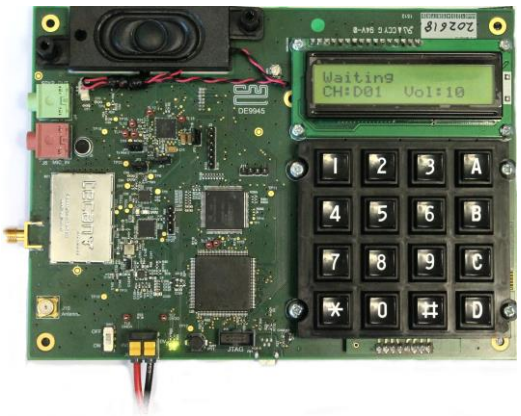
CML Microcircuits
COMMUNICATION SEMICONDUCTORS

DE9945/DE9945E SDR Demonstrator: PMR Common Platform

UM9945/4 June 2017 **USER MANUAL** Advance Information

Features

- **Direct Conversion Digital Radio Demonstrator**
- **Provides a demonstration platform for:**
  - **Direct Conversion Receiver CMX994A**
  - **Direct Conversion Receiver CMX994E**
  - **PMR Common Platform Processor CMX7341**
- **On-board ARM Host Processor:**
  (Cortex M0/M4 with internal flash and RAM)
- **16-button (4 x 4) Keypad**
- **2 x 16-character LCD Display**
- **Can function in the following modes:**
  - **Completely stand-alone**
  - **Controlled by scripts running via a PC**
  - **User-defined host controller interface**
- **On-board Frac-N PLL and VCO for 444MHz to 450MHz Operation**
- **0.5W RF Power Amplifier**
- **On-board Microphone**
- **On-board Loudspeaker**
- **Jack sockets for audio in/audio out**
- **Powered by external 4.5V power supply**
- **Designed based on requirement of:**
  EN 300 113, EN 301 166,
  EN 300 086, TS 102 361, TS 102 490



1 Brief Description

The DE9945 is a compact demonstration/evaluation platform for a range of digital and analogue PMR technologies including 2-slot TDMA Digital Radio (DMR) and 6.25kHz FDMA systems. The design incorporates the CMX7341 PMR Common Platform Processor and the CMX994A Direct Conversion Receiver. The board can be used to demonstrate a complete RF transceiver and baseband function supporting a direct conversion receiver and VCO 2-point modulation transmitter. The DE9945 features a built-in keyboard, display, AMBE+2 vocoder[1], microphone and loudspeaker and so can be used to demonstrate DMR peer-to-peer operation in a stand-alone configuration. The board has an ARM processor which handles initial board power up and loading of the Function Image™ for the CMX7341. Once the system is powered up, the processor will handle basic radio functionality (channel selection etc) and baseband control, allowing demonstration of a simple voice call and data transfer.

The DE9945 provides a Fractional-N PLL and VCO plus associated circuits to provide local oscillator signals for the CMX994A. The design also includes a 0.5W power amplifier, harmonic filter and Tx/Rx switch. The RF performance is designed to be compliant with EN 300 086 / EN 300 113 / EN 301 166 and all the circuits are provided with power-down capability to allow standby functionality.

The DE9945E is also available. This is similar in functionality to the DE9945 but is fitted with a CMX994E as the target device. For further information refer to the CMX994/CMX994A/CMX994E Datasheet.

[1] Using AMBE3000 Integrated Circuit.

CONTENTS

It is recommended that you check for the latest product datasheet version from the Products page of the CML website: www.cmlmicro.com.

This is Advance Information; changes and additions may be made to this document. Parameters marked TBD or left blank will be included in later issues of this document. Text in grey shows features that may be included in later releases of software or in later issues of this document. Information in this advance document should not be relied upon for final product design.

IMPORTANT: By using the demonstration kit described in this User Manual you agree to comply with the CML Function Image licence agreement. This is included at the end of this document.

2 History

Version	Changes	Date
4	0.5 W nominal Tx output power	June 2017
3	Added dPMR and Analogue sections in MMI section to reflect changes in ARM code version 2.0.0.0	October 2016
2	First page of User Manual – note added to introduce the DE9945E which provides a demonstration platform for the CMX994E	November 2015
1	First Issue	October 2015

3 Block Diagram

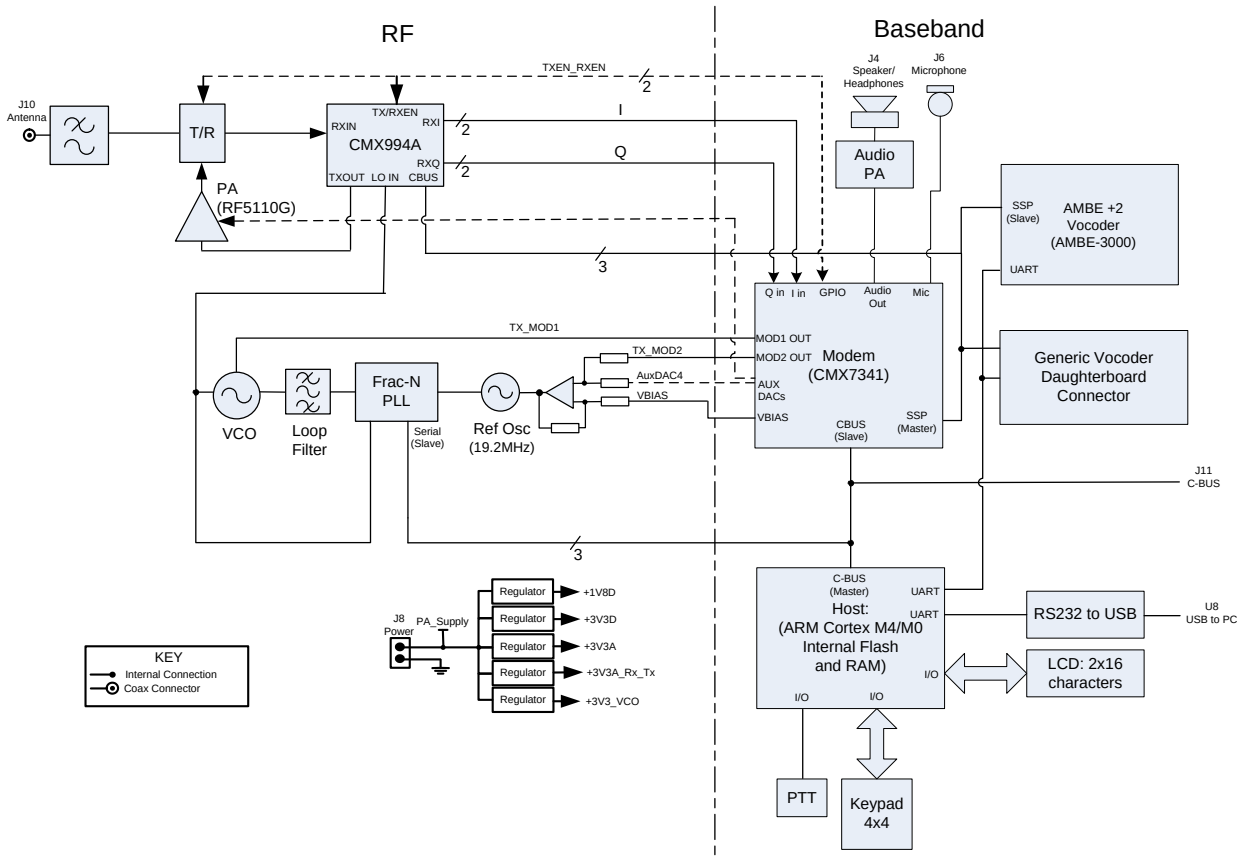


Figure 1 Block Diagram

4 Preliminary Information

The DE9945 provides a complete platform for demonstrating and evaluating the CMX7341 PMR Common Platform Processor and the CMX994A Direct Conversion Receiver. The functionality of the PCB is defined by the Function Image™ which is loaded into the CMX7341. The DE9945 can store two Function Images™ in separate areas of the ARM processor's flash memory. For details of the functionality of CMX7341 Function Images™ consult the individual datasheets available from www.cmlmicro.com.

A 0.5W power amplifier has been included plus Frac-N PLL and VCO. A keypad, LCD, loudspeaker and microphone allow the PCB to function in stand-alone mode. It is possible to connect an external sound source and/or external headphones via the audio in/out jack sockets.

Alternatively, the system can be controlled by a PC over USB. PC software is available for use with the DE9945. This software allows scripts to be used to control the CMX7341. The Frac-N synthesiser can also be controlled by scripts and the CMX994A is controlled via the CMX7341. Various scripts are available for use with the DE9945 (see Section 7.4.1) or the user may connect their own host controller solution to the control interface.

This document refers to revision A of the DE9945 PCB (PCB592A).

4.1 Laboratory Equipment

The following items may be useful:

- Laboratory power supply
- External electret microphone
- Headphones or an external loudspeaker
- Personal computer
- RF signal generator
- RF spectrum analyser

For more detailed design or investigation work, additional RF test equipment may be required.

4.1.1 Power Supply

The supply input voltage to the PCB is nominally 4.5V (absolute limits: 3.6V to 6.0V). On-board regulators provide the five (3.3V and 1.8V) power rails used on the PCB. The 4.5V power supply should be rated at 2 A.

NOTE: Care should be exercised with the 4.5V supply as it directly feeds both the RF and audio power amplifiers (no regulation). These amplifier supplies should not exceed 4.8V for nominal operating limits.

4.2 Handling Precautions

Like most evaluation kits, this product is designed for use in office and laboratory environments. The following practices will help ensure its proper operation.

4.2.1 SSD Devices

This product uses low-power CMOS circuits that can be damaged by electrostatic discharge. Partially-damaged circuits can function erroneously, leading to misleading results. Observe ESD precautions at all times when handling this product.

4.2.2 Contents - Unpacking

Please ensure that you have received all of the items on the separate information sheet (EK9945) and notify CML within seven working days if the delivery is incomplete.

4.3 Approvals

This product is not approved to any EMC or other regulatory standard. Users are advised to observe local statutory requirements, which may apply to this product and the radio frequency signals that may emanate from it.

5 Quick Start

This section provides instructions for users who wish to experiment immediately with this Evaluation Kit. A more complete description of the kit and its uses appears later in this document. The user should also read the appropriate CMX7341 and CMX994A Datasheets before using the DE9945 board.

NOTES:

- Two DE9945 Demonstration Boards are required for the Quick Start configuration.
- Default configuration of DE9945 uses DMR 2-slot TDMA transmission using 7341FI-2.x.

5.1 Setting-Up

The following procedure is recommended:

1. Connect the boards as shown in Figure 2.

   THE USE OF AN EXTERNAL 50Ω ATTENUATOR OR LOAD ON THE ANTENNA SOCKET (J10) IS ESSENTIAL TO PREVENT POSSIBLE DAMAGE TO THE RF POWER AMPLIFIER STAGE. ENSURE THAT THIS ATTENUATOR/LOAD IS CAPABLE OF HANDLING GREATER THAN +30dBm.

2. Apply power to both boards.
3. Ensure that SW2 on both boards is set to 'ON'

The boards are now ready for operation.

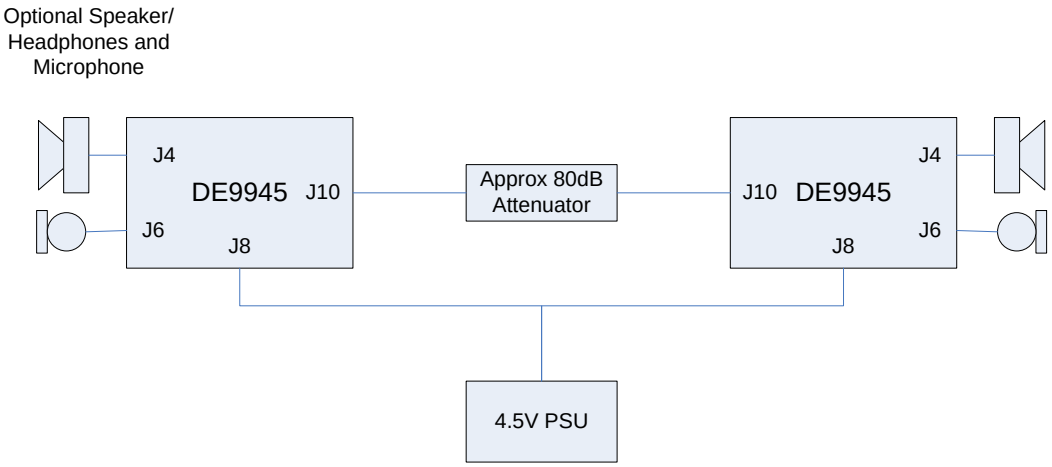


Figure 2 Typical Evaluation Connections for DE9945

5.2 Adjustments

VC1 is a trimmer capacitor used to centre the tuning voltage of the main VCO. The tuning voltage can be monitored at TP7. VC1 has been adjusted during production testing and should not require user adjustment.

VR1 is a variable resistor used to adjust the LCD contrast voltage. VR1 has been adjusted during production testing and should not require user adjustment.

5.3 Operation

When power is applied to the DE9945, the display will show:

```
DE9945 Demo
* for GUI Mode
```

After a few seconds, initialisation will complete and the MMI (Man-Machine Interface) will start. The display will briefly show:

```
CML DMR/dPMR/FM
Version <version number>
```

It will then change to show:

```
Ready     RSSI:xxx
Ch: A01     Vol:10
```

Ensure that both DE9945s are displaying the same channel number. If there is a difference, change the channel using the A and B keys on the keypad.

At this point the DE9945 will have automatically loaded the CMX7341 with its Function Image (FI), which is held in the host (ARM) processor flash memory, and put the CMX7341 into frame sync search mode.

Press and hold the PTT button (SW1) near the power connector on one DE9945 and speak into the microphone or play an external audio source connected to J6.

THE USE OF AN EXTERNAL 50Ω ATTENUATOR OR LOAD ON THE ANTENNA SOCKET (J10) IS ESSENTIAL TO PREVENT POSSIBLE DAMAGE TO THE RF POWER AMPLIFIER STAGE. Ensure that this attenuator/load is capable of handling greater than +30dBm.

