filtered. |
| 0010 | 1011 | Data message; retransmission of last packet |
| 0011 | 1011 | Data message; location data |
| 0100 | 1011 | Data message; 'open' text message with no scrambling |
| 0101 | 1011 | Data message; 'private' text message with scramble seed 0xFFFF (default seed) |

Table 3: XTCSS Code Usage

- Lower byte of XTCSS Codes (\$CB) register is not used and should be configured with 0x00.
- Load 0x9000 into the Interrupt Mask register to allow an interrupt upon completion of the XTCSS transmission.
- Load 0x6002 into Mode Control (\$C1) register to activate transmit mode.

When the "XTCSS 4 tone set complete" interrupt occurs, the host microcontroller should disable XTCSS transmission and start a timer with duration equal to the XTCSS tone length. Any subsequent transmission, if required, should only occur once this timer has elapsed to ensure that the XTCSS "silence suffix" is observed.

For receive operation, the user's address should be loaded into b7-0 of the Audio and Device Address Control (\$C2) register. An interrupt with "XTCSS 4 tone set complete" (Status register b12=1) indicates that an XTCSS burst with correct addressing has been received. The host microcontroller should then read out the RX DATA (\$C9) register contents, interpret the message format, and configure the CMX882 accordingly.

3.3.1 XTCSS (Transmit) Operating Tips

The CMX882 should not be configured for XTCSS maintenance tone transmission and voice transmission simultaneously. If the application requires a sub-audio tone for squelch control purposes, one of the standard CTCSS tones should be selected.

For XTCSS transmission:

- The XTCSS address ('A0' and 'A1') is defined in the Audio and Device Address Control (\$C2) register.
- The XTCSS information ('S0' and 'S1') is defined in b15-8 of XTCSS Codes (\$CB) register.

The host application must wait one XTCSS tone period (e.g. 60ms in this example) after the XTCSS transmission is complete before beginning voice or FFSK/MSK data transmission.

3.3.2 XTCSS (Receive) Operating Tips

For XTCSS reception:

- The expected XTCSS address ('A0' and 'A1') is programmed into b7-0 of the Audio and Device Address Control (\$C2) register.
- The recovered XTCSS address is stored in b7-0 of RX DATA (\$C9) register.
- Parallel CTCSS and XTCSS operation limits the recovered address of either CTCSS or XTCSS to 51 or below.
- The recovered XTCSS information is stored in b15-8 of RX DATA (\$C9) register.

Once the XTCSS burst has been received, the user should disable the XTCSS decoder by setting b14-13=00 in the Mode Control (\$C1) register.

3.4 Programming Register (\$C8)

The Programming register (\$C8) is used to adjust many CMX882 settings. Please note that in order to write values to this register, the following steps must be taken:

- Power Down Control register (\$C0)
 - B5=1 (signal processing block enabled).
 - B3=0 (crystal circuit enabled).
 - B0=0 (Rx auto startup disabled).
- Interrupt Mask register (\$CE) = 0x8001.
 - Programming Flag interrupt enabled.
 - All other interrupts are masked.
- Status register (\$C6) b0=1.

3.5 Status Register (\$C6)

- Status register contents are only valid when Power Down Control register b5=1.

3.6 Signal Levels in Transmit and Receive

- The sum of the in-band signal and sub-audio signal must be less than the recommended maximum signal level through the CMX882, (e.g. 700mVrms Voice + 70mVrms CTCSS = 770mVrms < 800mVrms approx @ 3.3 Vdd). This rule applies to all functional elements in the Tx and Rx paths (limiter, offset adjust etc), all signal types (CTCSS, XTCSS, FFSK/MSK etc) and across the in-band and sub-audio frequency range.

4 Operating States

There are several possible operating states for the CMX882 in this application. The following state flow diagram illustrates the possible transitions between the various operating states.

