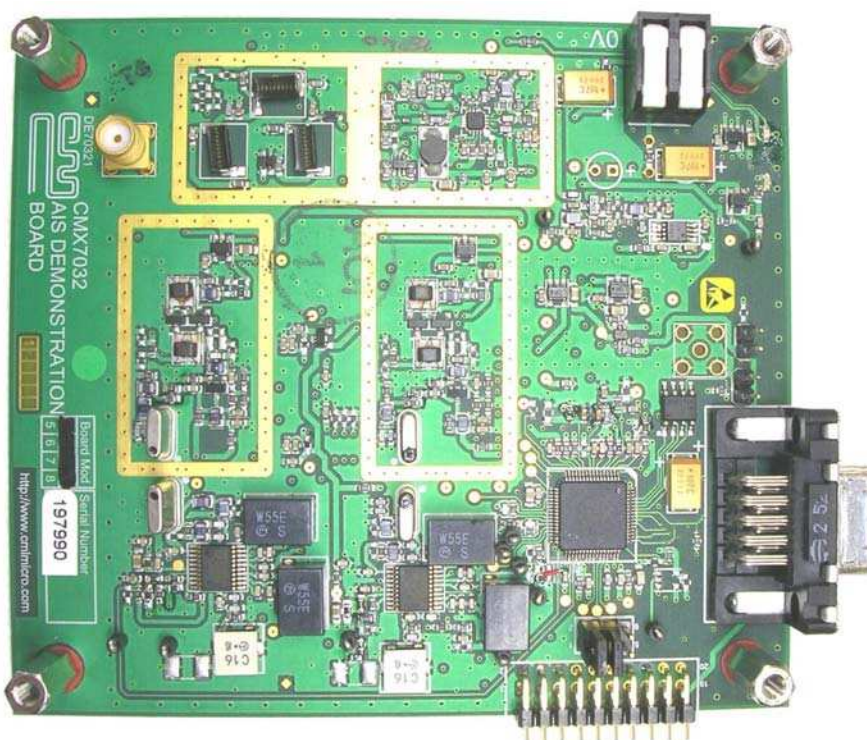


## Features

- Class B AIS transceiver technology demonstrator (DE70321T)
- Designed to meet IEC62287
- 2 Watt Tx operation
- 19.2MHz Reference for 9600bps data rate
- C-BUS interface to host  $\mu$ C
- Dual Channel Rx-only operation (DE70321)
- RS232 NMEA-0183 interface for host-less operation
- Dual, independent GMSK receivers
- On-board EEPROM



## 1 Brief Description

The DE70321(T) is a complete AIS Class B (IEC 62287) technology demonstrator aimed at speeding manufacturers' design and development of AIS Class B transponders and AIS receiver products using the CMX7032 AIS Class B Baseband Processor with RF Synthesiser IC. The design is a flexible platform which allows users to configure and evaluate the CMX7032 with two build options:

- DE70321T Class B Transceiver uses 7032/7042FI-1.x (FI-1.x used with CMX7032 or CMX7042)
- DE70321 Dual Channel Rx-only uses 7032FI-2.x (FI-2.x used with CMX7032 only)

Function Image™ FI-1.x allows full host control over all CMX7032 functions whereas Function Image™ FI-2.x automatically programs the CMX7032 RF synthesisers to the correct receive frequencies.

*continued on next page ...*

The DE70321 default board configuration is for dual channel receive (FI-2.x) on 161.975MHz (AIS channel 1) and 162.025MHz (AIS channel 2) with 25kHz channel spacing and 9600bps over-air data rate. An EEPROM (pre-programmed with FI-2.x) is included which can automatically load the Function Image™ FI-2.x into the CMX7032 at power-up. Received data is automatically provided as NMEA 0183-HS sentences at 38,400 baud from the DB9 RS232 port.

The DE70321T default board configuration is for a transceiver which is configurable over the C-BUS interface, once the CMX7032 has been loaded with the appropriate Function Image™. An EEPROM is included which can automatically load a Function Image™ into the CMX7032 at power-up. By default this is pre-programmed with FI-2.x, although the EEPROM can easily be loaded with FI-1.x instead. Alternatively, FI-1.x can be loaded directly over C-BUS into the CMX7032, without using the EEPROM.

All necessary RF circuits, such as VCOs, a 2 watt PA, harmonic filter, antenna switching and LNA, are provided on the DE70321T, to facilitate easy evaluation and demonstration of the design as a Class B unit.

A C-BUS interface is provided for control of the CMX7032T by a host microcontroller (which is required to perform the higher level protocol functions on a Class B implementation).

Wherever EEPROM is referred to in this document, either EEPROM or Serial Flash memory may be assumed, as either type may be fitted to the board. The former has a two byte memory address whereas the latter has a three byte memory address. Function Images™ can be used with either type of memory: the loading mechanism automatically accounts for the type of memory used.

The DE70321 and DE70321T designs are production engineered for low cost, with a minimum number of component types and values and using only low-cost, off-the-shelf components. All references to DE70321(T) in this document imply both the DE70321 and DE70321T Demonstration Kits.

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## 1.1 History

Version	Changes	Date
1	• Advance information (PCB568 Rev A)	14.09.07
2	• First Release (PCB568 Rev A)	20.09.07
3	• First Release (PCB568 Rev B)	24.01.08
4	• Clarification of FI loading methods	24.07.08
5	• Corrections to instructions in section 7.4	05.09.08
6	• Corrections to tables 4, 9 & 10 to agree with mod state changes	21.01.09
7	• Additions to tables 9 and 10, defining the fitting of R192	24.03.09
8	• Introduction of DE70321T (DE70321 configured for Tx/Rx operation)	03.07.09
9	• Use of Analog Devices & Fujitsu PLL's as a replacement for the LMX2332, plus other alternative components.	13.09.10