The display will change to show:

```
Tx Audio
Ch:A01      Vol:10
```

The display on the other DE9945 should change to:

```
Rx       RSSI:xxx
Ch:A01     Vol:10
```

The audio should be played and be audible from the loudspeaker or headphones, if attached. Volume can be adjusted on the receiving unit using the C and D keys on the keypad. Note that if a USB cable is attached to U8, then noise picked up from the USB / PC may be audible on the speaker.

To transmit on a different channel, release PTT, change the channel using the A and B keys on the keypad (ensure that both boards are tuned to the same channel) and press PTT again.

To investigate the performance and features of the DE9945 in more detail, a Windows GUI can be used to control the CMX7341 (and CMX994A) either by manual register accesses, or by running scripts. See Section 7.3 Script/GUI Mode for details.

5.4 Signal Lists

CONNECTOR PINOUT				
Connector Ref.	**Connector Pin No.**	**Signal Name**	**Signal Type**	**Description**
J10	N/A	ANTENNA	RF	Tx Output or Rx Input
J8	2	+V	DC	4.5V Power supply input
J8	1	GNDA	DC	Power supply ground

Table 1 Signal List

CONNECTOR PINOUT for J14			
Connector Pin No.	**Signal Name**	**Signal Type**	**Description**
1	3V3D	Power	Connection to Digital Power Supply
2	SWIO/TMS	I/O	JTAG Test Mode Select
3	GNDD	Power	Connection to Digital Ground
4	SWDCLK/TCLK	I/O	JTAG Test Clock
5	GNDD	Power	Connection to Digital Ground
6	SWO/TDO	I/O	JTAG Test Data Out
7	~	Spare	Spare pin. Leave unconnected
8	NC/TDI	I/O	JTAG Test Data In
9	GNDD	Power	Connection to Digital Ground
10	RESETN	Reset	Reset signal

Table 2 ARM JTAG Interface

CONNECTOR PINOUT for J2				
Connector Pin No.	**Signal Name**	**Signal Type**	**Description**	
1	CSN	ARM O/P	Chip Select	Allows external control of CMX7341 C-BUS if ARM Host Controller outputs are first taken to a high-impedance state, or by removing 0R links R111 – R115.
2	CDATA	ARM O/P	Command Data	
3	SCLK	ARM O/P	Serial Clock	
4	RDATA	ARM I/P	Reply Data	
5	IRQN	ARM I/P	Interrupt Request (open-drain)	
6	GNDD	Power	Connection to Digital Ground	

Table 3 External C-BUS Host Interface

CONNECTOR PINOUT for J12				
Connector Pin No.	**Signal Name**	**Signal Type**	**Description**	
1	CSN_994	I/P	Chip Select	Monitoring of C-BUS interface between CMX7341 and CMX994A
2	RDATA	O/P	Reply Data (Not connected to CMX7341)	
3	SCLK_994	I/P	Serial Clock	
4	CDATA_994	I/P	Command Data	

Table 4 CMX994A C-BUS Monitor

CONNECTOR PINOUT for J4 and J6			
Connector Pin No.	**Signal Name**	**Signal Type**	**Description**
J4 TIP	LEFT SPEAKER	O/P	Output 1 from Audio PA
J4 RING	RIGHT SPEAKER	O/P	Output 2 from Audio PA (= inverted Output 1)
J4 SLEEVE	GROUND	Power	Analogue Ground
J6 TIP	MIC / LINE IN	I/P	Mic / Audio in Signal
J6 RING	MIC BIAS	I/P	Bias for electret microphone capsule
J6 SLEEVE	GROUND	Power	Analogue Ground

Table 5 Audio Connectors

CONNECTOR PINOUT for J11			
Connector Pin No.	**Signal Name**	**Signal Type**	**Description**
1	VBUS	I/P	Reset for FT232RL
2	DATA –	I/P	FT232RL: USBDM pin
3	DATA +	I/P	FT232RL: USBDP pin
4	GND	Power	Connection to Digital Ground
5	SHELL	Power	Connection to Digital Ground
6	CASE	Power	Connection to Digital Ground
7	CASE	Power	Connection to Digital Ground

Table 6 USB Interface

CONNECTOR PINOUT for J1			
Connector Pin No.	**Signal Name**	**Signal Type**	**Description**
1	GNDA	Power	Connection to Analogue Ground
2	+V	Power	Connection to Power Supply
3	7341_SPI_RX	I/O	SPI/PCM data from CMX7341 to codec
4	MIC_IN_DB	I/O	Microphone signal to codec (fit R97 to use)
5	7341_EPSO	I/O	SPI/PCM data from codec to CMX7341
6	AUDIO_OUT_DB	I/O	Speaker signal from codec (fit R96 to use)
7	7341_SPI_CLK	I/O	SPI/PCM Clock from CMX7341
8	SSPI_SSEL	I/O	SPI/C-BUS Chip Select from ARM
9	7341_SSOUT	I/O	SPI/PCM Chip Select from CMX7341
10	SSPI_CLK	I/O	SPI/C-BUS Chip Select from ARM
11	IRQN_DB	I/O	Interrupt Request from codec to ARM
12	U0_TXD	I/O	SPI/C-BUS data from codec to ARM / UART data from ARM to codec
13	GNDD	Power	Connection to Digital Ground
14	U0_RXD	I/O	SPI/C-BUS data from ARM to codec / UART data from codec to ARM

Table 7 Daughter Board Interface

TEST POINTS		
Test Point Ref.	**Default Measurement**	**Description**
TP1	-	AMBE-3000 TX_RDY
TP2	-	AMBE-3000 IDLE
TP3	-	CMX7341 RX MIC Input
TP4	-	Audio (to Audio PA)
TP5	-	Synth Mux Out
TP6	-	Synth Lock Detect
TP7	1.8V DC	Frac-N CP (Operating Frequency of 446.15625MHz)
TP8	-	RF PA Control Voltage
TP9	-	Microphone In
TP10	-	CMX7341 Spare Input (ADC2)
TP11	1.8V DC	1.8V Digital supply (1V8D)
TP12	-	CMX7341 Spare Input (ADC3)
TP13	-	CMX7341 DAC1 (PARAMP)
TP14	-	AMBE-3000 STDBY_EN
TP15	-	AMBE-3000 RUN
TP16	-	CMX7341 DAC2 Output
TP17	3.3V DC	3.3V Digital supply (3V3D)
TP18	3.3V DC	Baseband analogue supply (3V3A)
TP19	3.3V DC	Rx and Tx supply (3V3A_RX_TX)
TP20	3.3V DC	VCO supply (3V3_VCO)
TP21	-	Void
TP22	-	CMX994A Rx Output RXIP
TP23	-	CMX994A Rx Output RXIN
TP24	-	CMX994A Rx Output RXQP
TP25	-	CMX994A Rx Output RXQN
TP26	-	CMX994A RX Enable
TP27	-	CMX994A TX Enable

Table 8 Test Points

TEST LOOPS		
Test Loop Ref.	**Default Measurement**	**Description**
TL1	-	Void
TL2	-	ARM Spare GPIO5_6
TL3	-	ARM Spare GPIO5_7
TL4	-	Void
TL5	-	Void
TL6	0V DC	Analogue Ground
TL7	0V DC	Digital Ground
TL8	-	Void
TL9	-	Void
TL10	-	CMX7341 Rx I Channel
TL11	-	CMX7341 Rx Q Channel
TL12	-	CMX7341 SYSCLK1
TL13	-	CMX7341 SYSCLK2 (Slotclock in 7341FI-2.x)
TL14	-	CMX7341 VBIAS (buffered)

Table 9 Test Loops

JUMPERS		
Ref.	**Default Measurement**	**Description**
JP1	-	CMX7341 AVDD Supply
JP2	-	CMX7341 DVDD Supply
JP3	-	TX_MOD1 Connection
JP4	-	TX_MOD2 Connection

Table 10 Jumpers

ADJUSTMENTS			
Adjustment Ref.	**Adjustment**	**Adjustment Range**	**Description**
VC1	VCO Tuning	1.0 to 3.0VDC	Adjustment used to centre the tuning voltage of the main VCO
VR1	LCD Contrast	0 to –3.0VDC	Used to adjust the LCD contrast.

Table 11 Adjustments

Notes:
I/P = Input
O/P = Output
TL = Test Loop
TP = Test Point

6 Circuit Schematics and Board Layouts

For clarity, the circuit schematic diagrams are available as separate high-resolution files, which can be downloaded from the CML website. The layout on each side of the PCB is shown in Figure 3, Figure 4 and Figure 5:

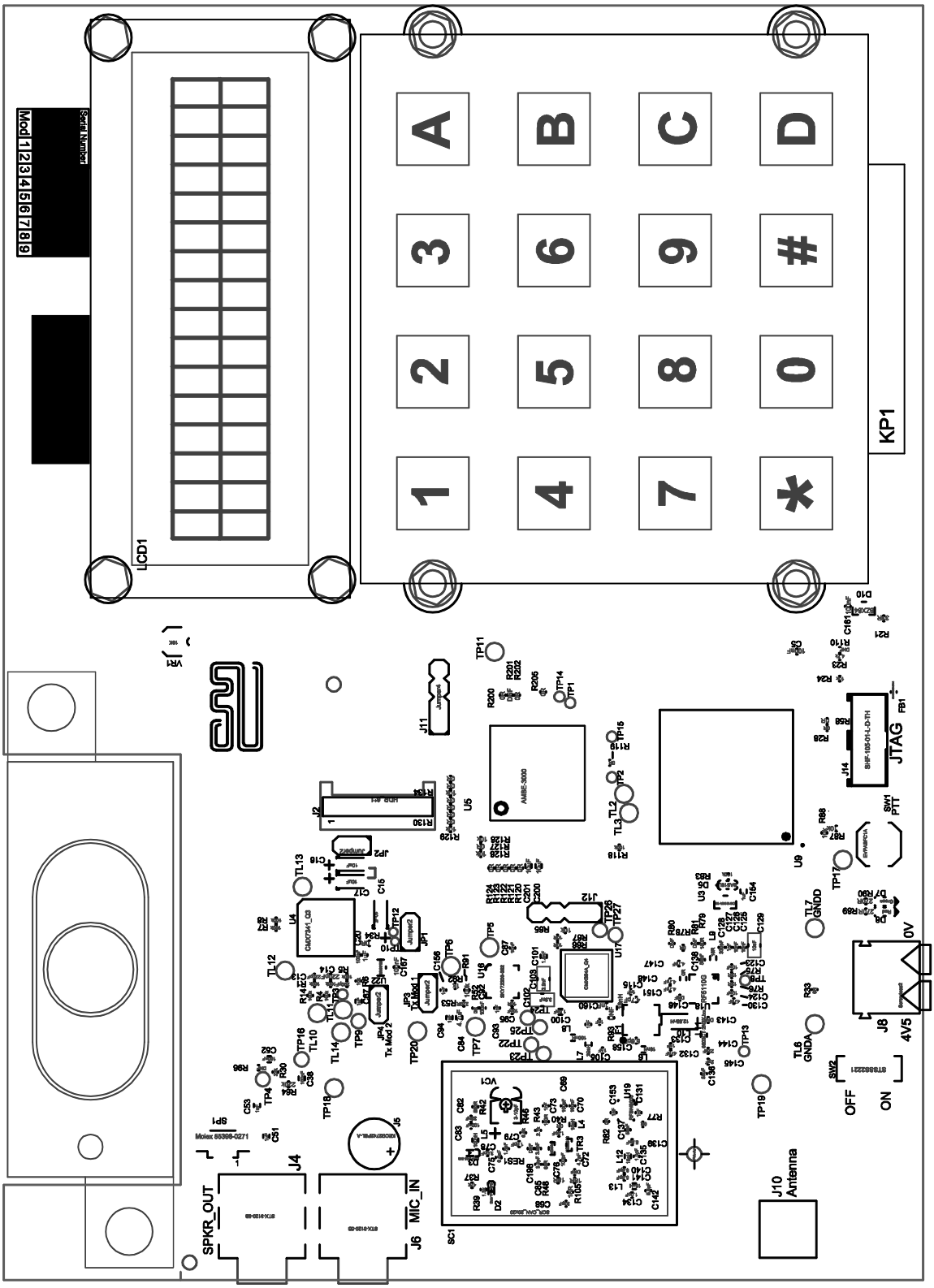


Figure 3 PCB Layout: top

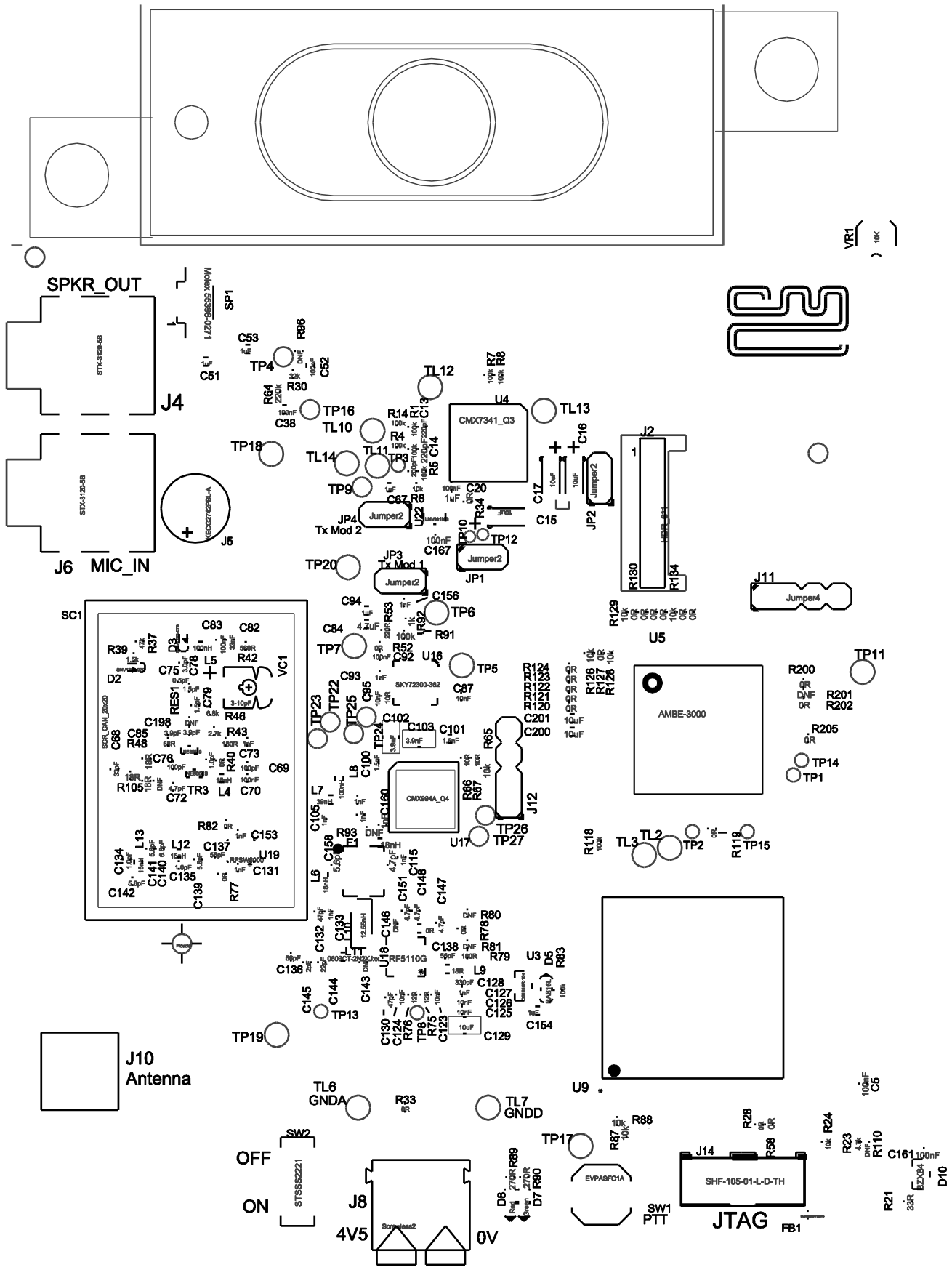


Figure 4 PCB Layout: top – detailed

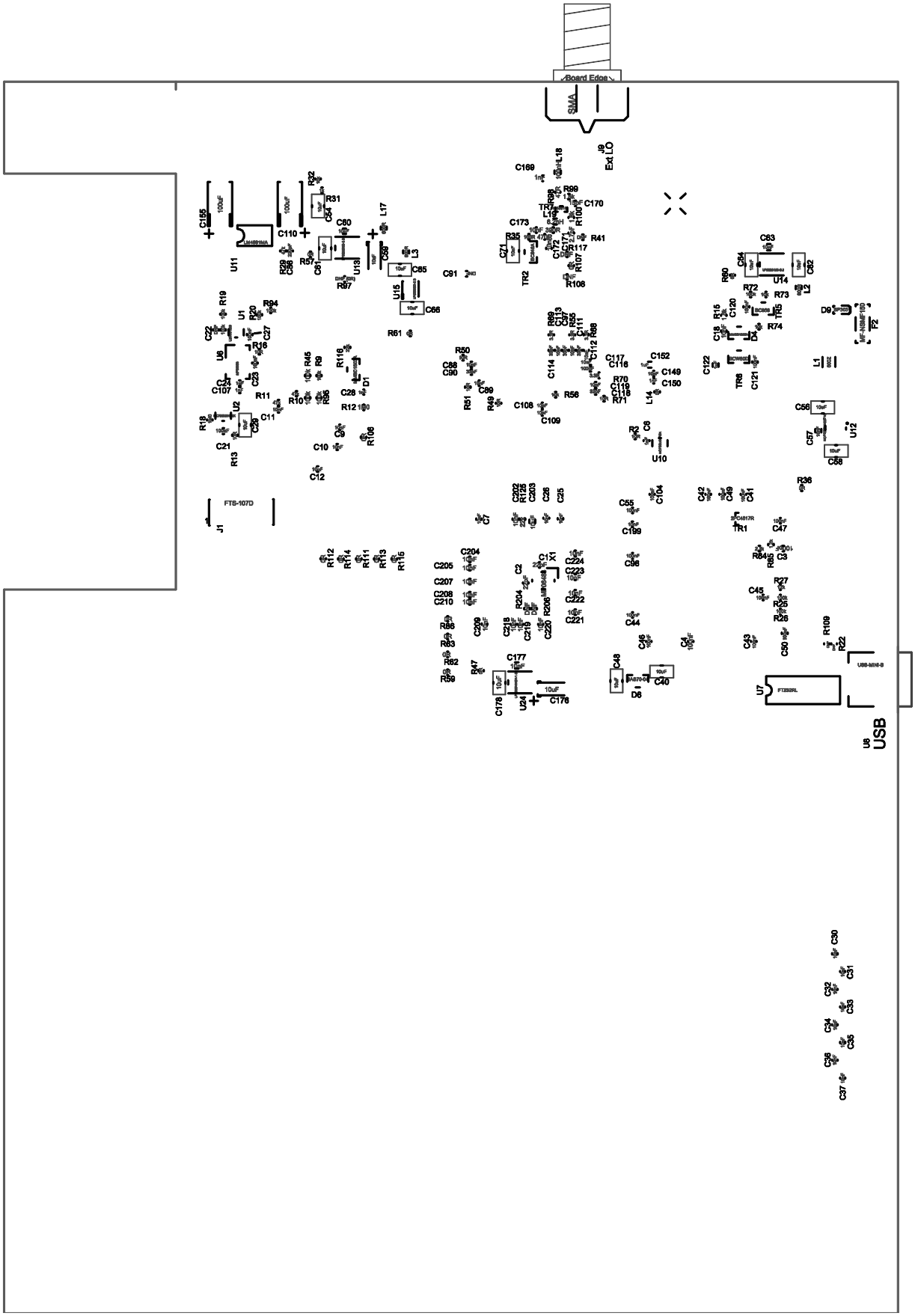


Figure 5 PCB Layout: bottom

7 Detailed Description

The DE9945 functionality includes:

- Nominal +4.5V Supply
- Direct Conversion Receiver
- Two-point Modulation Transmitter
- 0.5W Power Amplifier
- VCO and Fractional-N PLL
- 19.2MHz VCTCXO
- Operation from 444 to 450MHz (nominal 446MHz PMR446 Channels)
- ARM Processor
- MMI with 4x4 keypad and 16x2 character display
- Capability to demonstrate the performance of the CMX7341 TDMA Digital Radio Processor
- Capability to demonstrate the performance of the CMX994A Direct Conversion Receiver
- USB Interface to CML standard GUI, to allow script control

The DE9945 serves as a demonstrator for a range of PMR systems as supported by the CMX7341. These include 2-slot TDMA Digital Radio designs, such as DMR, 6.25kHz FDMA, such as dPMR and analogue FM. The DE9945 RF hardware, ARM controller, keypad and display allow the user to make and receive voice calls with no external equipment. More detailed investigations can be performed by connecting the DE9945 to a PC via USB and controlling the hardware using a script language.

7.1 Hardware Description

7.1.1 Harmonic Filter

L12, L13 and associated components form a low-loss low pass filter with taps centred at the 2nd and 3rd Tx harmonics. This filter is common to the transmitter and receiver paths and is connected between the Tx/Rx switch and the antenna connector J10.

7.1.2 Tx/Rx Switch

The Tx/Rx switch is an integrated wideband switch from RFMD (RFSW8000). The switch is controlled via two control voltage inputs: these are RXENA and TXENA signals from the CMX7341. The transmit path is activated when TXENA is high and RXENA is low. The receiver path is activated when TXENA is low and RXENA is high.

7.1.3 Power Amplifier

The DE9945 includes a 0.5 W Power Amplifier U18 (RF5110G), configured for 450MHz operation, and is capable of producing +27dBm output power with constant envelope modulation e.g. 4-FSK or analogue FM.
The CMX7341 RAMDAC (AUXDAC1) output is connected to the PA control line via a diode and transistor (D4 and TR6) to provide sufficient current to the PA control pins.

7.1.4 Local Oscillator

The LO (Local Oscillator) is common for transmit and receive operation. It is based on a VCO running at twice the final operating frequency. This is achieved with a VCO at 888MHz to 900MHz. Note the same VCO is used for transmit and receive, it is possible to use the TXMOD outputs for Rx debug purposes with JP3 and JP4 not fitted.

The VCO consists of TR3 and TR4 which are connected in DC cascode and share the same input biasing network. At RF frequencies, TR3 works as a common emitter amplifier with the emitter grounded through C76. The oscillator stage is fed to the buffer amplifier through the coupling capacitor C169. To ensure that the frequency range of the VCO can be achieved with good noise performance, a variable capacitor (VC1) has been included to centre the VCO tuning range. The output level from the VCO buffer is ~ -4dBm. The VCO is locked with a Skyworks Fractional N PLL (U16 - SKY72300) controlled via the ARM processor (U9 – LPC4337JBD144) and uses chip select 2 (SPI_SSEL). The Skyworks Frac-N synthesiser has a lock detect output which is fed back to the ARM.

7.1.5 Transmitter

The transmitter is based on a two-point modulation architecture. A separate varactor diode (D2) in the VCO is used for applying modulation from TX MOD1 and then modulation from TX MOD2 is applied to the reference oscillator (U6 – MP05955). The reference modulation (TX MOD2) can be summed with a AFC signal from CMX7341 AUXDAC4 and buffered VBIAS is used as the reference, these signals are summed in amplifier LMV931MG (U1).The output of the VCO buffer is fed to the CMX994A (U17), which has a transmit path. The divide by 2 is used and the output from the CMX994A (U17), typically 446MHz, is fed to the power amplifier.

7.1.6 Receiver

The receiver uses the CMX994A Direct Conversion Receiver IC (U17), capable of supporting a range of digital radio systems of both constant envelope and linear modulation types. The CMX994A integrated LNA is used with the output of the LNA matched to a 446MHz RF SAW Filter (F1 – MA07511). The output of the SAW filter is then matched to the I/Q downconversion mixer. The mixer converts the received signal to I/Q baseband format, where C100 and C101 combine with on-chip components to remove off-channel signals. The signal is then amplified before further filtering to remove adjacent channel signals (C102 and C103). The nominal maximum bandwidth of the adjacent channel filters is 8kHz and this is scaled by a factor of 1/2 or 1/4 in the other filter bandwidth states. The nominal CMX994A setting used for DMR channels (12.5kHz channel spacing) is the intermediate channel bandwidth (see CMX994A datasheet for further details). A final amplifier stage completes the CMX994A receiver line-up, providing differential I/Q outputs directly to the CMX7341 Input Op-amps.

The overall receiver gain and noise figure for the default configuration is ~60.5dB and 6.5dB respectively.

The Rx input third-order intercept point is ~ -1.5dBm.

The LO input is at twice the final operating frequency.

The CMX994A is controlled via the CMX7341 SPI-Thru port (EPSCSN labelled as CSN_994).

7.1.7 Reference Oscillator

A 1 ppm 19.2MHz VCTCXO (Golledge MP05955) is used as the reference for the Frac-N PLL, the CMX7341 and the ARM processor. Note in transmit mode the reference is modulated but modulation can easily be removed by not fitting JP4.

7.1.8 Microprocessor

The main system microprocessor is a NXP ARM processor (U9 – LPC4337JBD144). This is a dual-core M4 / M0 device. A USB interface (U7) is provided to connect to a PC.

7.1.9 Vocoder

The PCB includes an AMBE-3000R IC from DVSI (U5). This provides a AMBE+2 vocoder so that DE9945 can interoperate with equipment using this vocoder such as all DMR radios and dPMR radio based on ETSI TS 102 658. Connections from the vocoder to the ARM and the CMX7341 are provided as supported by CMX7341 vocoder interfacing detailed in the device datasheet.

7.1.10 MMI

The DE9945 is fitted with a keypad (KP1) and a LCD (LCD1) connected to the ARM and speaker (SP1), and microphone (J5) connected to the CMX7341. An audio PA (LM4991-U11) is also provided.

7.1.11 Power Supply

The input to the PCB is nominally 4.5V (absolute limits: 3.6V to 6.0V). On-board regulators are provided to generate the five voltage rails used on the DE9945.

NOTE: Care should be exercised with the 4.5V supply as it directly feeds both the RF and audio power amplifiers (no regulation). These amplifier supplies should not exceed 4.8V for nominal operating limits.

7.1.12 Inductors

All inductors used in the RF sections of the design are manufactured by Coilcraft (www.coilcraft.com). Performance of the circuits with inductors from other manufacturers may vary.

7.2 Adjustments and Controls

7.2.1 Man-Machine Interface (MMI)

When power is applied to the DE9945 the display shows:

```
DE9945 Demo
* for GUI Mode
```

After a few seconds a demonstration application will load from ARM Flash memory and the CMX7341 will be loaded with a Function Image™. If * (star key) is pressed whilst the display still shows the board initialisation message, the board will instead boot into the Script/GUI Mode (see Section 7.3), so that it can be controlled by a PC.

The application will function in one of three modes: Analogue PMR, dPMR or DMR. The CMX7341 uses FI-1.x for Analogue PMR and dPMR modes, whilst FI-2.x is used for DMR. The mode is determined by the channel selection. Scrolling through the channels reveals the Analogue PMR channels (**A01** to **A08**), followed by the dPMR channels (**dP01** to **dP16**), followed by the DMR channels (**D01** to **D08**). The application starts in Analogue PMR mode, on channel **A01**. The channel can be changed using the 'A' and 'B' key on the keypad.

7.2.2 DMR Mode

In DMR Mode, the board can be in one of four states – Waiting, Receive, Transmit or Setup.

Waiting State

This is the state that the board will be in when DMR mode is entered. In this state the Rx circuitry will be enabled and the modem will be searching for a frame sync. The display will show: **'Ready'**, the RSSI level, the channel number and the audio volume level.

The channel can be changed by scrolling through a list using the A and B buttons on the keypad. The Rx audio volume can be adjusted using the C and D buttons on the keypad.

Pressing * on the keypad will switch the DE9945 to Setup state.

Receive State

The board will automatically switch to this state when the modem finds a frame sync. In this state, the display will show: '**Rx'**, the ID of the calling radio, the channel number and the audio volume level. After 2 seconds the Calling ID will be replaced with the RSSI level.

If received data is vocoded audio it will be decoded and output from the loudspeaker or audio output jack. The audio volume can be adjusted using the C and D buttons on the keypad. It is not possible to change channel whilst in this state. The board will automatically revert to Waiting State when frame sync is lost.