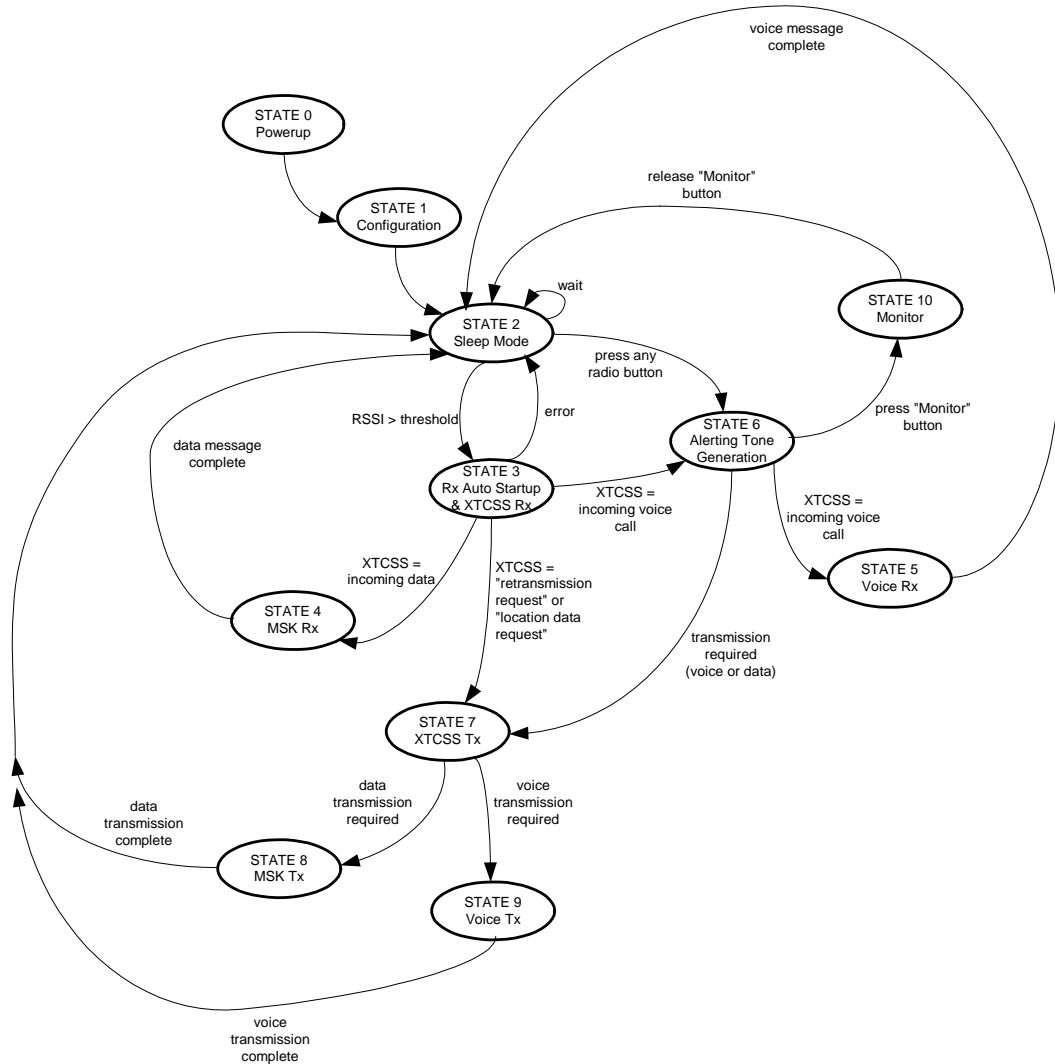


Figure 1: CMX882 Application State Flow Diagram

4.1 Initial States: State 0 and State 1

State 0 simply involves powering up the CMX882. To ensure that the CMX882 is powered up properly and that the device is placed in a known state, the following powerup procedure is recommended:

- Apply power to the device.
- Issue a C-BUS reset, which clears all registers except the Programming registers (\$C8).
- Set Power Down Control register (\$C0) b5=1. This action will set all Programming registers (\$C8) to their default condition.

Once these steps have been completed, \$C0 bits b5 and b2 can both be set to 0 to minimize power consumption, if desired.

State 1, "Configuration", involves resetting the CMX882 and configuring registers that will not normally require adjustment during operation. The registers adjusted in the Configuration state are provided in the following table. The following notes provide additional clarification on the steps provided in the Configuration table:

1. The first few steps are intended to prepare the CMX882 for writes to its Programming register. Since the C-BUS RESET in State 0 causes the Mode Control register (\$C1) = 0x0000, the CMX882 is in Idle Mode which is required for Programming register writes. Also, the act of setting \$C0 b5=1 in State 0 is a required step for Programming register writes. Since this too has already been done, it does not need to be performed again in State 1.
2. No writes are made to Block 0 of the Programming register because the default values for MSK parameters are used in this scenario.
3. Writes are made to P1.1 of the Programming Register to configure the XTCSS detection threshold. MSK detection threshold is adjusted in STATE 8, FFSK/MSK Reception.
4. No write is made to P4.7, Transmit Limiter Control, so the default limiting value (+/- Vdd/2) is used. This effectively results in no Tx voice signal limiting being performed by the CMX882.