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

## 2 Block Diagram

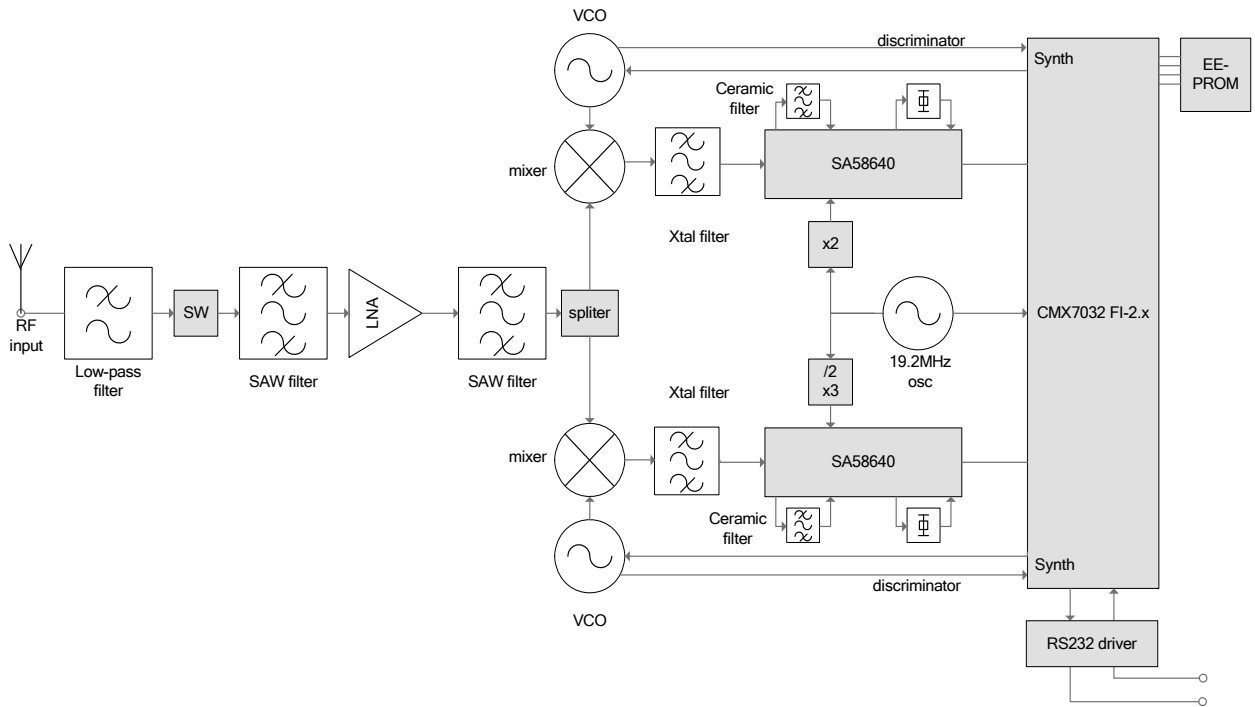


Figure 1 Rx-only Block Diagram: DE70321

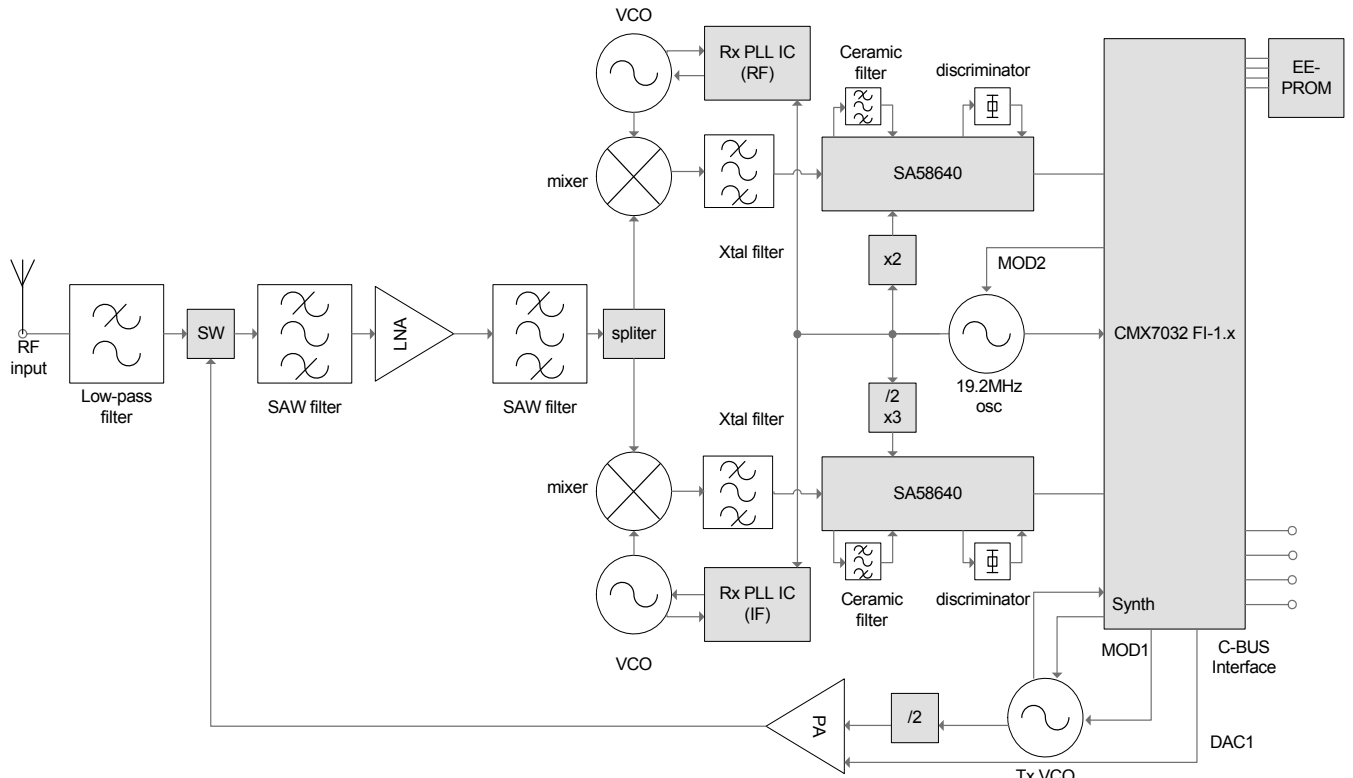


Figure 2 Tx/Rx Block Diagram: DE70321T

### 3 Preliminary Information

The DE70321T and DE70321 provide platforms for the evaluation and demonstration of the CMX7032 using either FI-1.x (Class B transceiver) or FI-2.x (dual channel Rx-only). By default, the DE70321 is configured for dual channel Rx-only use and the DE70321T is configured for transceiver use. In both DE70321(T) variants, the EEPROM is pre-programmed with FI-2.x. Either kit can be reconfigured into the other variant by a few small component changes. Details of these are given in sections 7.2 and 7.3 for dual-channel Rx or Tx/Rx transceiver operation, respectively.