NOTE: The AMBE-3000R IC on the DE9945 mutes the audio output when errors are detected in 1031Hz tone packets, but not with 'normal' speech packets. This is different from the behaviour of newer, software implementations of AMBE+2. Using a 1031Hz tone can show much lower sensitivity and so SHOULD NOT BE USED for performance measurements or comparisons. Speech samples or BER measurements should be used instead.

If received data is a CSBK, data header or rate ½ data packet, the data type will be briefly shown on the LCD as it is received. If the correct format for a text message is followed, the message will be displayed on the LCD when reception is complete. The message can be scrolled using the # key. Press the * key to return to Waiting State. The format used for these messages varies between manufacturers, so the DE9945 is not compatible with all DMR radios. The format used by the DE9945 is 16 CSBKs followed by 1 data header and the required number of rate ½ data blocks.

The DE9945 does not check any source or destination addressing / ID fields, and will therefore respond to any DMR transmission on the correct channel.

If Rx Modes 'Rx Eye' or 'Passthrough' have been selected in the setup menu, see Table 13, then the relevant signals will be output on the Tx Mod outputs. In this case, jumpers JP3 and JP4 should be removed to avoid the mod outputs affecting the VCO. Audio is not available in these test modes.

Transmit State

The board will switch to this state from Waiting State when PTT is pressed. In this state, transmission will occur according to the Tx Mode selected in the setup menu, see Table 13. All voice and data transmissions use an 'All Call' ID, so any DMR radio on the same channel should respond.

- Voice
  Audio from the built-in microphone or audio input jack will be vocoded, passed to the modem and transmitted on the selected channel. The display will show: '**`Tx Audio`**', the channel number and the audio volume level. It is not possible to change channel or audio volume in this state. The board will revert to Waiting State when PTT is released.

- AMBE 1k Tone
  A fixed voice data packet representing a 1031 Hz tone will be transmitted on the selected channel. The display will show: '**`Tx AMBE 1k Tone`**', the channel number and the audio volume level. It is not possible to change channel or audio volume in this state. The board will revert to Waiting State when PTT is released.

- Mod Setup
  A fixed data sequence ($55FF) is transmitted, resulting in a pattern of +3,+3,-3,-3 symbols. The display will show '**`Tx Mod Attn`**' on the top and '**`1:xxdB 2:xxdB`**' on the bottom. The A and B keys can be used to adjust the attenuation for Mod Output 1 and C and D keys can be used to adjust the attenuation for Mod Output 2. PTT 'latches' in this mode, i.e. press and release PTT to start transmission, press and release again to stop transmission and return to Waiting State.

- PRBS
  An internally-generated PRBS will be transmitted on the selected channel. The display will show: '**`Tx PRBS`**', the channel number and the audio volume level. It is not possible to change channel or audio volume in this state. PTT 'latches' in this mode, i.e. press and release PTT to start transmission, press and release again to stop transmission and return to Waiting State.

- Data Message 1, Data Message 2
  One of two fixed text messages will be sent, using the format described in the Rx section. Transmission stops automatically and the board will revert to Waiting State at the end of the message.

THE USE OF AN EXTERNAL 50Ω ATTENUATOR OR LOAD ON THE ANTENNA SOCKET (J10) IS ESSENTIAL TO PREVENT POSSIBLE DAMAGE TO THE RF POWER AMPLIFIER STAGE. Ensure that this attenuator/load is capable of handling greater than +30dBm.

Channels

The frequencies of the eight DMR446 channels are shown in Table 12. These are indicated on the display as **D01 – D08**.

There is no MMI function to change the frequencies associated with these channel numbers.

DMR446 Channel	Frequency (MHz)
1	446.10625
2	446.11875
3	446.13125
4	446.14375
5	446.15625
6	446.16875
7	446.18125
8	446.19375

Table 12 DMR446 Channel Frequencies (7341FI-2.x)

Setup State

This state presents a Setup Menu: the top line of the display will show the parameter name and the bottom line will show its value. The list of parameters can be scrolled through using the A and B keys. For parameters with a fixed number of values, the values can be scrolled through using the C and D keys. For others, values can be typed in directly, as shown in Table 13 below, using # at the end to enter the value.
Pressing ✳ on the keypad will switch the DE9945 to waiting state.

Parameter	Possible Values	Description	Notes
Tx Mode	Voice	Tx voice from mic or external	
	AMBE 1k Tone	Tx fixed 1kHz tone	
	Mod Setup	Allows setup of 2-point mod	
	PRBS	Tx PRBS	
	Data Message 1	Send fixed text message	
	Data Message 2	Send fixed text message	
PA	Low Power	PA On, approx 23dBm	3,4
	Full Power	PA On, approx 27dBm	3,4
	Off	PA Off	4
Rx Mode	Normal	Rx voice or data	
	Passthrough	Rx On, display inputs	5
	Eye	Rx On, display eye diagram	5
CMX994 Type	CMX994A, CMX994, CMX994E	Set in production test to match hardware.	1,2
Freq Control	Numeric entry via keypad: 0 – 1023, decimal	Value is applied to AUXDAC4 for frequency correction. Nominal 512	1,2
CMX994A DC Offset	I:±xxmV Q:±xxmV	Readback of CMX994A DC offset correction (measured by CMX7341).	
DMR Mod Output	1:xxdB 2:xxdB	Readback of Mod output levels. These levels can be set using Mod Setup Tx mode.	1
Mic Input Gain	0dB to +22.4dB in 3.2dB steps	Set audio input gain to corresponding value	1,2
Keypad Test	Numeric entry via keypad	Allows testing of all number keys.	
Save	Not Saved Saved	Saves ‘Freq Control’, ‘Mod Output’, ‘CMX994 Type’ and ‘Mic Input Gain, to ARM EEPROM.	
CMX7341 Version	<version> (read only)	Reports FI version for CMX7341	

Table 13 DMR Setup Menu

Notes:

1. This parameter will be saved by the ‘Save’ command.
2. This parameter is common to all three operating modes (DMR, dPMR, Analogue).
3. **Turning the PA on without a 50Ω load attached to the antenna socket (SMA connector J10) is likely to result in damage to the DE9945 board.**
4. This parameter is not saved to EEPROM. Whenever the mode changes (between DMR, dPMR, Analogue) the PA will be set to ‘Low power’.
5. These functions send test signals from the Main DACs. As Tx and Rx use the same VCO, this will result in unwanted VCO/VCTCXO modulation and poor Rx performance, unless the DACs are isolated from the VCOs. This can be done by not fitting JP3 and JP4.

7.2.3 dPMR Mode

In dPMR mode the board can be in one of four states – Waiting, Receive, Transmit or Setup.

Waiting State

This is the state that the board will be in when dPMR mode is entered. In this state the Rx circuitry will be enabled and the modem will be searching for a frame sync. The display will show: **'Ready'**, the RSSI value, the channel number and the audio volume level.

The channel can be changed by scrolling through a list using the A and B buttons on the keypad. The audio volume can be adjusted using the C and D buttons on the keypad.

Pressing * on the keypad will switch the DE9945 to Setup state.

Receive State

The board will automatically switch to this state when the modem finds a frame sync. The display will briefly show the detected sync type and then revert to showing: '**Rx'**, the RSSI value, the channel number and the audio volume level.

Received data will be decoded. Audio will be passed to the AMBE vocoder and output from the speaker or audio output jack. Status messages are displayed when received. Press * to clear the status message display and revert to Waiting state. With reference to ETSI TS 102 490 section 5.10.1, the transmitted call information sends extended headers for powersave. In the receiver, this results in lost audio at the start of the call for the duration of the extended header.

The audio volume can be adjusted using the C and D buttons on the keypad. It is not possible to change channel whilst in this state. The board will automatically revert to Waiting State when frame sync is lost or when a frame terminator is detected.

Transmit State

The board will switch to this state from Waiting State when PTT is pressed. In this state, transmission will occur according to the Tx Mode selected in the setup menu, see Table 16. All voice and data transmissions use an 'All Call' ID, so any dPMR radio on the same channel should respond.

- Voice
  Audio from the built-in microphone or audio input jack will be vocoded, passed to the modem and transmitted on the selected channel. The display will show: '**Tx Audio'**, the channel number and the audio volume level. It is not possible to change channel or audio volume in this state. The board will revert to Waiting State when PTT is released.

- AMBE 1k Tone
  A fixed voice data packet representing a 1031Hz tone will be transmitted on the selected channel. The display will show '**Tx AMBE 1k tone**', the channel number and the audio volume level. It is not possible to change channel or audio volume in this state. The board will revert to Waiting State when PTT is released.

- Mod Setup
  A fixed data sequence ($55FF) is transmitted, resulting in a pattern of +3,+3,-3,-3 symbols. The display will show '**Tx Mod Attn**' on the top and '**1:xxdB 2:xxdB**' on the bottom. The A and B keys can be used to adjust the attenuation for Mod Output 1 and C and D keys can be used to adjust the attenuation for Mod Output 2. PTT 'latches' in this mode, i.e. press and release PTT to start transmission, press and release again to stop transmission and return to Waiting State.

- PRBS
  An internally-generated PRBS will be transmitted on the selected channel. The display will show: '**Tx PRBS**', the channel number and the audio volume level. It is not possible to change channel or audio volume in this state. PTT 'latches' in this mode, i.e. press and release PTT to start transmission, press and release again to stop transmission and return to Waiting State.

- Status
  To send a status message, press '#'. The list of status messages can be scrolled through using the A and B keys. Once a Status message has been selected, it will be transmitted by pressing PTT. The Status message is transmitted twice; once per TS 102 490 standard and once per TS 102 658 standard. After transmitting the message the board will revert to Waiting State.

STAT Field	Displayed Text
0	Status1
1	Status2
….	….
28	Status29
29	Call Home
30	Urgent
31	Return to Base

Table 14 List of Status codes and associated messages

Channels

The frequencies of the 16 dPMR channels are shown in Table 15. These are indicated on the display as **`dP01`** – **`dP16`**.

There is no MMI function to change the frequencies associated with these channel numbers.

dPMR446 Channel	Frequency (MHz)
1	446.103125
2	446.109375
3	446.115625
4	446.121875
5	446.128125
6	446.134375
7	446.140625
8	446.146875
9	446.153125
10	446.159375
11	446.165625
12	446.171875
13	446.178125
14	446.184375
15	446.190625
16	446.196875

Table 15 dPMR446 Channel Frequencies (7341FI-1.x)

Setup State

This state presents a Setup Menu: the top line of the display will show the parameter name and the bottom line will show its value. The list of parameters can be scrolled through using the A and B keys. For parameters with a fixed number of values, the values can be scrolled through using the C and D keys. For others, values can be typed in directly, as shown in Table 16 below, using # at the end to enter the value.

Pressing ∗ on the keypad will switch the DE9945 to waiting state.

Parameter	Possible Values	Description	Notes
Tx Mode	Voice	Tx voice from mic or external	
	AMBE 1k Tone	Tx fixed 1kHz tone	
	Mod Setup	Allows setup of 2-point mod	
	PRBS	Tx PRBS	
	Status	Tx status message	
PA	Low Power	PA On, approx 23dBm	8,9
	Full Power	PA On, approx 27dBm	8,9
	Off	PA Off	9
Power save	Numeric entry via keypad	Sets the Rx-off time for powersave. Limited to 0-4095.	6,10
CMX994 Type	CMX994A, CMX994, CMX994E	Set in production test to match hardware.	6,7
Freq Control	Numeric entry via keypad: 0 – 1023, decimal	Value is applied to AUXDAC4 for frequency correction. Nominal 512	6,7
CMX994A DC Offset	I:±xxmV Q:±xxmV	Readback of CMX994A DC offset correction (measured by CMX7341).	
dPMR Mod Output	1:xxdB 2:xxdB	Readback of Mod output levels. These levels can be set using Mod Setup Tx mode.	6
Mic Input Gain	0dB to +22.4dB in 3.2dB steps	Set audio input gain to corresponding value	6,7
Keypad Test	Numeric entry via keypad	Allows testing of all number keys.	
Save	Not Saved	Saves 'Freq Control', 'Mod Output', 'CMX994 Type' and 'Mic Input Gain, to ARM EEPROM.	
	Saved		
CMX7341 Version	<version> (read only)	Reports FI version for CMX7341	

Table 16 dPMR Setup Menu

Notes:

6. This parameter will be saved by the 'Save' command.
7. This parameter is common to all three operating modes (DMR, dPMR, Analogue).
8. **Turning the PA on without a 50Ω load attached to the antenna socket (SMA connector J10) is likely to result in damage to the DE9945 board.**
9. This parameter is not saved to EEPROM. Whenever the mode changes (between DMR, dPMR, Analogue) the PA will be set to 'Low power'.
10. Powersave is disabled by setting this parameter to 0. Any non-zero value sets the powersave Rx-off time. The powersave setting is common to dPMR and analogue mode.

7.2.4 Analogue (or PMR) Mode

In Analogue PMR Mode, the board can be in one of four states – Waiting, Receive, Transmit or Setup.

Waiting State

This is the state that the board will be in when analogue mode is entered. In this state the Rx circuitry will be enabled and the modem will be checking the reported squelch level. The display will show: **'Ready'**, the channel number and the audio volume level.

The channel can be changed by scrolling through a list using the A and B buttons on the keypad. The audio volume can be adjusted using the C and D buttons on the keypad.

Pressing * on the keypad will switch the DE9945 to Setup state.

Receive State

The board will automatically switch to this state when the squelch level drops below a pre-set squelch threshold (a low squelch level indicates a good signal). In this state, the display will show: '**Rx'**, the RSSI level, the channel number and the audio volume level.

The received audio from the CMX7341 will be output from the speaker.

The audio volume can be adjusted using the C and D buttons on the keypad. It is not possible to change channel whilst in this state. The board will automatically revert to Waiting State when the squelch level rises above the squelch threshold.

It is possible to toggle squelch on and off by pressing '#' on the keypad. When squelch is on, the DE9945 will behave as described above. When squelch is off, the DE9945 will stay in Receive State, regardless of the reported squelch level.

Transmit State

The board will switch to this state from Waiting State when PTT is pressed. In this state, transmission will occur according to the Tx Mode selected in the setup menu, see Table 18.

- Voice
  Audio from the built-in microphone or audio input jack will be transmitted on the selected channel. The display will show: '**Tx Audio'**, the channel number and the audio volume level. It is not possible to change channel or audio volume in this state. The board will revert to Waiting State when PTT is released.