| Register Address | Register Name | Register Contents | Effect |
|------------------|-------------------------|-------------------|---|
| \$CE | INTERRUPT MASK | 0x8001 | Programming Flag IRQ enabled. |
| \$C8 | PROG REG (P1.0) | 0xD4A6 | XTCSS Tx level = Alerting Tone Tx level = MSK Tx level = 308mVrms. |
| \$C8 | PROG REG (P1.1) | 0x5459 | 60ms XTCSS tone length, XTCSS tone detection threshold=18.2mVrms, +/-1.3% "will decode" bandwidth. (NOTE: P1.1 settings for XTCSS and MSK detection thresholds differ. Since XTCSS will always precede MSK in this application, the XTCSS threshold is programmed first in this section. MSK detection threshold value is adjusted in STATE 8, FFSK/MSK Reception.) |
| \$C8 | PROG REG (P2.0) | 0xE1DC | CTCSS Tx level = 31mVrms |
| \$C8 | PROG REG (P2.1) | 0x6088 | 16mVrms CTCSS detection threshold, +/-1.1% CTCSS "will decode" bandwidth. |
| \$C8 | PROG REG (P2.2) | 0x6000 | Must write to this register in order to write to subsequent registers in P2.x block. |
| \$C8 | PROG REG (P2.3) | 0x6000 | Must write to this register in order to write to subsequent registers in P2.x block. |
| \$C8 | PROG REG (P2.4) | 0x6900 | Subaudio dropout time 72ms. Typical dropout immunity = (72 + 40) = 112ms, and typical deresponse time = (72 + 90) = 162ms. |
| \$C8 | PROG REG (P4.0) | 0x8000 | Fine Input Gain = 0dB. |
| \$C8 | PROG REG (P4.1) | 0x0000 | Must write to this register in order to write to subsequent registers within Block 4. |
| \$C8 | PROG REG (P4.2) | 0x0000 | Fine Output Gain 1 = 0dB (affects Audio output gain stage). |
| \$C8 | PROG REG (P4.3) | 0x0000 | Fine Output Gain 2 = 0dB (affects MOD_2 output). |
| \$C8 | PROG REG (P4.4) | 0x0000 | Must write to this register in order to write to subsequent registers in the P4.x block. |
| \$C8 | PROG REG (P4.5) | 0x0000 | Must write to this register in order to write to subsequent registers in the P4.x block. |
| \$C8 | PROG REG (P4.6) | 0x0183 | Tx Ramp Up Control = Tx Ramp Down Control = 3 which corresponds to 5.3ms ramp time. |
| \$C0 | POWER DOWN CONTROL | 0x0057 | Enabled: Bias, Programming register Save, xtal oscillator circuit, Aux ADC, Rx Auto Startup. |
| \$B1 | SIGNAL ROUTING | 0x0030 | Analog I/P from discriminator. |
| \$B2 | AUXILIARY ADC THRESHOLD | 0x9E4D | ADC high threshold=1.85V, low threshold=0.9V |
| \$B3 | AUXILIARY ADC CONTROL | 0x06 | 8-bit register write, ADC input from SIG MONITOR, conversion interval = 125µs (recommended for Rx Auto Startup mode). |

Table 4: CMX882 'STATE 1' Settings

4.2 STATE 2: Sleep Mode

This is the default operating state for the CMX882 in this application.

In this condition, the CMX882 is powered down to the maximum extent possible while monitoring for incoming carrier. The Received Signal Strength Indicator (RSSI) signal is supplied to the SIG_MONITOR pin, and the CMX882 monitors RSSI with its auxiliary ADC.

The following table illustrates the register configurations needed for State 2. Additional information pertaining to these register configurations is provided below:

1. The Mode Control (\$C1) register is placed in 0x0000 to activate Idle Mode. This is performed because multiple Tx and Rx states can transition back to State 2, and Idle Mode acts as a baseline for subsequent operations. Idle mode is also required to be activated prior to enabling Rx Auto Startup.
2. Blocks 1.0 & 1.1 of the Programming register are written to the same values in this state as they are in State 1. The reason is multiple states can transition to State 2, including the State 4 "MSK Rx" which changes the Block 1.0 & 1.1 values. To ensure proper transition out of State 2, these Programming register blocks are reprogrammed here.