#### FI-1.x (Class B transceiver)

To use the DE70321T in Class B transceiver mode, a separate micro-controller is needed to provide control and perform the higher levels of Class B protocol and user interface. The PE0002 (see [www.cmlmicro.com](http://www.cmlmicro.com) for information) provides the basic host micro-controller functionality from a PC via a USB interface. The PE0002 supersedes the PE0001, previously used to interface the DE70321(T) kits to a PC via its RS232 interface. The PE0001 kit can still be used, if available. Before use, the Function Image™ has to be loaded into the CMX7032. A choice of loading FI-1.x from EEPROM or loading it directly over C-BUS (host micro-controller mode) is available: this choice is determined by the configuration of the 'BOOTEN' pins (see *Table 3* and *Table 4*). To load FI-1.x from EEPROM, it first has to be re-programmed with the correct Function Image™: by default it is pre-programmed with FI-2.x. See section 7.4.2 for EEPROM re-programming details. The DE70321 hardware can be reconfigured as a DE70321T, for use with FI-1.x and the C-BUS interface. Details of this are given in section 7.3.

#### FI-2.x (dual channel Rx-only)

To use the DE70321 in Rx-only mode with FI-2, the RS232 interface is used instead of the C-BUS interface: both interfaces use the same pins on the CMX7032. A jumper (J4) on the DE70321 is used to configure the CMX7032 into either C-BUS or RS232 operation. Typical operation is to use the pre-programmed EEPROM on the DE70321, which will automatically load FI-2.x into the CMX7032 at power-on. Both EEPROM and RS232 options are available for loading the FI, however the RS232 method requires a non-standard baud rate. For loading the FI, the 'BOOTEN' pins need to be correctly configured (see *Table 3* and *Table 4*).

In operation, NMEA-083HS data is automatically output on the RS-232 port as soon as valid data has been detected. A simple PC terminal application (e.g. HyperTerminal) running at 38,400 baud, 8 bits, no parity, no handshake, will display the information received on a PC connected to the DE70321's RS232 port. If a suitable antenna for the AIS frequencies (162MHz) is connected, the received data can be used with chart plotting software in order to display local AIS activity. This assumes that the test location is within reasonable range of AIS equipped vessels.

When a later version of FI-2.x becomes available, it is possible to re-program the EEPROM with this FI. However, the EEPROM has to be programmed via the C-BUS interface, not via RS232. Further details of how to do this are given in section 7.4.3.

The DE70321T hardware can be reconfigured as a DE70321, for use with FI-2.x and the RS232 interface. Details of this are given in section 7.2.

### 3.1 Laboratory Equipment

The following laboratory equipment is recommended for use when testing this Demonstration Kit:

- Power Supply
- Spectrum Analyser
- RF Power Attenuator
- RF Signal Generator
- AIS Message Generator

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

#### 3.1.1 Power Supply

The supply input voltage to the PCB is nominally 7.2V (5.5V to 7.6V acceptable). On board regulators are provided to generate all voltage rails used on the PCB (3V and 5V rails are used in the receivers and 4.75V for the transmitter PA). The 7.2V supply should be rated at 2A.

**NOTE:** Care should be exercised with the supplies as they are not protected for reverse polarity. Operation at 12V will exceed the power dissipation ratings of the internal regulators.

## 3.2 Handling Precautions

In common with other Demonstration Kits, this product is designed for use in office and laboratory environments. The following practices will help ensure its proper operation.

### 3.2.1 Static Protection

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.

### 3.2.2 Contents - Unpacking

Please ensure that you have received all of the items detailed on the separate information sheet (EK70321) and notify CML within 7 working days if the delivery is incomplete.

## 3.3 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.**

## 4 Quick Start

This section provides instructions for users who wish to experiment immediately with the DE70321 or DE70321T Demonstration Kits. A more complete description of these kits and their use appears later in this document. The user should read the appropriate CMX7032 Datasheet and User Manual (FI-1.x or FI-2.x) before using these kits.

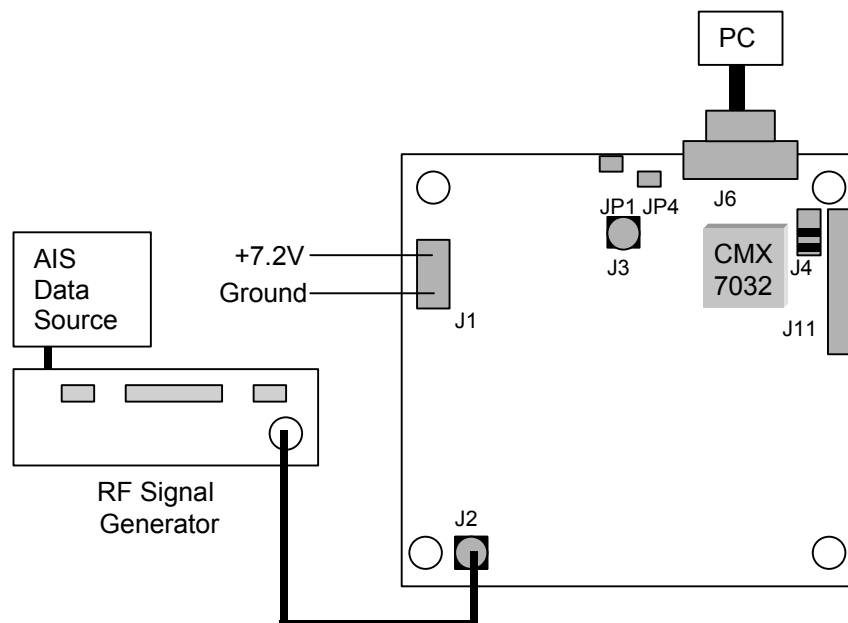
### 4.1 Setting-Up – FI-2.x Rx-only mode

By default, the DE70321 is supplied with components (see *Table 9*) and jumpers (see *Table 3*) set for (EEPROM configured) FI-2.x Rx-only operation, to act as a dual channel AIS receiver.

The following procedure is recommended:

1. Connect test leads as shown below.
2. J2 should be connected to an RF signal generator modulated with a suitable AIS data source.
3. Power should be applied to the main supply (7.2V nominal). The CMX7032 device will be reset on power-up.