- AMBE 1k Tone
  An internally generated 1kHz tone will be transmitted on the selected channel. The display will show: '**Tx 1k Tone'**, the channel number and the audio volume level. It is not possible to change channel or audio volume in this state. The board will revert to Waiting State when PTT is released.

- Mod Setup
  An internally generated 1kHz tone will be transmitted on the selected channel. The display will show '**Tx Mod Attn**' on the top and '**1:xxdB 2:xxdB**' on the bottom. The A and B keys can be used to adjust the attenuation for Mod Output 1 and C and D keys can be used to adjust the attenuation for Mod Output 2. PTT 'latches' in this mode, i.e. press and release PTT to start transmission, press and release again to stop transmission and return to Waiting State.

Channels

The frequencies of the eight Analogue PMR channels are shown in Table 17. These are indicated on the display as **A01 – A08**.

There is no MMI function to change the frequencies associated with these channel numbers.

PMR446 Channel	Frequency (MHz)
1	446.00625
2	446.01875
3	446.03125
4	446.04375
5	446.05625
6	446.06875
7	446.08125
8	446.09375

Table 17 Analogue PMR446 Channel Frequencies (7341FI-1.x)

Setup State

This state presents a Setup Menu: the top line of the display will show the parameter name and the bottom line will show its value. The list of parameters can be scrolled through using the A and B keys. For parameters with a fixed number of values, the values can be scrolled through using the C and D keys. For others, values can be typed in directly, as shown in Table 18 below, using # at the end to enter the value.

Pressing ∗ on the keypad will switch the DE9945 to waiting state.

Parameter	Possible Values	Description	Notes
Tx Mode	Voice	Tx voice from mic or external	
	AMBE 1k Tone	Tx fixed 1kHz tone	
	Mod Setup	Allows setup of 2-point mod	
PA	Low Power	PA On, approx 23dBm	13,14
	Full Power	PA On, approx 27dBm	13,14
	Off	PA Off	14
Squelch	Numeric entry via keypad Max level: 2047 On/Off option	Sets CMX7341 squelch threshold. Default value is 2000.	11,12
Power save	Enter value via keypad	Sets the Rx-off time for powersave. Limited to 0-4095.	11,15
CMX994 Type	CMX994A, CMX994, CMX994E	Set in production test to match hardware.	11,12
Freq Control	Numeric entry via keypad: 0 – 1023, decimal	Value is applied to AUXDAC4 for frequency correction. Nominal 512	11,12
CMX994A DC Offset	I:±xxmV Q:±xxmV	Readback of CMX994A DC offset correction (measured by CMX7341).	
Analogue Mod Output	1:xxdB 2:xxdB	Readback of Mod output levels. These levels can be set using Mod Setup Tx mode.	11
Mic Input Gain	0dB to +22.4dB in 3.2dB steps	Set audio input gain to corresponding value	11,12
Keypad Test	Numeric entry via keypad	Allows testing of all number keys.	
Save	Not Saved	Saves ‘Freq Control’, ‘Mod Output’, ‘CMX994 Type’ and ‘Mic Input Gain, to ARM EEPROM.	
	Saved		
CMX7341 Version	<version> (read only)	Reports FI version for CMX7341	

Table 18 Analogue PMR Setup Menu

Notes:

11. This parameter will be saved by the ‘Save’ command.
12. This parameter is common to all three operating modes (DMR, dPMR, Analogue).
13. **Turning the PA on without a 50Ω load attached to the antenna socket (SMA connector J10) is likely to result in damage to the DE9945 board.**
14. This parameter is not saved to EEPROM. Whenever the mode changes (between DMR, dPMR, Analogue) the PA will be set to ‘Low power’.
15. Powersave is disabled by setting this parameter to 0. Any non-zero value sets the powersave Rx-off time. The powersave setting is common to dPMR and analogue mode.

7.3 Script/GUI Mode

To investigate the performance and features of the DE9945 in more detail, a Windows GUI can be used to control the CMX7341 and CMX994A – either by manual register accesses or by running scripts. If ∗ (star key) is pressed whilst the display still shows the board initialisation message, the board will boot into the Script/GUI Mode. In this mode, the board can only be controlled via the GUI and not via the keypad. Likewise, the DE9945 cannot be controlled via the GUI if it is in Radio Mode or Setup Mode. To leave Script/GUI Mode, remove all power from the DE9945 board.

Setting-Up

- Copy the file 'ES9945xx.zip', which is downloaded from the CML website following registration, to the hard drive of your host PC.
- Extract the files to the hard drive of your host PC.
- **Ensure that an external 50 Ω attenuator or load is connected to the Antenna Socket (J10). Turning the PA on without a 50Ω load attached to the SMA connector (J10) is likely to result in damage to the DE9945.**
- Connect a dc supply to the DE9945 Interface Card and set the voltage level to 4.5V.
- Attach a USB cable between connector U8 of the DE9945 Interface Card and the USB port of the PC.
- Turn on the power supply.

Install the USB driver when requested. The driver is in the same folder as the 'ES9945xx.zip' files were extracted to (..\Driver). Follow instructions on the screen to install the USB driver. Select the 'Install this driver software anyway' option when the Message Box below is displayed:

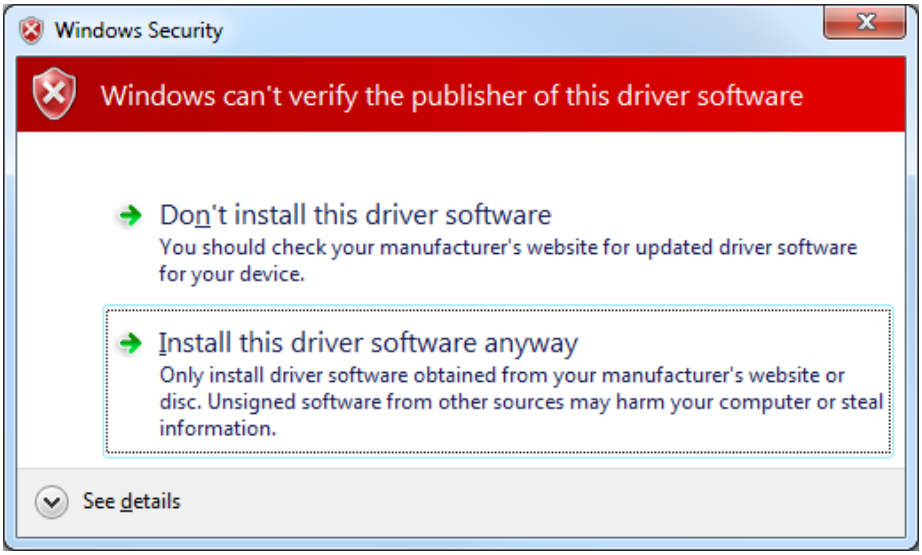


Figure 6 Driver Verification Dialogue

The executable ES9945xx.EXE can now be run. There are five sheets within the tabbed dialog box structure. These are described in the following sections.

Note: The AMBE 3000 vocoder is not accessible by using scripts.

7.3.1 The C-BUS Control Tab

This tab provides basic C-BUS read, write and general reset functions. Each character entered into the Address and Data edit boxes is checked to ensure that it is a valid hexadecimal value. The radio buttons select an 8-bit or 16-bit read/write operation. The lengths of the entered values are limited to 2 characters (1 byte) for read or write register addresses and 2 or 4 characters (1 or 2 bytes) for the register write data. The General Reset button writes 01H to the CMX7341.

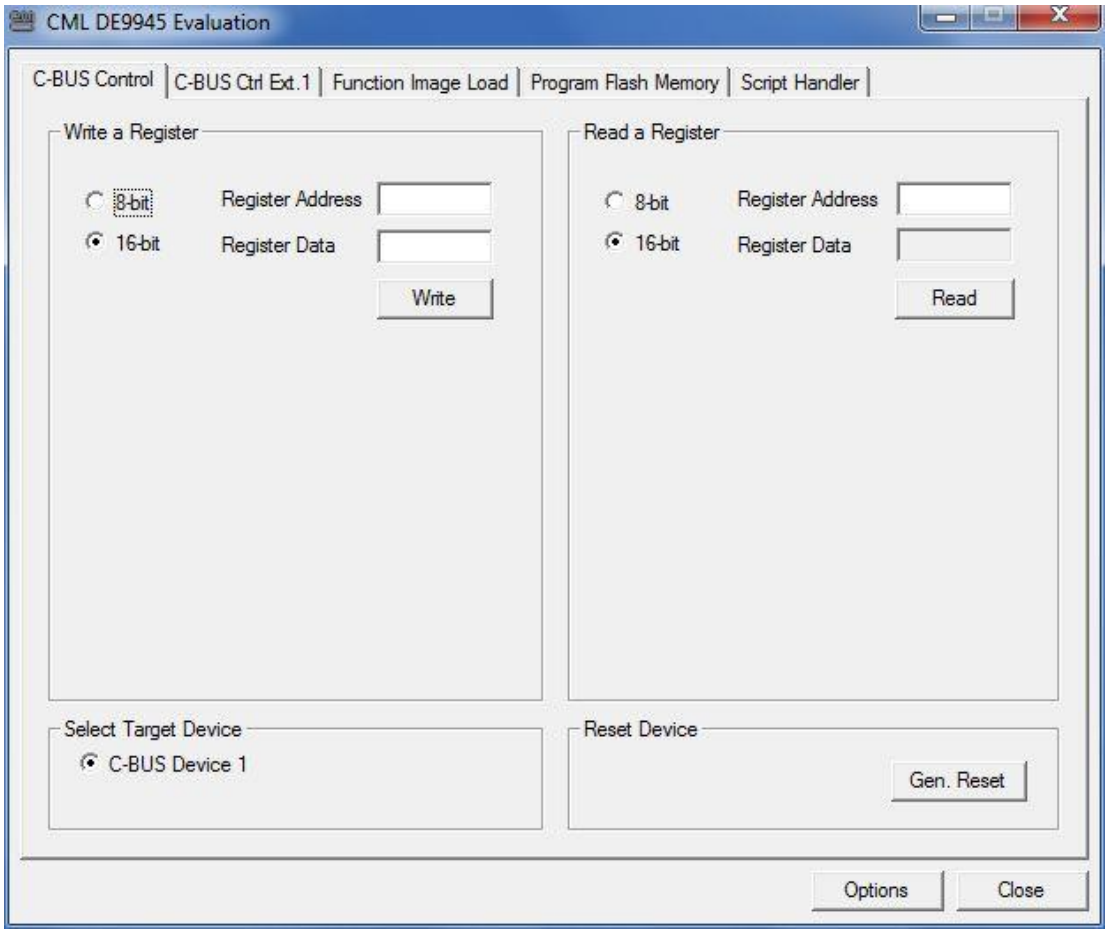


Figure 7 C-BUS Control Tab

7.3.2 The C-BUS Control Extended Tab (C-BUS Ctrl Ext. 1)

This tab provides multiple C-BUS read and write functions. Each row in the table represents a single action on a C-BUS register. Select the C-BUS register type from the drop down list. The Update button and the Data edit box will be configured according to the selection. Each character entered into the Address and Data edit boxes is checked to ensure that it is a valid hexadecimal value. The lengths of the entered values are limited to 2 characters (1 byte) for register addresses and 2 or 4 characters (1 or 2 bytes) for the register data. Click the Update button to read or write a single C-BUS register. For multiple C-BUS read or write operations, select the C-BUS registers using the Enable check boxes and click on the 'Wr all', 'Rd all' or 'Wr\Rd all' buttons. Click on the 'Wr all' button to write all the selected write type C-BUS registers. Click on the 'Rd all' button to read all the selected read type C-BUS registers. Click on the 'Wr\Rd all' button to read or write all of the selected C-BUS registers.

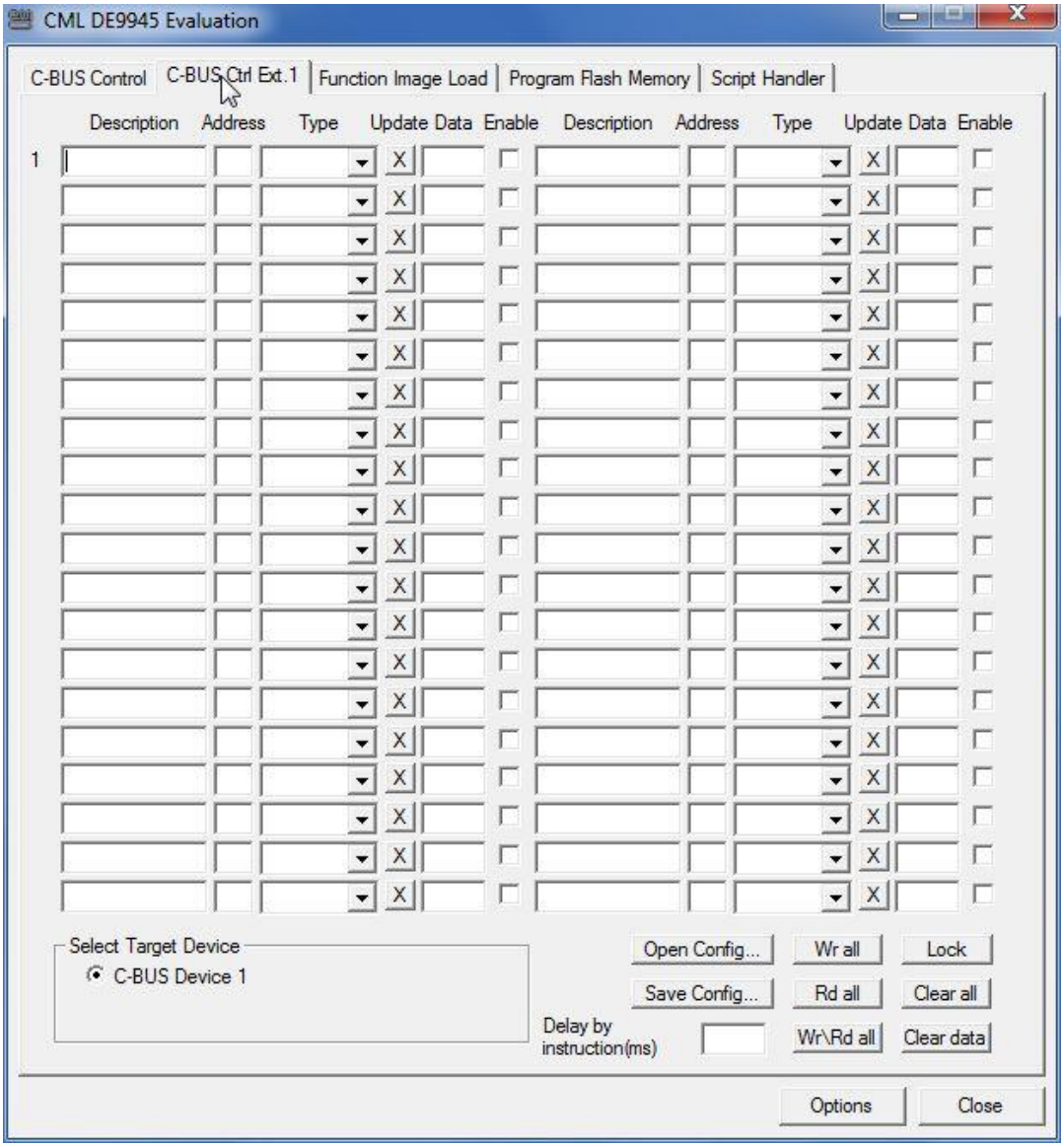


Figure 8 C-BUS Control Extended Tab

The C-BUS actions in the table are executed sequentially, starting at "1" (top left of the table). The 'Delay by instruction (ms)' box introduces a delay between the execution of each C-BUS action (default = no delay).