| Register Address | Register Name | Register Contents | Effect |
|-------------------|----------------------------------|-------------------|---|
| \$C1 | MODE CONTROL | 0x0000 | Idle mode. |
| Wait 350us | | | |
| \$C0 | POWER DOWN CONTROL | 0x0064 | Enable signal processing and xtal circuit. |
| \$CE | INTERRUPT MASK | 0x8001 | Programming Flag IRQ enabled. |
| \$C8 | PROG REG (P1.0) | 0xD4A6 | XTCSS level = alerting tone level = MSK level = 308mVrms. |
| \$C8 | PROG REG (P1.1) | 0x5459 | 60ms XTCSS tone length, XTCSS tone detection threshold=18.2mVrms, +/-1.3% "will decode" bandwidth. (NOTE: P1.1 settings for XTCSS and MSK detection thresholds differ. Since XTCSS will always precede MSK in this application, the XTCSS threshold is programmed here. This register is adjusted in the FFSK/MSK Reception state.) |
| \$C0 | POWER DOWN CONTROL | 0x0057 | Enabled: Bias, Programming register save, crystal oscillator circuit, Aux ADC, Rx Auto Startup. |
| \$B1 | SIGNAL ROUTING | 0x0030 | Analog I/P from discriminator. |
| \$C2 | AUDIO AND DEVICE ADDRESS CONTROL | 0x1401 | 25.0kHz channel filtering, pre/de-emphasis enabled, XTCSS address 1 selected (user's identity, pre-loaded for receive purposes). |
| \$CE | INTERRUPT MASK | 0x8200 | Aux ADC High IRQ enabled. |
| \$C1 | MODE CONTROL | 0x6819 | Voice path disabled, XTCSS tones monitored, CTCSS tones monitored, FFSK/MSK 1200bps and 2400bps monitored, Rx mode. |

Table 5: CMX882 'STATE 2' Settings

4.3 STATE 3: RX Auto Startup and XTCSS Reception

In order to reach this state, incoming RF carrier has caused the RSSI signal to exceed the CMX882's Auxiliary ADC high threshold. When this happens, Status register (\$C6) b9=1 and an interrupt is issued.

The CMX882 automatically starts up in Rx mode and monitors for the previously selected signaling schemes (XTCSS, CTCSS, and FFSK/MSK in this example). The Rx auto startup sequence will also set b5, b12, and b13 in the Power Down Control register (\$C0) to enable:

- Signal Processing
- Input Gain stage
- Disc I/P amplifier

A few more configuration changes should be performed at this time:

| Register Address | Register Name | Register Contents | Effect |
|------------------|----------------------------------|-------------------|--|
| \$C0 | POWER DOWN CONTROL | 0x3076 | Enabled: Disc amp, Input Gain amp, Bias, Signal Processing, Prog Reg Save, xtal oscillator circuit, Aux ADC. |
| \$B0 | ANALOG GAIN | 0x0000 | Input gain 0dB |
| \$C2 | AUDIO AND DEVICE ADDRESS CONTROL | 0x0001 | XTCSS address 1 selected (user's identity). |
| \$CE | INTERRUPT MASK | 0x9900 | Enabled IRQs: XTCSS 4-tone detection, CTCSS detection, Aux ADC Low (to detect loss of carrier). |
| \$C1 | MODE CONTROL | 0x6801 | XTCSS monitored, CTCSS monitored, Receive mode enabled. |

Table 6: CMX882 'STATE 3' Settings

The CMX882 sets Status register (\$C6) b12=1 to indicate that a 4-tone XTCSS sequence with proper addressing has been received. The microcontroller should then read out the XTCSS information from RX DATA register (\$C9) and transition to the required state according to the format of the incoming message.

If the CMX882 does not detect a 4-tone XTCSS sequence with proper addressing, the host microcontroller should revert to STATE 2.

4.4 STATE 4: FFSK/MSK Reception

At this point, the CMX882 has:

- Detected the presence of incoming RF carrier.
- Detected a valid 4-tone XTCSS burst with required “silence suffix”.
- Interpreted the XTCSS sequence and provided its information in the RX DATA register (0xC9).

The XTCSS “S1” and “S0” codes indicate that a FFSK/MSK message (2400b/s Type 5 format) is about to be received. The CMX882 is configured for this message as follows:

| Register Address | Register Name | Register Contents | Effect |
|-------------------|----------------------------------|-------------------|--|
| \$C1 | MODE CONTROL | 0x0000 | Idle device mode (facilitates writes to the Programming register). |
| Wait 350us | | | |
| \$C0 | POWER DOWN CONTROL | 0x0064 | Enabled: Bias, Signal Processing, crystal oscillator circuit. Rx Auto Startup disabled to allow for writes to Programming register. |
| \$CE | INTERRUPT MASK | 0x8001 | All IRQs disabled with the exception of the Programming Flag IRQ (IRQ will be generated when it is permissible to write to the Programming register). |
| \$C8 | PROG REG (P1.0) | 0x0000 | Must write to this register in order to write to subsequent registers in P1.x block. |
| \$C8 | PROG REG (P1.1) | 0x55C9 | FFSK/MSK detection threshold=102mVrms. |
| \$C0 | POWER DOWN CONTROL | 0x3076 | Enabled: Disc amp, Input gain amp, Bias, Signal Processing block, Prog Reg Save (protects Programming register contents), crystal oscillator circuit, Aux ADC. |
| \$B0 | ANALOG GAIN | 0x0000 | Input Gain=0dB. |
| \$B1 | SIGNAL ROUTING | 0x0030 | Analog input from DISC. |
| \$C2 | AUDIO AND DEVICE ADDRESS CONTROL | 0x004F | No filtering or de-emphasis applied; FFSK/MSK address 79d (0x4F). |
| \$C7 | MODEM CONTROL | 0x00A0 | Data packeting enabled, Type 5 FFSK/MSK message format, standard scrambling. |
| \$CE | INTERRUPT MASK | 0x81D0 | Enabled IRQs; Aux ADC Low (to detect loss of carrier), FFSK/MSK data end, FFSK/MSK data transfer ready, Rx 2400b/s detection. |
| \$C1 | MODE CONTROL | 0x0011 | 2400b/s FFSK/MSK monitored, receive mode. |

Table 7: CMX882 'STATE 4' Settings

An IRQ is expected at this point due to the detection of a valid ‘Frame Head’ with correct CRC. If this ‘Frame Head detection’ IRQ doesn’t occur, the CMX882 should be placed in STATE 7, XTCSS Transmission, and a retransmission request made to the remote user.

When the IRQ occurs, the Status register (\$C6) should be read and appropriate action taken as follows:

- If b5-4=1x:
 - Block CRC error has been detected.
 - GO TO STATE 9 “XTCSS Transmission” and request retransmission of FFSK/MSK frame.
- If b5-4=01:
 - The 2400b/s FFSK/MSK Frame Head detection process is complete.
 - Correct CRC is detected and Address Byte matches the programmed FFSK/MSK address.
 - Address and Size bytes from Frame Head can be read out of \$C5 and \$C9, respectively.

Once the Frame Head detection process is successfully completed, the CMX882 will issue interrupts to indicate when FFSK/MSK data is available for reading. (Status register b6=1 indicates a received data byte is available.) The microcontroller must read FFSK/MSK data out of \$C5 and \$C9; register \$C9 is used as a second FFSK/MSK receive data buffer in Type 5 message format.

An IRQ with Status register b7-6=11 indicates that the received FFSK/MSK frame is complete. The microcontroller must read the final FFSK/MSK data out of 0xC5 and 0xC9.

The FFSK/MSK reception process is now complete, and the CMX882 software can go back to STATE 2, Sleep Mode.

4.5 STATE 5: Voice Reception

At this point, the CMX882 has:

- Detected incoming RF carrier.
- Detected a valid 4-tone XTCSS burst and the required “silence suffix”.

The microcontroller has read out the “S0” and “S1” XTCSS information and determined that an incoming voice message is being received.

The receiving radio will notify the user of an incoming call by generating an audible ring tone. This step can be accomplished by temporarily transitioning to STATE 6 (Alerting Tone Generation). Once the audio tone generation is complete, the audio tone can be terminated and the CMX882 prepared for voice processing with the following commands:

| Register Address | Register Name | Register Contents | Effect |
|-------------------|----------------------------------|-------------------|--|
| \$C1 | MODE CONTROL | 0x0000 | Idle mode. |
| Wait 350us | | | |
| \$C0 | POWER DOWN CONTROL | 0x38F6 | Enabled: Disc amp, Input Gain amp, Output Fine Gain 1, Audio Output, Bias, Signal Processing, Prog Reg Save (protects Programming register contents), crystal oscillator circuit, Aux ADC. |
| \$B0 | ANALOG GAIN | 0x000F | Input gain stage set for 0dB, audio output set for 0dB attenuation. |
| \$B1 | SIGNAL ROUTING | 0x0034 | Analog input = discriminator, audio output=received voice. |
| \$C2 | AUDIO AND DEVICE ADDRESS CONTROL | 0x1400 | HPF (to remove sub-audio) + LPF filtering, de-emphasis enabled. |
| \$CE | INTERRUPT MASK | 0x8900 | Enabled IRQs: Rx CTCSS detect, Aux ADC Low (to detect loss of carrier). |
| \$C1 | MODE CONTROL | 0x8801 | Voice path enabled, CTCSS enabled, Receive mode. |

Table 8: CMX882 'STATE 5' Settings

At this point, the incoming voice signal will be presented to the external speaker driver.