The board is now ready for operation. An example of typical connections to the DE70321 is shown in *Figure 3*.



**Figure 3 Typical Connections for DE70321 (Rx only configuration)**

## 4.2 Adjustments – FI-2.x Rx-only mode

None.

## 4.3 Operation – FI-2.x Rx-only mode

To use the DE70321 the user should attach an RS232 compatible terminal to the DB-9 connector, J6, (a PC running HyperTerminal is suitable). The EEPROM should already be loaded correctly with FI-2.x and jumpers J4: 1-2 and 3-4 set to enable the RS232 interface and EEPROM boot modes. The CMX7032 FI-2.x datasheet gives details of the available commands and programmable options. In this mode, there are no configurable options using the RS232 interface, the device is completely autonomous and will output all correctly received AIS data as a formatted NMEA-0183HS data stream. To confirm operational status, the device will output the "\$PCML<crLf>" data string at power-on. (Note: The device will also confirm the version number of the FI-2.x firmware which was pre-programmed into the EEPROM. If no version number is reported, then this is FI-2.0.0.2.). See *Table 5* for details of the RS232 connections on DB-9.

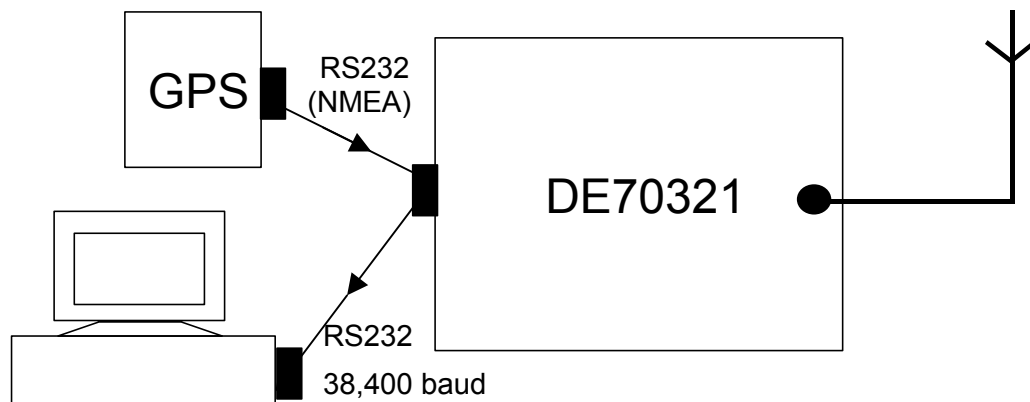
### Data Rate

A 19.2MHz reference (as provided) is required for compatibility with FI-2.x. This will set the over-air data rate to 9600bps.

### Receive Mode

AIS1 and AIS2, NMEA-0183, 38,400 baud, 8bits, 1 stop bit, no parity, no handshake.

Using the default Rx-only operation with FI-2.x it is possible to simply connect an antenna and power to the DE70321 and start receiving data, configuration is shown in *Figure 4*. As shown, a GPS unit can provide data to the DE70321 RS232 data input at 4,800 baud. This data is checked by the DE70321, then forwarded to the PC at 38,400 baud along with the AIS data, so that 'own position' information is included in the NMEA output. Further details are given in the CMX7032 FI-2.x datasheet. Note that NMEA-0183HS does not include the provision for handshaking or flow control.



**Figure 4 'Rx only' Operation, using DE70321 and FI-2.x**

It is recommended that the user familiarise themselves with the datasheet of the CMX7032 FI-2.x device prior to attempting further testing.

#### 4.4 Setting-Up – FI-1.x Class B transceiver mode

By default, the DE70321T is supplied with components (see Table 10) set for FI-1.x Rx/Tx transceiver operation, whereas the jumpers (see Table 3 and Table 4) are set for (EEPROM configured) FI-2.x Rx-only operation, to act as a dual channel AIS receiver.

Reconfigure the DE70321 (see Figure 8), by changing the appropriate jumpers (see Table 3 and Table 4) to load FI-1.x either from the on-board EEPROM or via the C-BUS interface (J11). If loading from the on-board EEPROM is to be used, it will first have to be re-programmed with FI-1.x (see section 7.4.2 for EEPROM re-programming details).

Connect a 50Ω load to the PA output stage. The board is now ready for operation. An example of typical connections to the DE70321 is shown in Figure 5.

#### 4.5 Adjustments – FI-1.x Class B transceiver mode

None.

#### 4.6 Operation – FI-1.x Class B transceiver mode

It is recommended that users familiarise themselves with the datasheet of the CMX7032 FI-1.x device prior to attempting to use the DE70321T in Class B transceiver mode.

The following procedure is recommended:

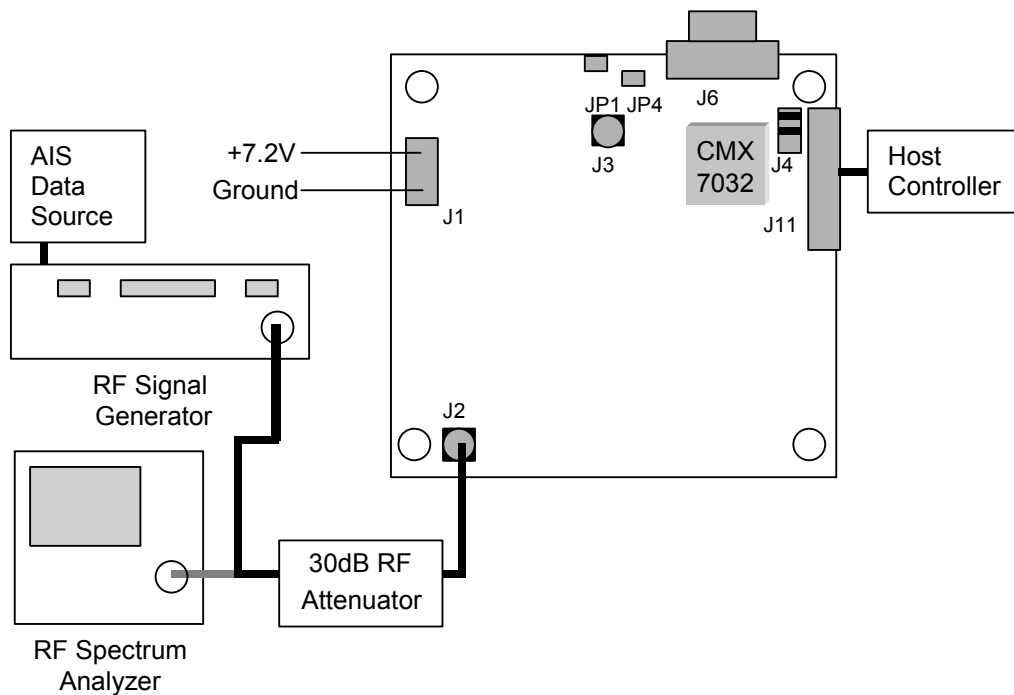
1. Ensure the DE70321T has been correctly configured (see Table 10 and section 7.1.5) and the EEPROM re-programmed with FI-1.x, if it is intended to use the EEPROM method of FI loading. The jumpers (see Table 3 and Table 4) will need to be set for loading FI-1.x either from the on-board EEPROM or via the C-BUS interface (J11).
2. Connect test leads as required, (including the host  $\mu$ Controller to C-BUS interface J11).
3. If testing the transmitter, the RF output J2 should be connected to a suitable 50Ω load.