Click on the 'Clear all' button to reset the table. Click on the 'Clear data' button to reset the Data edit boxes.

The 'Lock' button may be used to disable the Description, Address and Type controls, preventing accidental changes. Click on the 'Lock' button again to re-enable these controls.

Use the 'Save Config…' button to save the current table. The Description, Address, Type, Data and Select columns are saved in the specified file. Use the 'Open Config…' button to load a previously saved table.

7.3.3 The Function Image™ Load Tab

This tab provides a utility for loading a CMX7341 Function Image™ from the host PC. Enter the name of the file containing the Function Image™, or navigate to the required file using the 'Browse' button. Enter the Activation Code, if required**.** The Activation code can be typed in, selected from the drop-down list or selected from a previously created list using the Activation Codes button. Select the target device and click the 'Load' button. The progress of the download from the host PC is shown visually on the progress bar and when the download has completed, a message box will be displayed indicating if the result of the download operation was successful or not.

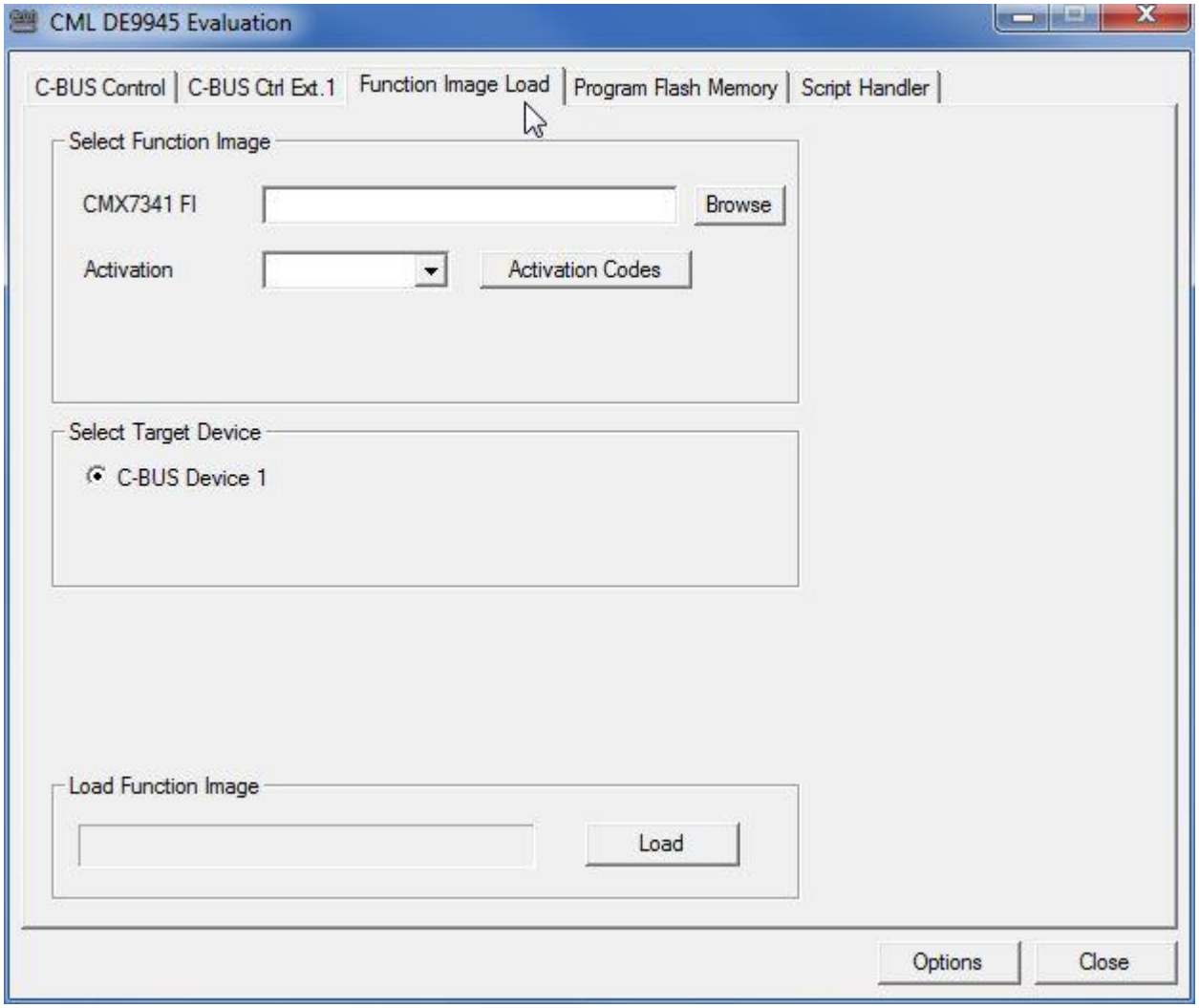


Figure 9 Function Image™ Load Tab – via C-BUS

7.3.4 The Program Flash Memory Tab

This tab provides a way to program ARM application code or Function Images™ for the CMX7341 into Flash memory on the ARM processor. To load ARM application code, enter or browse to a .bin file in the 'ARM Flash' section and click on the 'Program' button. To load the DMR function image (FI-2) enter or browse to the FI (.h file) using the 'FI Flash Area A' section, and click on the 'Load' button. The 'FI Flash Area B' section is used to load the dPMR and Analogue Function Image (FI-1).

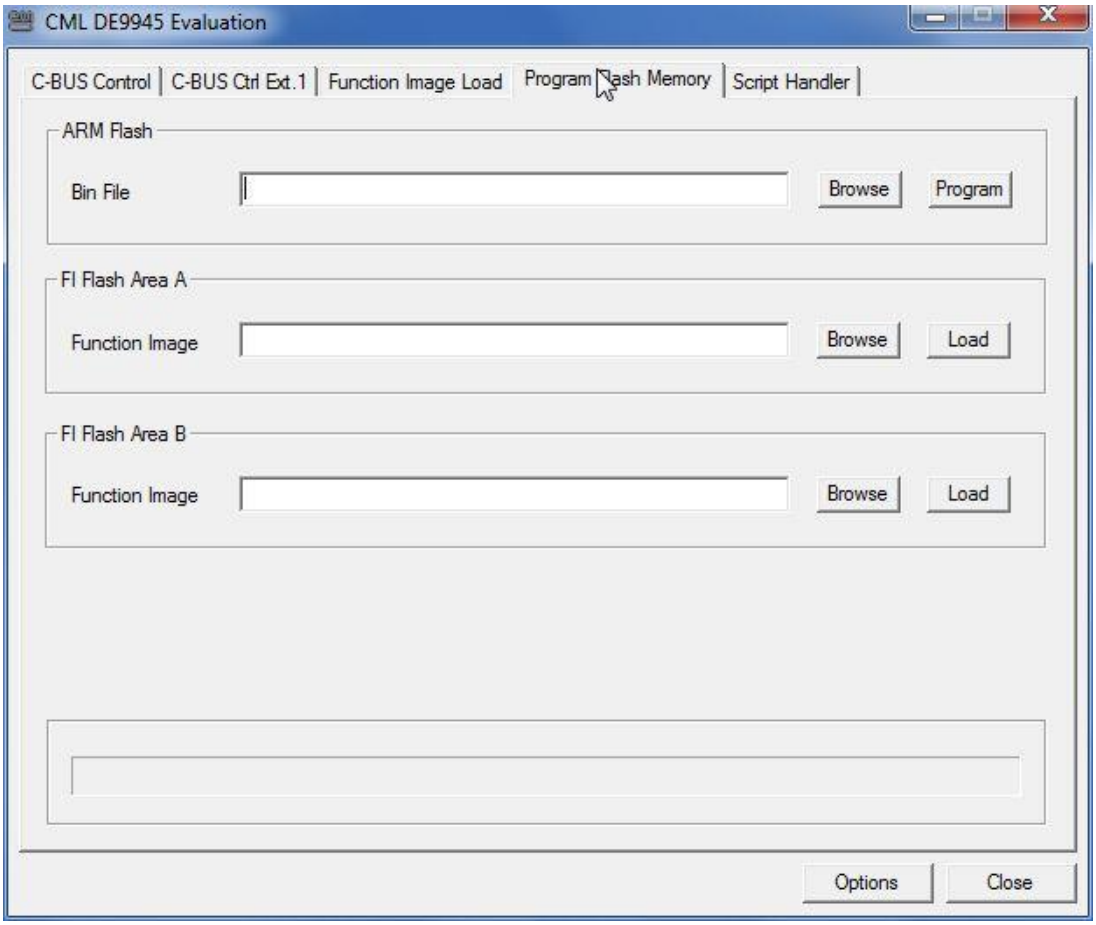


Figure 10 Program Flash Memory Tab

7.3.5 The Script Handler Tab

The Script Handler tab allows the execution of scripts. These are plain text files on the host PC which are compiled by the GUI, but executed on the ARM Microprocessor on the DE9945. The script language is documented separately in the "Script Language Reference" document, which can be downloaded with the PE0003 support package from the CML website at www.cmlmicro.com.

The script language used by the DE9945 is identical to that used by the PE0003, except that the commands relating to 'static buffers' are not supported and the mapping of the 'port' commands to I/O pins is different, as shown in Section 7.3.6.

Section 7.4.1 gives detailed information about scripts developed for the DE9945 Evaluation Kit.

To select a script file, click on the 'Select Script' button. The Open File Dialog is displayed. Browse and select the script file. The folder that contains the script file will be the working folder of the script (i.e. all the files referenced in the script will be searched in this folder). Alternatively, select a script file from the recent files list. Click on the '>' button to display the list.

The results window displays the values returned by the script. These results can be saved to a text file or discarded by clicking on the 'Save Results' or 'Clear Results' buttons, respectively. When a script file is being executed, the 'Run Script' button will change to be the 'Abort' button, the rest of the tab will be disabled and the other tabs cannot be selected.

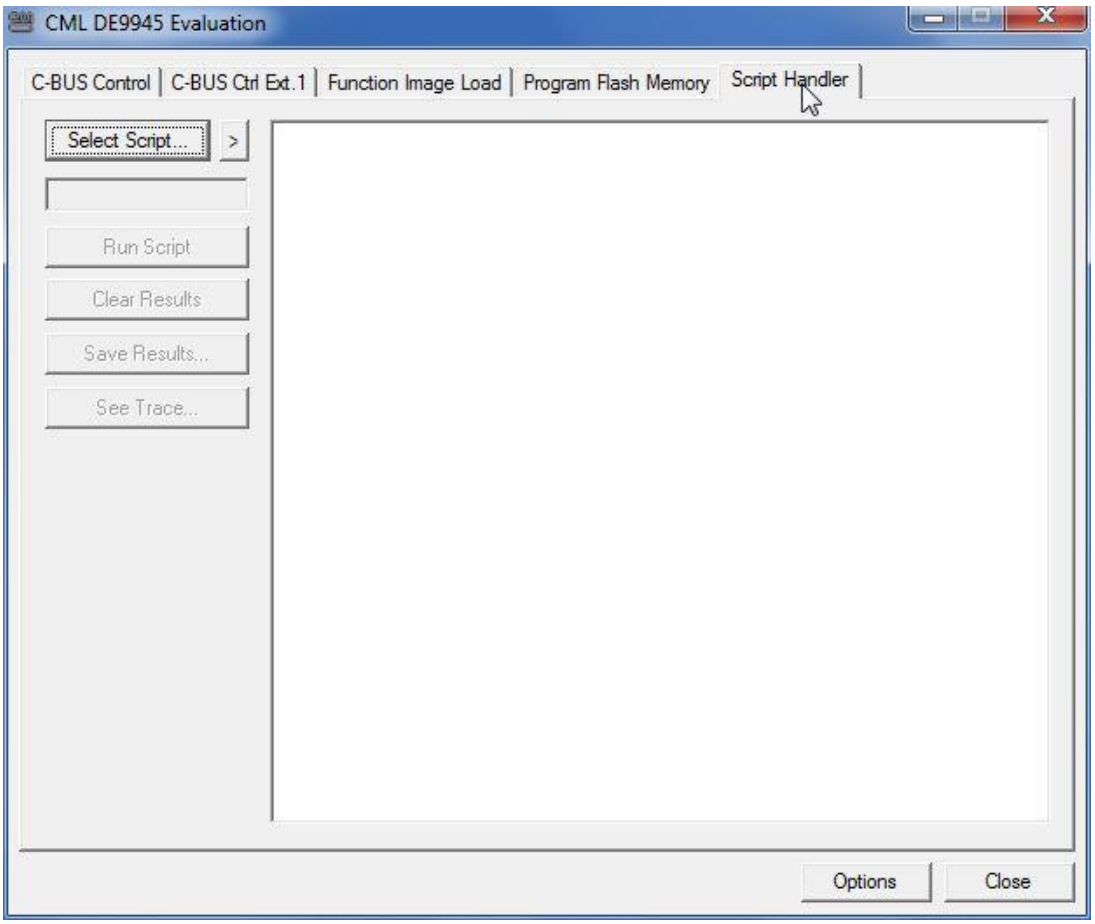
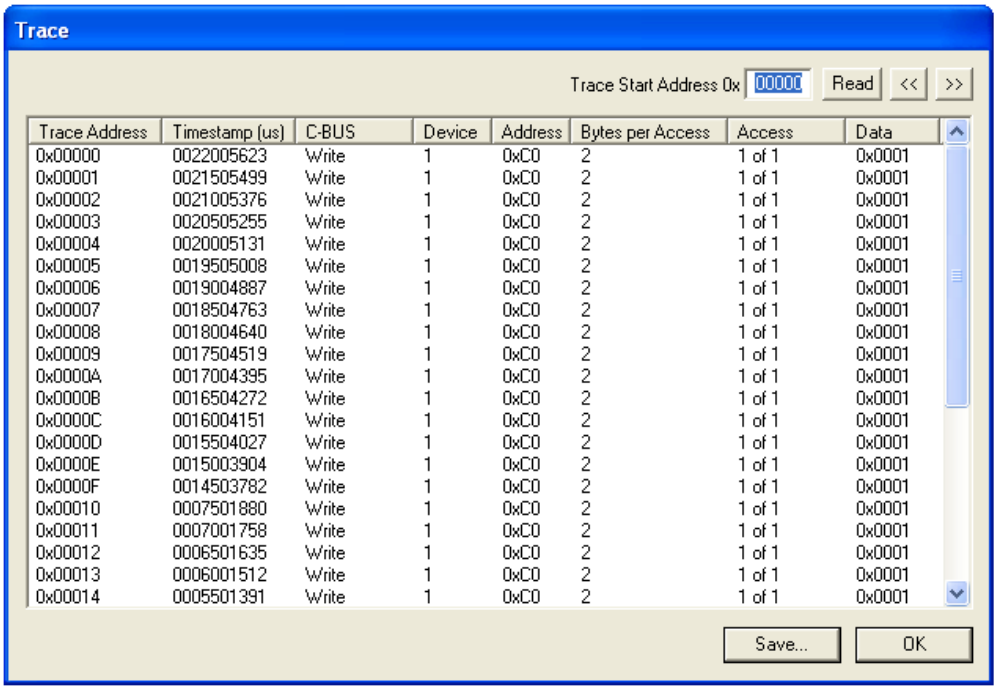