An interrupt will be issued when the CTCSS sub-audio tone is no longer present. At this point the voice transmission has terminated, and the host microcontroller should revert to STATE 2, “Sleep”.

Please note that the first step of State 2 places the CMX882 into Idle Mode, and this is the preferred method for muting the audio signal.

4.6 STATE 6: Alerting Tone Generation

The conditions that will result in reaching this state include:

- An XTCSS 4-tone burst (with “silence” suffix) indicative of an incoming voice message has been detected.
- The user has pressed a button on the radio, such as “PTT”, “Poll”, or a keypad button while entering a text message.

The CMX882 can be configured to generate audible tones for various purposes. The designer may wish to implement different alerting tones for different buttons. For example, the “PTT” button could generate one alerting tone, while the “Poll” button could generate a different alerting tone, and so on. This feature can allow the radio user to quickly determine which button has been pressed. Additionally, the CMX882 can create simple melodies by sequentially generating different tones.

The following register configurations will cause an alerting tone of 1250Hz to be delivered to the external speaker driver. Other alerting tones, or combinations of tones (i.e. melodies), are possible by loading different values into the Audio TONE register (\$CD).

| Register Address | Register Name | Register Contents | Effect |
|-------------------|----------------------------------|-------------------|--|
| \$C1 | MODE CONTROL | 0x0000 | Idle mode. |
| Wait 350us | | | |
| \$B0 | ANALOG GAIN | 0x000F | Audio output attenuation = 0dB. |
| \$B1 | SIGNAL ROUTING | 0x0008 | Audio output = MOD_1 signal, no Tx ramping. |
| \$C2 | AUDIO AND DEVICE ADDRESS CONTROL | 0x0000 | No filtering applied. |
| \$C0 | POWER DOWN CONTROL | 0x08F4 | Enabled: O/P Fine Gain 1, Audio Output amp, Bias, Signal Processing, Prog Reg Save (protects Programming register contents), crystal oscillator circuit. |
| \$CD | AUDIO TONE | 0x04E2 | Loads 1250Hz tone for generation. |
| \$C1 | MODE CONTROL | 0x1002 | Audio Tone Generation enabled, Transmit mode. |

Table 9: CMX882 'STATE 6' Settings

Once the above steps have been performed, all that is required to generate a different tone is to load a different value into the Audio TONE (\$CD) register; no other C-Bus transaction is required for the tone update to be accepted. This feature can allow simple melodies to be played over the radio’s speaker.

Once the desired ring tone generation is complete, the CMX882 software should move to one of the following states as needed:

- STATE 5 “Voice Reception”
- STATE 7 “XTCSS Transmission”
- STATE 10 “Monitor Mode”

4.7 STATE 7: XTCSS Transmission

In order to reach this state, one of the following has occurred:

- The user pressed the “Poll” button so they can learn the location of a remote user. An alerting tone has been generated.
- The user pressed the “PTT” button so they can speak to a remote user. An alerting tone has been generated.
- A remote radio has sent a retransmission request (e.g. the most recently transmitted location data was not received correctly by the remote radio).
- A remote radio has sent a request for location data.
- The time for regular location transmission to the remote user has arrived (i.e. the radio occasionally transmits its location to another user).

In summary, either a data or a voice transmission is required in order to reach this state.

To transmit an XTCSS tone burst, the CMX882 should be configured as follows:

| Register Address | Register Name | Register Contents | Effect |
|-------------------|----------------------------------|--|--|
| \$C1 | MODE CONTROL | 0x0000 | Idle mode. |
| Wait 350us | | | |
| \$B0 | ANALOG GAIN | 0x7700 | 'True' signal produced on output, MOD_1 and MOD_2 set for 0dB. |
| \$B1 | SIGNAL ROUTING | 0x1003 | Tx in-band (XTCSS) signal to MOD_1, Tx sub-audio signal to MOD_2, Tx ramp up and ramp down enabled. |
| \$C2 | AUDIO AND DEVICE ADDRESS CONTROL | 0x000A | XTCSS address 10d (0x0A) entered. Note: Address 10 is arbitrarily chosen in this example; any valid XTCSS address can be inserted here. |
| \$CB | XTCSS CODES | The value loaded into this register for “S1” and “S0” is user-defined and depends on the information being conveyed. | |
| \$C0 | POWER DOWN CONTROL | 0x0A74 | Enabled: Output Fine Gain 1, Output Coarse Gain 1, Bias, Signal Processing, Prog Reg Save (protects Programming register contents), crystal oscillator circuit. Note: MOD_2 attenuator (Output Coarse Gain 2) is not powered because it is not required at this point. |
| \$CE | INTERRUPT MASK | 0x9000 | Enabled: XTCSS 4-tone set interrupt. |
| \$C1 | MODE CONTROL | 0x6002 | XTCSS enabled, Tx mode. |