**THE USE OF AN EXTERNAL 50Ω LOAD IS ESSENTIAL TO PREVENT POSSIBLE DAMAGE TO THE PA STAGE.**

**OPERATION OF THE DE70321 WITH FI-1.x (AIS CLASS B TRANSCEIVER MODE) IS ONLY INTENDED TO BE UNDER LABORATORY CONDITIONS AND IS NOT TO BE USED FOR A LIVE AIS CLASS B APPLICATION. ENSURE THAT THE INTEGRITY OF THE LIVE AIS SYSTEM IS NOT COMPROMISED BY ANY RF EMISSIONS FROM THE DE70321.**

4. If testing the receiver, J2 should be connected to an RF signal generator modulated with a suitable AIS data source. A 30dB power attenuator can be used to protect the generator if required.
5. Power should be applied to the main supply (7.2V nominal). The CMX7032 device should be reset and programmed appropriately.

To confirm operational status, the device's \$AA and \$A9 registers can be interrogated immediately after loading the FI. The value returned in \$AA represents the device identification code (either \$7032 or \$7042) and the value returned in \$A9 represents the version number of the FI loaded (e.g. \$1023 for FI-1.0 version 2.3).



**Figure 5 Typical Connections for DE70321T (transceiver configuration)**

To use the DE70321T the user will need a mechanism to send and receive data and commands via the C-BUS host  $\mu$ Controller interface on the CMX7032, which is brought out on connector J11. The CMX7032 Datasheet and User Manual give details of the registers and commands. Either PE0002 or PE0001 Interface Cards can be used to operate the CMX7032. The PE0002 has superseded the PE0001: it can handle higher data rates (e.g. transmission of continuous over-air data), by use of a scripting language. PE0002 scripts for some of the typical command sequences are available from the CML website (see [www.cmlmicro.com](http://www.cmlmicro.com) for details). For the PE0001, some typical command sequences are given in section 4.6.1.

#### 4.6.1 Typical PE0001 Command Sequences

##### Data Rate

The default over-air data rate with a 19.2MHz reference is 9600bps.

##### Receive Mode

The following example shows a typical configuration / initialisation script for the PE0001.

```
//set up SysCLK frequencies
w16 ab 0400
w16 ac 2e00
w16 ad 0800
w16 ae 2e00
```

```
//set up IRQ enable and Rx1
w16 c8 0001
w16 ce 8800
w16 c8 0002
```

##### Transmit Mode

The following example script shows a configuration for the CMX7032 transmitter (PRBS, 162.025MHz). Note that the CMX7032 PLL is programmed to double this frequency with a 50kHz step size.

```
//set up MOD levels
//enter config mode
w16 c8 002f
Delay 100
//write mod level data
w16 a7 0320
Delay 100
//set Tx Mod level command
w16 c8 8103
Delay 100
//exit config mode
w16 c8 0001
Delay 1000

//load RFsynth data
w16 b2 4980
w16 b2 4c00
w16 b2 4151
w16 b2 4406
w16 b3 ac2b
//enable Tx and RAMDAC
w16 a7 0005
w16 c8 002e
//wait for PA to ramp up
delay 1000
//Tx PRBS
w16 c8 002c
```

The above sequence enables the transmitter and scales the modulation accordingly. The power amplifier is enabled using the DAC0 Output. This DAC has an automatic ramping circuit to allow an accurate power ramping profile to be applied to the power amplifier.

## 5 Signal Lists

Input power supply connections are via a 2 way snap socket J1 as follows. These are paralleled with those of the host controller. J2 is an RF signal and uses an SMA 50ohm socket.

Signal	PCB Connector
Ground	J1 Pin 1
+Vin (7.2V nominal)	J1 Pin 2
VHF Rx input / Tx output	J2
Clock input / output (optional)	J3 (not fitted)

**Table 1 Signal List**

Connections to the host C-BUS interface are as follows. All are 3.3V logic levels unless otherwise stated. As supplied and configured for Rx-only operation (FI-2.x), no user connection is required to this port.

J11 Pin No.	Signal Name	Type	Description
1	IO0/CS2	I/P	Chip select input for the Rx PLL IC. For FI-1.x, pull high externally (disabled = low, by default).
2	CSN	I/P	C-BUS: Chip select input for the 7032 from host controller.
3	IO1/RX_ON	I/P	Enables the linear regulators for the receivers. For FI-1.x, pull low externally (disabled = high [3V3 DVdd], by default).
4	COMMAND DATA	I/P	C-BUS: Serial data input.
5	IO2/TXVCO	I/P	Enables the TXVCO supply. For FI-1.x, pull low externally to enable (disabled = high [3V3VCO], by default).
6	SERIAL CLOCK	I/P	C-BUS: Serial clock input
7	IO3	I/P	Option available to link this pin to the TXEN output from the CMX7032, or to use as an enable for VCCPA. For FI-1.x, connect if required (not connected, by default).
8	REPLY DATA	O/P	C-BUS: A 3-state C-BUS serial data output
9	IO4/UTC_IN	I/P	UTC input (for Tx synchronisation timing) from the host. For FI-1.x, connect if required (not connected, by default).
10	IRQN	O/P	C-BUS: IRQN open drain connection.
11	GNDD		
12	GNDD		
13	BOOTEN1	I/P	Remove jumper J4 (3-4) if connecting to this pin.
14	BOOTEN2	I/P	Remove jumper J4 (5-6) if connecting to this pin.
15	RS232/ C-BUSN	I/P	Remove jumper J4 (1-2) if connecting to this pin.
16	Not connected		
17	Not connected		
18	Not connected		
19	+3V3D	O/P	
20	+3V3D	O/P	