Figure 11 Script Handler Tab

After a script has finished running and when trace data is available, the 'See Trace…' button will be enabled. Click on the 'See Trace…' button to display the Trace dialog box. Note that the C-BUS transactions are only logged if the feature has been enabled in the script. See the "Script Language Reference" document for details.



Trace Address	Timestamp (us)	C-BUS	Device	Address	Bytes per Access	Access	Data
0x00000	0022005623	Write	1	0xC0	2	1 of 1	0x0001
0x00001	0021505499	Write	1	0xC0	2	1 of 1	0x0001
0x00002	0021005376	Write	1	0xC0	2	1 of 1	0x0001
0x00003	0020505255	Write	1	0xC0	2	1 of 1	0x0001
0x00004	0020005131	Write	1	0xC0	2	1 of 1	0x0001
0x00005	0019505008	Write	1	0xC0	2	1 of 1	0x0001
0x00006	0019004887	Write	1	0xC0	2	1 of 1	0x0001
0x00007	0018504763	Write	1	0xC0	2	1 of 1	0x0001
0x00008	0018004640	Write	1	0xC0	2	1 of 1	0x0001
0x00009	0017504519	Write	1	0xC0	2	1 of 1	0x0001
0x0000A	0017004395	Write	1	0xC0	2	1 of 1	0x0001
0x0000B	0016504272	Write	1	0xC0	2	1 of 1	0x0001
0x0000C	0016004151	Write	1	0xC0	2	1 of 1	0x0001
0x0000D	0015504027	Write	1	0xC0	2	1 of 1	0x0001
0x0000E	0015003904	Write	1	0xC0	2	1 of 1	0x0001
0x0000F	0014503782	Write	1	0xC0	2	1 of 1	0x0001
0x00010	0007501880	Write	1	0xC0	2	1 of 1	0x0001
0x00011	0007001758	Write	1	0xC0	2	1 of 1	0x0001
0x00012	0006501635	Write	1	0xC0	2	1 of 1	0x0001
0x00013	0006001512	Write	1	0xC0	2	1 of 1	0x0001
0x00014	0005501391	Write	1	0xC0	2	1 of 1	0x0001

Figure 12 Trace Dialog Box

Click on the '>>' or '<<' buttons to upload and display the next or previous C-BUS transaction data block. Click on the 'Read' button to upload and display the C-BUS transaction data block starting at the address displayed in the Trace Start Address edit box. Use the 'Save…' button to save the trace data to a file.

7.3.6 Port Mapping

The eight I/O bits referred to by scripts as 'Port 1' are mapped to GPIO5-2 to GPIO5-9 on the ARM microprocessor. These are connected on the PCB as follows. Port 2 is not supported.

Port 1 bits	ARM Reference	Hardware	I/O
0	GPIO5-2	Audio PA Shutdown	O
1	GPIO5-3	Skyworks synth Lock detect	I
2	GPIO5-4	CMX7341 Slotclock	I
3	GPIO5-5	Not Used	N/A
4	GPIO5-6	Test Loop 2 (TL2)	I/O
5	GPIO5-7	Test Loop 3 (TL3)	I/O
6	GPIO5-8	Red LED	O
7	GPIO5-9	Green LED	O

Table 19 Port Mapping

7.4 Application Information

See Section 5.1 for board setup details and Section 5.3 for operation of the DE9945.

7.4.1 Scripts

Scripts to support the DE9945 can be downloaded from the Technical Portal at www.cmlmicro.com.

7.4.2 Typical Receiver Results

Typical receiver test results for the DE9945 are shown below. In all cases, test methods follow ETSI EN 300 113-1 and the CMX994A ACR filter is set at intermediate bandwidth. BER results are measured using PRBS data sent in a frame structure typical of a DMR base-station.

Typical DE9945 sensitivity with 7341FI-2 (DMR) is -123dBm for 5 % BER.
Typical DE9945 sensitivity with 7341FI-1 (dPMR) is -118.5 dBm for 1 % BER.
Typical DE9945 sensitivity with 7341FI-1 (Analogue) is -120dBm for 12dB SINAD.

Typical DE9945 Adjacent Channel Rejection (ACR) results are shown in Table 20. The wanted signal is at 446.15625MHz at -107dBm and the interfering signal is FM modulated with a 400 Hz tone at +/-1.5kHz deviation. The EN 300 113 requirement is > 60dB.

Separation (dB)	+12.5kHz Offset BER	-12.5kHz Offset BER
64	1.37E-03	1.44E-03
65	2.54E-03	2.87E-03
66	5.42E-03	5.51E-03
67	9.15E-03	1.10E-02

Table 20 DE9945 Rx Adjacent Channel Rejection (7341FI-2 DMR)

Typical Co-Channel results for DE9945 are shown in Table 21; the wanted signal is at 446.15625MHz at -107dBm and the interfering signal is FM modulated with a 400 Hz tone at +/-1.5kHz deviation, at the same frequency as the wanted signal. The EN 300 113 requirement is < 12dB.

Separation (dB)	BER
10	6.06E-03
9.5	9.35E-03
9	1.34E-02

Table 21 DE9945 Rx Co-Channel Rejection (7341FI-2 DMR)

Typical DE9945 intermodulation results are shown in Table 22. The wanted signal is at 446.15625MHz at -107dBm, the interfering signal at 50kHz offset is unmodulated and the interfering signal at 100kHz offset is FM modulated with a 400 Hz tone at +/-1.5kHz deviation. The results in Table 22 are with the CMX994A IM register set to 0x3F. The EN 300 113 requirement is 65dB for mobile / handportable stations.

	+50/+100kHz Offset	-50/-100kHz Offset
Separation (dB)	BER	BER
65	1.26E-03	8.68E-04
66	4.29E-03	3.51E-03
66.5	7.32E-03	
67	1.30E-02	1.06E-02

Table 22 DE9945 Rx Intermodulation Rejection (7341FI-2 DMR)

Typical DE9945 blocking results are shown in Table 23. The wanted signal is at 446.15625MHz at -107dBm and the interfering signal is unmodulated. The EN 300 113 requirement is 84dB.

Unwanted Freq offset (MHz)	Separation (dB)	BER
1	94	4.04E-03
-1	94	4.24E-03
2	95	2.44E-03
-2	95	2.58E-03
5	95	1.51E-03
-5	95	6.40E-03
10	96	2.15E-04
-10	95	3.07E-03

Table 23 DE9945 Rx Blocking Performance (7341FI-2 DMR)

The DE9945 has excellent Spurious Response Rejection performance, comfortably meeting EN 300 113 requirements. It should be noted that care is needed with the test setup to ensure that the harmonics of signal generators are removed by filtering, as the harmonics can cause erroneous test failures.

The DE9945 Conducted Spurious Emissions have been tested to 8GHz and worst case emissions are below -60dBm, typical spurious results are less than – 70dBm.

7.4.3 Typical Transmit Performance (7341FI-2.x DMR)

The DE9945 2-point modulation scheme can require adjustment of gain settings for best performance; typical modulation setup values are ($register = 0xValue):

$B0 = 0x6300 (Tx Mod Coarse Gain control)

$80 = 0x33 (Tx Mod Fine Gain Control)

Performance should be verified using a Tx test mode ($C1 = 0xA1 and $CB = 0x55FF) that produces a test pattern of repeated symbols (i.e. 16 +3 symbols and 16 -3 symbols sent repeatedly). Figure 13 shows the typical modulation setup waveform after correct alignment.

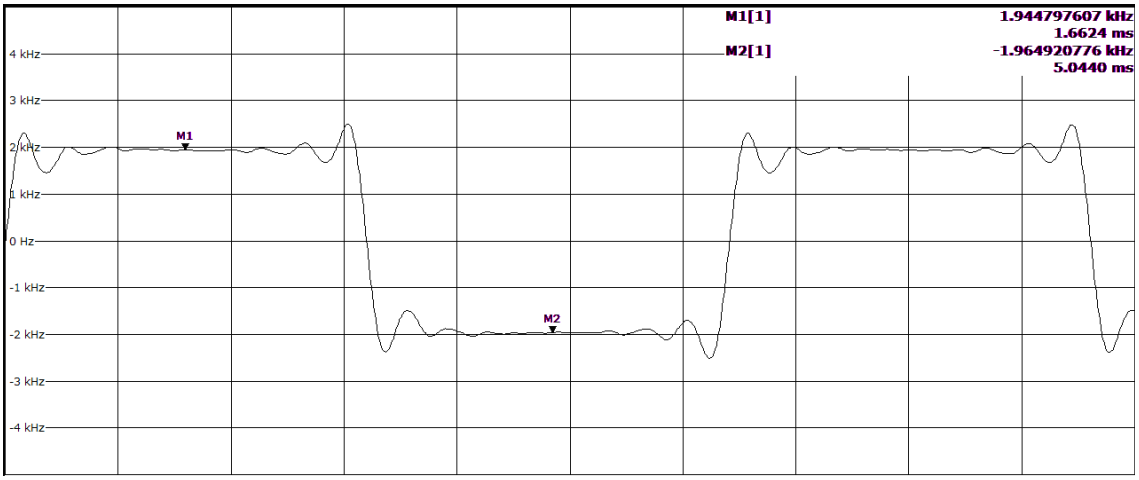


Figure 13 Tx Mod Setup

The plots in Figure 14 and Figure 16 show the Tx performance in continuous mode; the PA AUXDAC1 uses max scaling (default condition), based on the Tx Ramp profile loaded (Table 24) for these measurements, which results in circa +27 dBm output level.

Figure 14 shows that the Adjacent Channel Power only just meets the EN 300 113 requirement of 60dB. This is typical of the DMR modulation with the specified 1.944kHz deviation; it is not a fault of the DE9945 or the CMX7341. If more margin is required it is recommended that the deviation is slightly reduced.