Table 10: CMX882 'STATE 7' Settings

The CMX882 will begin transmitting the XTCSS four-tone sequence when these steps are completed. An IRQ will be generated at the conclusion of the XTCSS transmission. The host application must wait one XTCSS tone period (e.g. 60ms in this example) after the XTCSS transmission is complete (i.e. “silence suffix”) before beginning voice or FFSK/MSK transmission.

The next software “state” depends on the type of XTCSS burst that was transmitted:

| If the XTCSS burst indicated this type of message: | The next state should be: |
|--|--------------------------------|
| Retransmission Request | STATE 2, Sleep Mode |
| Location Data Request | STATE 2, Sleep Mode |
| Voice Transmission | STATE 9, Voice Transmission |
| Data Transmission | STATE 8, FFSK/MSK Transmission |

Table 11: Transition States From XTCSS Transmission State

4.8 STATE 8: FFSK/MSK Transmission

In order to reach this point, an XTCSS transmission has occurred and a data transmission is required.

The "Type 5" FFSK/MSK message format has been selected for this application. With this format, the host is responsible for loading the "Address" and "Size" bytes for transmission. Once this is done, the CMX882 will add the "Format" byte and all necessary formatting information.

Note: FFSK/MSK transmissions are not accompanied by a sub-audio tone in this example. If it is desired for a sub-audio tone to accompany the FFSK/MSK transmission, the following steps should be performed:

- Transmit an XTCSS 4-tone burst at the beginning of the transmission.
- Load the address of the desired CTCSS tone into b7-0 of Audio and Device Address Control (\$C2) register.
- When the XTCSS burst is complete, deselect XTCSS and select CTCSS + FFSK/MSK transmission in the Mode Control register.

FFSK/MSK data transfer is initiated with the following commands:

| Register Address | Register Name | Register Contents | Effect |
|-------------------|----------------------------------|--|---|
| \$C1 | MODE CONTROL | 0x0000 | Idle device mode. |
| Wait 350us | | | |
| \$CA | TX DATA | 0x1E14 | Address=0x1E (30 decimal), size=0x14 (20 in decimal). |
| \$CB | TX DATA | The contents to be loaded into \$CB at this time are the first two bytes of actual user data. After these two bytes have been written, subsequent FFSK/MSK data writes should be made to both \$CA and \$CB; the Tx data buffer is four bytes long with Type 5 message format. | |
| \$C7 | MODEM CONTROL | 0x00A0 | Type 5 message format, standard scrambling seed. (Note that bit 2, "User Data", is not used in this application.) |
| \$B0 | ANALOG GAIN | 0x7700 | 'True' signal produced on output, MOD_1 and MOD_2 set for 0dB. |
| \$B1 | SIGNAL ROUTING | 0x1003 | Tx FFSK/MSK signal to MOD_1, Tx sub-audio signal to MOD_2, Tx ramp up and ramp down enabled. |
| \$C0 | POWER DOWN CONTROL | 0x0A74 | Enabled: Output Fine Gain 1, Output Coarse Gain 1, Bias, Signal Processing, Prog Reg Save (protects Programming register contents), crystal oscillator circuit. |
| \$C2 | AUDIO AND DEVICE ADDRESS CONTROL | 0x1000 | 25.0kHz channel filtering. |
| \$CE | INTERRUPT MASK | 0x80C0 | Enabled: FFSK/MSK transmission end, FFSK/MSK data transfer required. |
| \$C1 | MODE CONTROL | 0x0012 | 2400bps FFSK/MSK enabled, Transmit mode enabled. |

Table 12: CMX882 'STATE 8' Settings

The CMX882 will issue interrupts when additional Tx data is required. The host application must load this data before the current data has been transmitted; otherwise, the current data will be retransmitted. Subsequent FFSK/MSK data bytes should be written to \$CA and \$CB; the Tx data buffer is four-bytes deep for Type 5 message format. The data to be loaded into \$CA and \$CB must be loaded with separate C-BUS transactions (i.e. one C-BUS transaction for \$CA data, and another C-BUS transaction for \$CB data).