**Table 2 C-BUS Header Interconnect Table**

Jumper/ Link	Function if fitted	Factory Default	Function if not fitted
J4, 1-2	RS232/C-BUSN pulled high by an on-board 1kΩ resistor. This selects RS232 mode, for use with FI-2.x.	Fitted	This signal is internally pulled low, which selects C-BUS mode. Remove the link when using FI-1.x or when re-programming the EEPROM with FI-2.x (which is done in C-BUS mode).
J4, 3-4	BOOTEN1 pulled high	Fitted	Each of these signals is internally pulled low. See Table 4 for details of the bootstrap options.
J4, 5-6	BOOTEN2 pulled high	Not fitted	
JP1, 1-2	EEPROM WPN pulled low	Not fitted	EEPROM is not write-protected (pulled high by an on-board 10kΩ resistor). This allows EEPROM re-programming.
JP2	Void – not available.	~	Void – not available.
JP3	Void – not available.	~	Void – not available.
JP4, 1-2	IO2/TXVCO is pulled low if R173 is fitted. This link currently has no function, so the Tx VCO supply is always disabled. Pulling IO2/TXVCO low externally enables the TXVCO supply.	Not fitted	The Tx VCO power supply is disabled (pulled high by an on-board 10kΩ resistor).

**Table 3 Jumpers and Configuration Headers**

	BOOTEN2	BOOTEN1	
RS232 host load or C-BUS host load	1	1	
<i>reserved</i>	1	0	
EEPROM load	0	1	<= factory default setting
No FI load	0	0	

**Table 4 BOOTEN Pin States**

CONNECTOR PINOUT FOR J6 (DB9F)	
D type Pin No.	Signal Description
1	Not connected
2	RXD (i.e. data output to PC)
3	TXD (i.e. data input from PC)
4	Not connected
5	Ground
6	Not connected
7	RTS (input from PC)
8	CTS (output to PC)
9	Not connected – Optional +V input

**Table 5 RS232 Interface (J6)**

<b>TEST LOOPS</b>		
<b>Test Loop Ref.</b>	<b>Default Measurement</b>	<b>Description</b>
TL1		Receiver A discriminator output
TL2		Receiver B discriminator output
TL3		Receiver A RSSI output
TL4		Receiver B RSSI output
TL5		Inverted TxEN
TL6		UTC Input
TL7		Receiver A discriminator input to CMX7032 after inverting op-amp
TL8		Receiver B discriminator input to CMX7032 after inverting op-amp
TL9		DAC1 (VCO modulation output)
TL10		DAC2 (VCTCXO modulation output)
TL11		GNDD
TL12		Void – not available
TL13		GNDA
TL14		Void – not available
TL15		Void – not available
TL16		Void – not available
TL17		Power amplifier control voltage

**Table 6 Test Loops**

TEST POINTS		
Test Point Ref.	Typical Value	Description
TP1	3.14V	Receiver LNA collector voltage
TP2		Void – not available
TP3	3.33V	Receiver A IF amplifier collector voltage
TP4	4.94V	Receiver A IF Demodulator IC supply voltage
TP5	3.3V	+3.3V Digital supply
TP6	4.6V	Receiver A 2 <sup>nd</sup> LO multiplier supply voltage
TP7	3.33V	Receiver B IF amplifier collector voltage
TP8	4.94V	Receiver B IF Demodulator IC supply voltage
TP9		DE70321(T) is not configured to use this signal (SPARE3)
TP10	3.3V	+3.3V VCO supply
TP11		Void – not available
TP12	5.0V	Receiver A +5V supply regulator output
TP13	5.0V	Receiver B +5V supply regulator output
TP14		Void – not available
TP15		Void – not available
TP16		Void – not available
TP17	1.53V	Receiver B 2 <sup>nd</sup> LO multiplier supply voltage
TP18		DE70321(T) is not configured to use this signal (SPARE1)
TP19		DE70321(T) is not configured to use this signal (SPARE2)
TP20	2.8V	Receiver B / PLL2 tuning voltage
TP21	3.3V	+3.3V Analogue supply
TP22	2.66V	Receiver A / Tx / PLL1 tuning voltage
TP23		XTALN
TP24	4.66V	PA supply regulator output
TP25	2.51V	Tx VCO collector voltage
TP26		TxEN+V monitor
TP27		Monitor for buffered VCTCXO output
TP28		SYCLK2 output - reserved for future use
TP29		AUXDAC2 output
TP30		AUXDAC3 output
TP31		AUXDAC4 output
TP32	1.32V	Tx VCO buffer collector voltage
TP33	2.4V	Tx PA driver collector voltage
TP34		DE70321(T) is not configured to use this signal (MICFB)
TP35		DE70321(T) is not configured to use this signal (MIC)
TP36		DE70321(T) is not configured to use this signal (AUDIO OUT)
TP37		SYCLK1 output - reserved for future use
TP38		RxA VCO tuning voltage monitor point, if using separate PLL IC (Tx/Rx configuration)
TP39		RxB VCO tuning voltage monitor point, if using separate PLL IC (Tx/Rx configuration)

Table 7 Test Points

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

Note that the voltages are typical for their active state (i.e. Tx or Rx operation enabled).

## 6 Circuit Schematics and Board Details

For clarity, circuit schematics are available as separate high-resolution files. The layout on each side is shown in *Figure 6*, below. A bill of materials is also available from the CML website.

The PCB is a 6-layer design fabricated with FR4 material and is 1.6mm thick. Full Gerber and Drill files are available on request. The DE70321(T) has been designed for low-cost production.