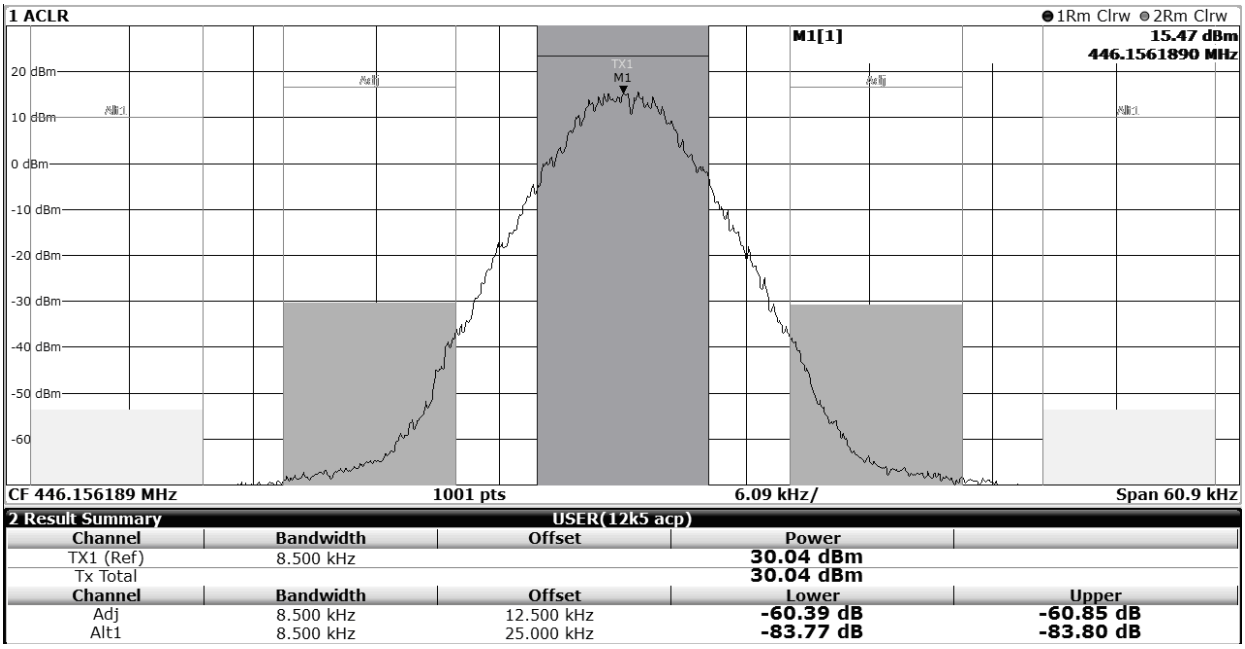


Figure 14 Tx Adjacent and Alternate Channel Powers

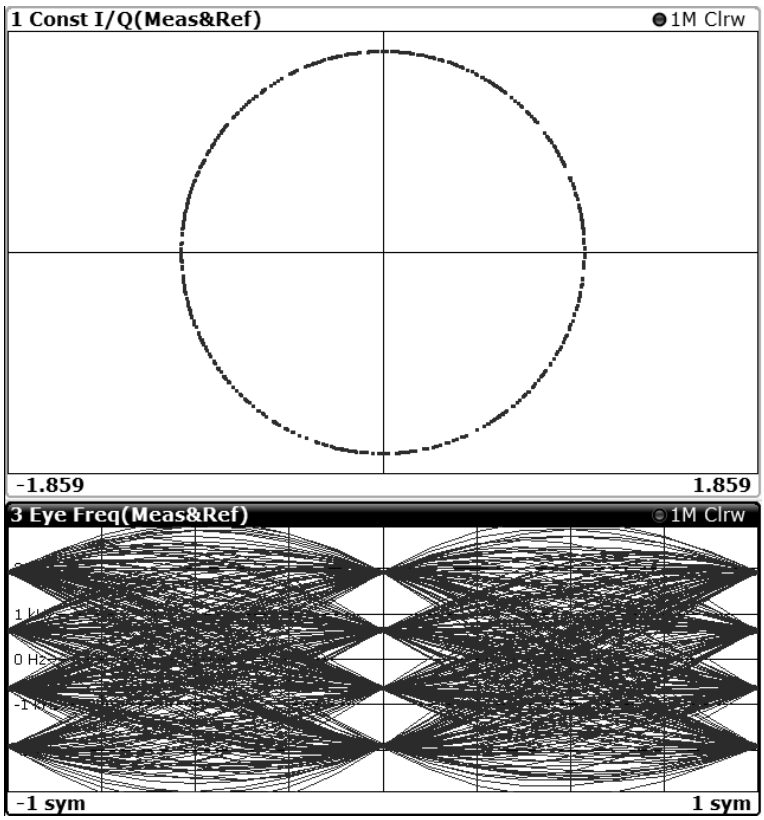


Figure 15 Transmitter Modulation / Eye Diagram

2 Result Summary			
	Current	Peak	Unit
Frequency Error RMS	**1.12**	52.66	%
Peak	**3.14**	-254.39	%
Magnitude Error RMS	**0.02**	46.00	%
Peak	**-0.06**	191.54	%
FSK Deviation Error	**-25.35**	2125.18	Hz
FSK Meas Deviation	**1919**	4069	Hz
FSK Ref Deviation	**1944**	1944	Hz
Carrier Frequency Error	**-17.32**	414.59	Hz
Carrier Frequency Drift	**0.00**	-0.58	Hz/sym
Power	**29.67**	29.99	dBm

Figure 16 Tx Vector Accuracy

For testing with slotted mode the ramp values shown in Table 24 are recommended and the resulting ramp profile is shown in Figure 17. The measured spectrum using 'Peak Hold' on the spectrum analyser is shown in Figure 19.

0	0	455	460	465	470	475	480
486	494	502	510	516	522	528	534
540	545	550	555	560	565	570	574
578	582	586	590	594	598	602	606
610	614	618	622	625	628	631	634
637	640	643	646	649	652	655	658
661	664	667	670	673	676	679	682
685	688	691	694	697	700	703	703

Table 24 Ramp Profile

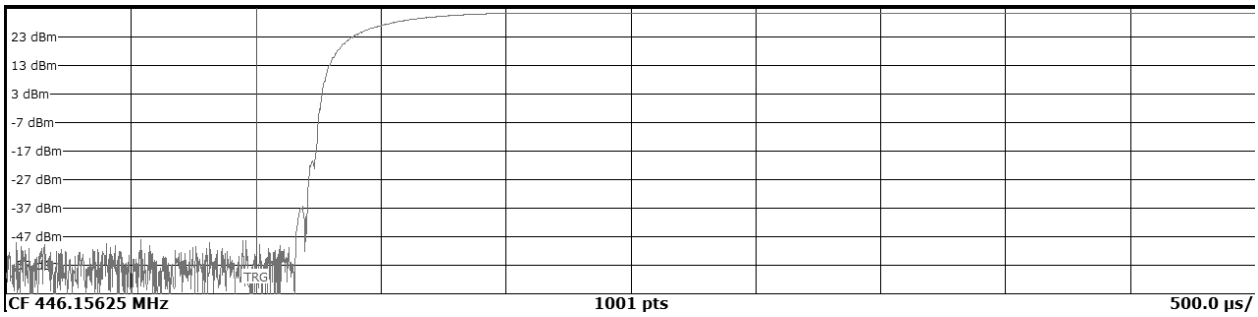


Figure 17 Tx Ramp Up

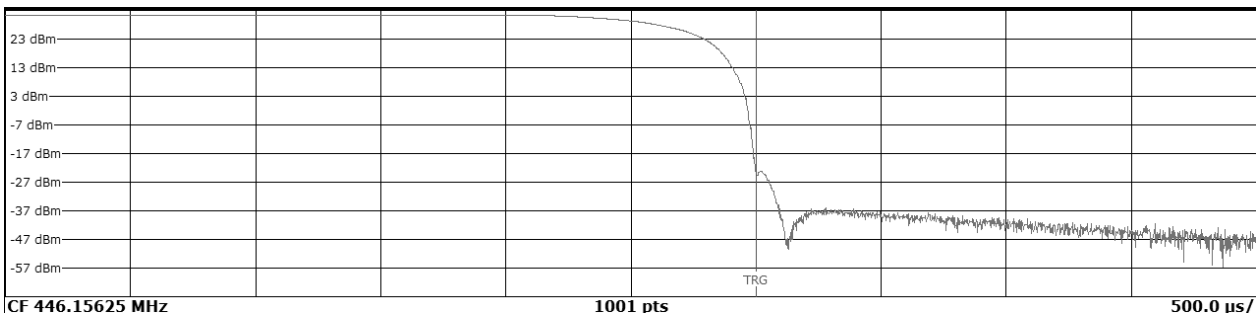


Figure 18 Tx Ramp Down

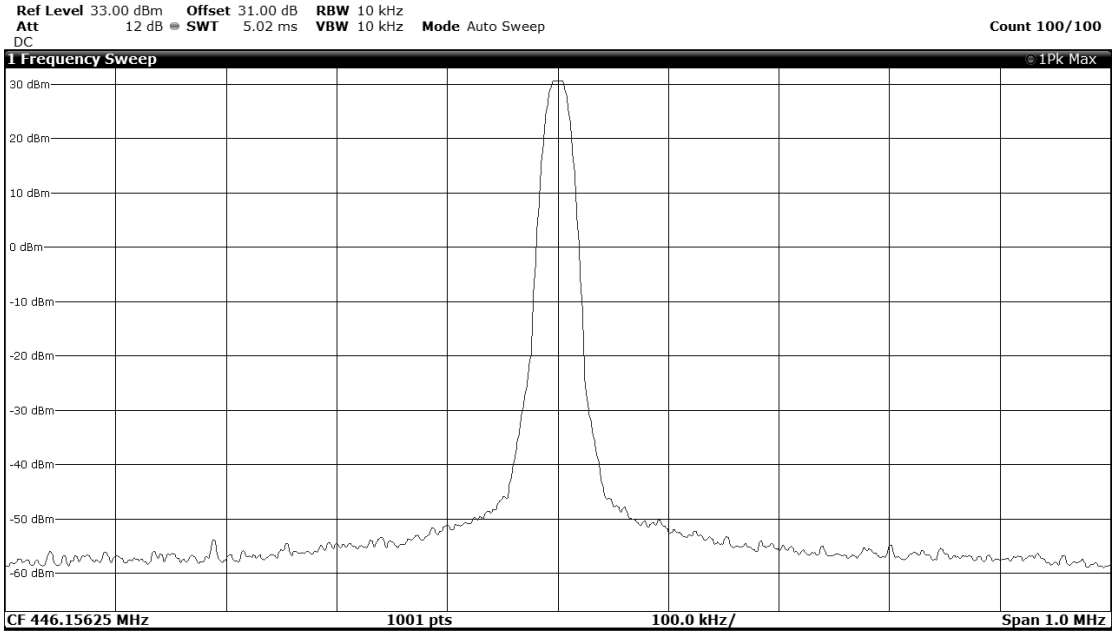


Figure 19 Tx Transient Spectrum, 1MHz Span, RBW = 10kHz, VBW = 10kHz, Auto Sweep and Peak Hold

7.5 Troubleshooting

The DE9945 is a complex RF and Baseband system. If incorrectly programmed or modified, results will be at variance from datasheet performance. Please study the CMX7341 and CMX994A datasheets, along with the User Manuals, associated schematics and layout drawings for the DE9945 board when troubleshooting. This section provides suggestions to help users resolve application issues that may be encountered.

7.5.1 Receiver Operation

Error Observed	Possible Cause	Remedy
Received data is not provided by the receiver	Incorrect set-up	Ensure that suitable values are written to the CMX7341 registers that control receiver gains and polarity. Also check the dc offsets and signal levels into the CMX7341 I/Q Inputs (Test loops 10 and 11).
Received data is not provided by the receiver	Incorrect set-up	CMX994A has not been programmed correctly. Check signals as above.
Synthesiser not locked	Incorrect configuration components	Check that the SKY72300 synthesiser programming data is correct. Measure VCO control voltage at TP7 and ensure that it is ~ 1.8Vdc for any of the RF channel frequencies specified.

Table 25 Receiver – Possible Errors

7.5.2 Transmitter Operation

Error Observed	Possible Cause	Remedy
Synthesiser not locked	Incorrect configuration components	Check that the SKY72300 synthesiser programming data is correct. Measure VCO control voltage at TP7 is ~ 1.8Vdc for any of the channel frequencies specified.
Poor Tx modulation spectrum	Modulation levels incorrect	Check that the CMX7341 main DAC attenuators have the desired values. (See Section 7.4.3). Ensure JP3 and JP4 are fitted.
Low power	PA not enabled	Check that the RAMDAC output is being enabled. Check that the PA control voltage at TP8 is ~2.6/2.7Vdc for maximum output power.

Table 26 Transmitter – Possible Errors

7.5.3 Error messages

For some error conditions, error codes will be displayed. These are detailed in Table 27. When displaying an error a similar message to that shown below will be displayed.

```
Err 01.01  01/02
FI Load Error
```

The two numbers at the right hand end of the top line show the current error being displayed, and the total number of errors. The '#' key will cycle through all current errors. The * key will exit the error display and return to normal operation.

Error Type	Error Code	Details
ARM Load Error	00.00	No ARM Application in Flash
FI Load Error	01.00	No FI in Flash
	01.01	Checksum or Prog Flag error
AMBE Error	02.00	AMBE Packet error
	02.01	AMBE Reset error
	02.02	AMBE Version error
	02.03	AMBE Rate error
	02.04	AMBE Mode error
	02.05	AMBE Start error
	02.06	AMBE Voice Packet error
	02.07	Not Used
	02.08	AMBE Sync error
Rx Packet Error	03.00	Rx Packet too big
	03.01	Rx Packet unrecognised
EEPROM Error	04.00	EEPROM parameters blank / corrupted
Error Buff Full	05.00	Error buffer is full

Table 27 Error Messages

8 Performance Specification

8.1 Electrical Performance

8.1.1 Absolute Maximum Ratings

Exceeding these maximum ratings can result in damage to the Evaluation Kit.

	Min.	Max.	Units
Supply (V_{IN} - V_{SS})	0	6.0	V
Current into or out of V_{IN} and V_{SS} pins	0	+1.5	A
Current into or out of any other connector pin	-20	+20	mA
Receiver Maximum Input Level		+10	dBm

8.1.2 Operating Limits

Correct operation of the Evaluation Kit outside these limits is not implied.

	Notes	Min.	Max.	Units
Supply (V_{IN} - V_{SS})		3.6	4.8	V

8.1.3 Operating Characteristics

For the following conditions unless otherwise specified:
Xtal Frequency = 19.2MHz, Bit Rate = 4.8 ksymbols/s,
Noise Bandwidth = 8.5kHz, V_{IN} = 4.5V, T_{AMB} = +25°C.
CMX7341 loaded with 7341FI-2.1.x.x

	Notes	Min.	Typ.	Max.	Units
DC Parameters					
I_{IN} (Script/GUI mode)	1	–	290	–	mA
I_{IN} (Rx enabled and SFS)	1	–	350	–	mA
I_{IN} (Rx enabled and Rx Data)	1	–	330	–	mA
I_{IN} (Tx and PA off)	1	–	300	–	mA
I_{IN} (Tx and PA enabled (+30dBm, continuous))	1	–	1300	–	mA
I_{IN} (Tx and PA enabled, (+30dBm, slotted))	1	–	800	–	mA
AC Parameters					
Frequency Range		444	–	450	MHz
Tx					
Mean Output Power	2,3	+26	+27	+31	dBm
Output Impedance		–	50	–	Ω
Adjacent Channel Power					
1st ACP	2,3	–	–	60	dBc
2nd ACP	2,3	–	80	–	dBc
Modulation RMS Frequency Error	2	–	1	–	%
Unwanted Emissions	4	–		-36	dBm
Frequency Error		–	0.5	–	ppm
Rx					
Input Impedance		–	50	–	Ω
Sensitivity	5	–	-123	–	dBm
Adjacent Channel Rejection	4	–	66	60	dB
Co-Channel Rejection	4	–	9.5	–	dB
Intermodulation	4	–	67	–	dB
Conducted Spurious	4	–	–	-54	dBm
Microcontroller Interface					
For timings see CMX7341 Datasheet					

Notes:

1.PCB current consumption, not current consumption of the CML devices.
2.Modulation 4FSK, Deviation 1.944kHz and RRC alpha = 0.2.
3.12.5kHz Channel Spacing and 8.5kHz Measurement Bandwidth
4.Tested as specified in EN 300 113. BER (Bit Error Rate) is 1 x 10^{-2} in all cases.
5.Measured at 5 % BER

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