When the final bit of FFSK/MSK data has been transmitted, an IRQ will be generated with Status register (\$C6) b7=1. This event indicates the conclusion of the FFSK/MSK transmission. The CMX882 can now be powersaved by returning to STATE 2, Sleep Mode.

4.9 STATE 9: Voice Transmission

To reach this point, the CMX882 has transitioned from Sleep Mode (STATE 2) and the XTCSS Transmission state (STATE 9). The following register configurations will make voice transmission possible:

| Register Address | Register Name | Register Contents | Effect |
|-------------------|----------------------------------|-------------------|--|
| \$C1 | MODE CONTROL | 0x0000 | Idle device mode. |
| Wait 350us | | | |
| \$CE | INTERRUPT MASK | 0x0001 | All IRQs disabled. |
| \$C0 | POWER DOWN CONTROL | 0x5F74 | Enabled: Mic amp, Input Gain amp, Output Fine Gain 1 and 2, Output Coarse Gain 1 and 2, Bias, Signal Processing, Prog Reg Save (protects Programming register contents), crystal oscillator circuit. |
| \$B0 | ANALOG GAIN | 0x7700 | 'True' signal produced on output, MOD_1 and MOD_2 set for 0dB, Input gain stage set for 0dB. |
| \$B1 | SIGNAL ROUTING | 0x1023 | In band to MOD_1, subaudio to MOD_2, analog input = microphone, Tx ramping enabled. |
| \$C2 | AUDIO AND DEVICE ADDRESS CONTROL | 0x1401 | 25.0kHz channel filtering, pre-emphasis enabled, CTCSS tone address 01 selected (67.0Hz). |
| \$C1 | MODE CONTROL | 0x8802 | Voice path enabled, CTCSS enabled, Transmit mode. |

Table 13: CMX882 'STATE 9' Settings

Once these steps are complete, processed voice will pass through the limiter and be transmitted from the MOD_1 attenuator, and a 67.0Hz CTCSS sub-audio tone will be transmitted from the MOD_2 attenuator.

When the user releases the "Push To Talk" button, the transmit phase is complete and the CMX882 software should migrate back to STATE 2. **Please note that the first step of STATE 2 places the CMX882 into Idle Mode, and this is the preferred means of terminating CTCSS transmission.**

4.10 STATE 10: Monitor Mode

In certain situations the radio user may wish to listen to all activity on a channel, and STATE 10, "Monitor Mode", will configure the CMX882 for this operation. This mode can be performed at any time but would most likely be performed while the radio is in STATE 2, Sleep Mode.

Activating a "monitor" mode can be done easily by configuring the CMX882 as follows.

| Register Address | Register Name | Register Contents | Effect |
|-------------------|----------------------------------|-------------------|--|
| \$C1 | MODE CONTROL | 0x0000 | Idle device mode |
| Wait 350us | | | |
| \$C2 | AUDIO AND DEVICE ADDRESS CONTROL | 0x1400 | HPF (to remove subaudio) + LPF enabled, de-emphasis enabled. |
| \$B0 | ANALOG GAIN | 0x000F | Input Gain = 0dB, Audio Output attenuation = 0dB. |
| \$B1 | SIGNAL ROUTING | 0x0034 | Analog I/P from DISC, audio O/P = Received voice. |
| \$C0 | POWER DOWN CONTROL | 0x38F4 | Enabled: Disc amp, Input Gain, O/P Fine Gain 1, Audio Output, BIAS, Signal Processing, Prog Reg Save (protects Programming register contents), crystal oscillator circuit. |
| \$CE | INTERRUPT MASK | 0x0000 | No interrupts enabled. |
| \$C1 | MODE CONTROL | 0x8001 | Voice path enabled, Receive Mode. |

Table 14: CMX882 'STATE 10' Settings

The CMX882 will now pass all recovered signals to the external speaker driver amplifier. When the channel monitoring is complete, the CMX882 can be powersaved by moving back to STATE 2, Sleep Mode. **Please note that the first step of State 2 places the CMX882 into Idle Mode, and this is the preferred method for muting the audio signal.**

5 Conclusion

FRS-type radios are very common in today's marketplace, and innovative features such as text messaging and the ability to display location information is key for product differentiation and market success.

The CMX882 is a feature-rich baseband processor that enables innovative features while allowing low power consumption and small form-factor end products. The purpose of this document was to illustrate how the CMX882 can be configured to perform such features in a real application. It is hoped that this document will assist the designer in developing exciting new products based on the CMX882