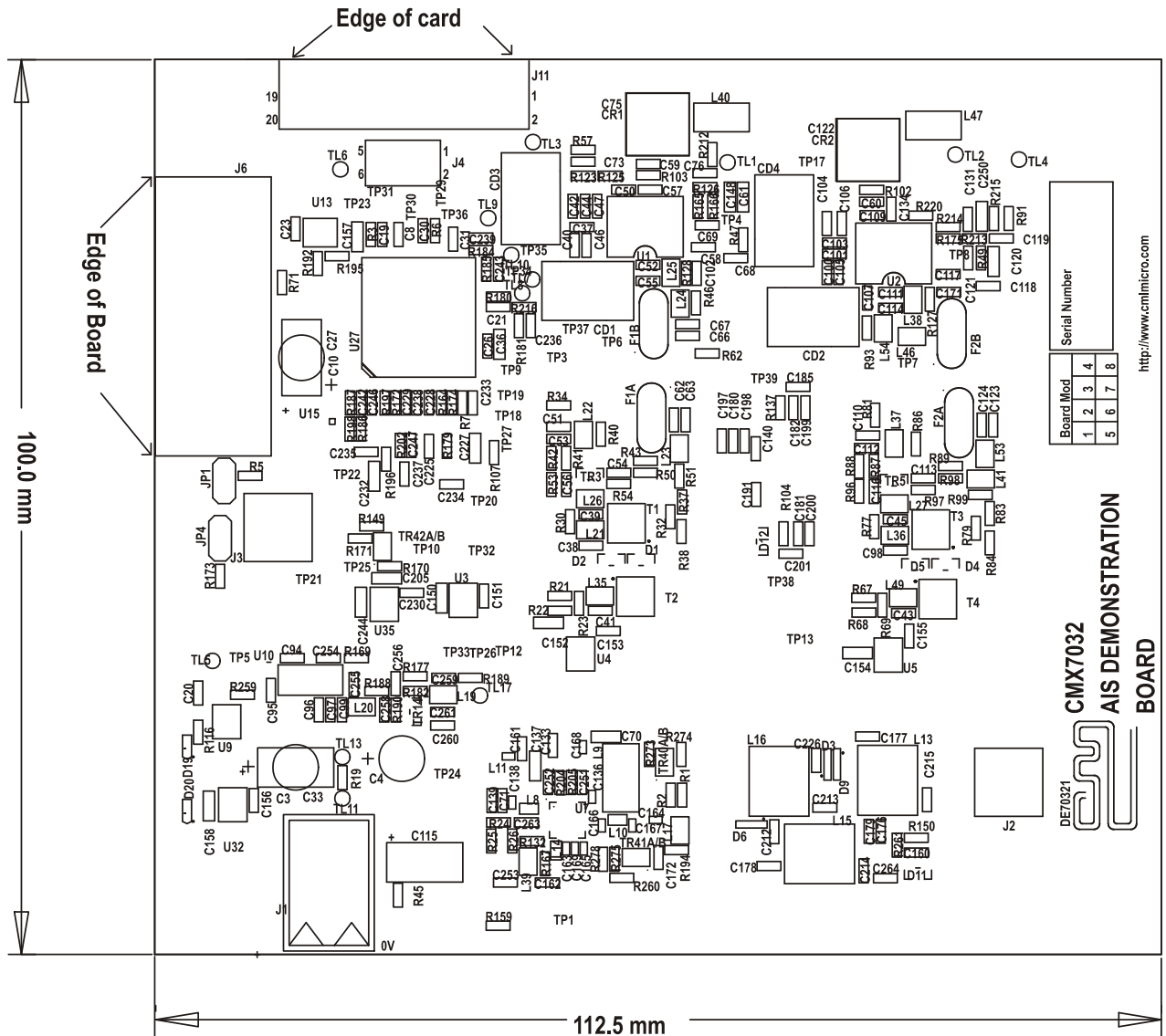


Figure 6a PCB Layout: top



Figure 6b PCB Layout: bottom

## 7 Detailed Description

The CMX7032 Datasheet and User Manual (available from [www.cmlmicro.com](http://www.cmlmicro.com)) should be referred to for a detailed description of the CMX7032 device. There are separate datasheets and user manuals for each Function Image™ (FI-1.x and FI-2.x).

The DE70321(T) functionality includes:

- Demonstration of the CMX7032 RF synthesiser functionality at  $\approx 125\text{MHz}$  (or  $\approx 320\text{MHz}$  in Tx mode).
- Demonstration of full dual AIS receiver performance.
- Capability to demonstrate an Rx-only application by automatically loading a Function Image™ from EEPROM at power on, outputting data to an RS232 port.
- An interface that allows the card to be connected to a host  $\mu\text{Controller}$ , to allow real-time control, or to a PC (a separate interface may be required).
- Demonstration of AIS transmitter performance.

In summary, the DE70321(T) provides the basis for the user to create a complete AIS class B transponder solution.

If further design support is required, please contact your regional CML office or an approved CML distributor.

### 7.1 Hardware Description

#### 7.1.1 Front End LNA

The PCB includes a 160MHz discrete bipolar LNA using TR1, which is designed to meet IEC62287 requirements.

#### 7.1.2 SAW Image Filters

Filters FL2 (before the LNA) and FL1 (after the LNA) are marine band SAW filters (Golledge MA06510) and provide image and other spurious response rejection. FL1 is followed by a two-way splitter to the independent receivers.

#### 7.1.3 Mixers

After provision for attenuation and matching, two transformers and two Schottky diode pairs form an inexpensive discrete double balanced diode ring mixer.

#### 7.1.4 IF Crystal Filters

The IF filters (F1 and F2) are 4-pole crystal filters (Golledge MA09567 and MA09568 respectively) with a pass-band of approximately  $\pm 7.5\text{kHz}$ . Correct matching of the filters is necessary to achieving optimum performance.

#### 7.1.5 Receiver 1st Local Oscillators

VCOs are provided for 1<sup>st</sup> LOs of the receivers. In an Rx only application, these can be locked using the two PLLs on the CMX7032. However, the available charge pump voltage (3.3V) means that the whole band cannot be covered and the LO phase noise would not meet the adjacent channel rejection requirements of the Class B standard. It is however perfectly sufficient for a receive only application. For a Class B application, the Rx VCOs can be locked using U8, a dual synthesiser IC. This has a 5V charge pump. The VCOs require a component value change (see *Table 10*) to optimise the tuning voltage range for each PLL option. A 5kHz step size is required so as to utilise the reference oscillator as a source for the 2<sup>nd</sup> LOs using a 455kHz 2<sup>nd</sup> IF.

Rx Band / MHz	Rx IF / MHz	LO Range / MHz
156.025-162.025	RXA 38.855	117.170-123.270
156.025-162.025	RXB 29.255	126.770-132.770

**Table 8 Local Oscillator Frequencies**

Note that the LMX2332 Dual PLL IC is now obsolete. The Analog Devices ADF4216 or ADF4218L may be used as pin compatible replacements but require minor programming changes. The Fujitsu MB15U36 may also be used; this too requires minor programming changes but also needs pin 9 isolating to disconnect this from ground.

#### 7.1.6 Reference Oscillator

A 19.2MHz VCTCXO is provided on the PCB. If C231 is removed and C241 fitted, an alternative clock source can be applied to J3. Note that for transmit operation, both the VCO and the reference need to be modulated.

The 19.2MHz signal is multiplied by two, using TR7, and filtered to provide a 38.4MHz 2<sup>nd</sup> LO signal for receiver A. The 19.2MHz is divided by two, then multiplied by 3 and filtered to provide a 28.8MHz 2<sup>nd</sup> LO signal for receiver B. In Rx-only mode the divide by 2 function could be achieved using the CMX7032 internal dividers, however in order to meet the AIS class B adjacent channel rejection requirements, a separate divider is provided.

#### 7.1.7 2<sup>nd</sup> IF / Demodulation

The IF signal from the crystal filter is matched to the input of the SA58640 FM/IF demodulation IC (U1 for receiver A, U2 for receiver B). This IC and surrounding circuitry provide a number of functions:

- A mixer from the 1<sup>st</sup> IF to 455kHz (the 2<sup>nd</sup> IF)
- Further channel filtering using inexpensive ceramic filters (e.g. Murata CFWLB455KEFA-B0, AEL LTM455EW)
- A limiter/discriminator demodulator using a ceramic resonator (e.g. Golledge MA05126, AEL D455K000S003)
- RSSI outputs that can be monitored by CMX7032 AUX ADCs.

#### 7.1.8 Transmitter

The transmitter provides at least +33dBm over the range 156.000 to 162.025MHz. The transmit VCO (TR12/13) operates at twice the wanted frequency. This can be locked using PLL1 on the CMX7032, which provides a 3.3V charge pump output. The VCO output is then divided by two using U10 and then amplified to approximately +3dBm using TR14. This then drives the RFMD RF5110G power amplifier module U7.

The CMX7032 RAM DAC output (DAC 0) is connected to the PA control line via a diode and transistor (D10 and TR2) to provide sufficient current to the PA control pin.

A high current linear regulator U6 provides the supply to the PA. This can be shut down using the optional circuitry of TR16/17, which provide a Tx time-out function.

#### 7.1.9 Tx/Rx Switch

Circuitry is provided to implement a classical series-shunt Tx/Rx switch using PIN diodes (D6 and D3 after a quarter wave section). The diodes are activated in transmit via the TxEN signal from the CMX7032. An additional diode (D9) is provided, anti-parallel to D3, to protect the SAW filter FL2 input from extremely strong signals (e.g. a nearby VHF DSC / voice transceiver). This branch of the switch then goes to the receiver LNA.

#### 7.1.10 Harmonic filter

L13, L15 and associated components form a low loss low pass filter with traps centred at the 2<sup>nd</sup> and 3<sup>rd</sup> Tx harmonics. This filter is common to the transmitter and receiver paths and is connected between the Tx/Rx switch and antenna connector J2.

#### 7.1.11 RF Detector

There is also provision for an optional RF power detector (D11 and associated circuitry) prior to the harmonic filter. The output from this can be monitored using AUX ADC3.

## 7.2 Rx-only Operation

By default, the DE70321 is configured for Rx-only operation, with the following components fitted. Please refer to the current schematic for required component values.

Function	Component	
	Fitted	Not Fitted
RxA locked using CMX7032 PLL1 – RF Feedback	R198	R186 (Tx feedback)
RxA locked using CMX7032 PLL1 – RF Feedback	R200	R130 (LMX feedback)
RxB locked using CMX7032 PLL1 – RF Feedback	R201	R395 (LMX feedback)
RxA locked using CMX7032 - Tuning Voltage	R197	R157 (Tx Tuning V)
RxA locked using CMX7032 - Tuning Voltage	R155	R105 (LMX Tuning V)
RxB locked using CMX7032 - Tuning Voltage	R281	R280 (LMX Tuning V)
Disable separate Rx PLL.		R104/ R137
Permanently enable Rx supplies		R113
Add pullup resistor as pin 51 = NRESET function	R192	
Link VCTCXO adjust to VBias	C31 – TL9	R184
RxA LO tuning range	C267	Rx: 2.2pF
RxB LO tuning range	C414	Rx: 3.9pF

**Table 9 Rx-only Configuration Components**

In this mode the CMX7032 RF PLLs are used to provide the Rx Local Oscillators.

## 7.3 Tx/Rx Operation

By default the DE70321T is configured for Tx and Rx operation with the following components fitted. Please refer to the current schematic for required component values.

Function	Component	
	Fitted	Not Fitted
Tx locked using CMX7032 PLL1 – RF Feedback	R186	R198 (Rx feedback)
Tx locked using CMX7032 - Tuning Voltage	R157	R197 (Rx Tuning V)
RxA locked using separate PLL – RF Feedback	R130	R200 (CMX feedback)
RxB locked using separate PLL – IF Feedback	R395	R201 (CMX feedback)
RxA locked using separate PLL – RF Tuning Voltage	R105	R155 (CMX Tuning V)
RxB locked using separate PLL – IF Tuning Voltage	R280	R281 (CMX Tuning V)
Enable separate.	R104/ R137	
Enable switching of Rx supplies	R113	
Remove pullup resistor as pin 51 = no connection		R192
Connect VCTCXO adjust to MOD2	R184	C31 – TL9 wire link
RxA LO tuning range	C267	Tx: 3.9pF
RxB LO tuning range	C414	Tx: 5.6pF

**Table 10 Tx and Rx Configuration Components**

In this mode, the CMX7032 RF PLL1 is used for the transmitter Local Oscillator and a separate PLL IC is used for the receiver Local Oscillators. The changes to C267 and C414 are to provide operation over the full Marine band.

## 7.4 Firmware Description

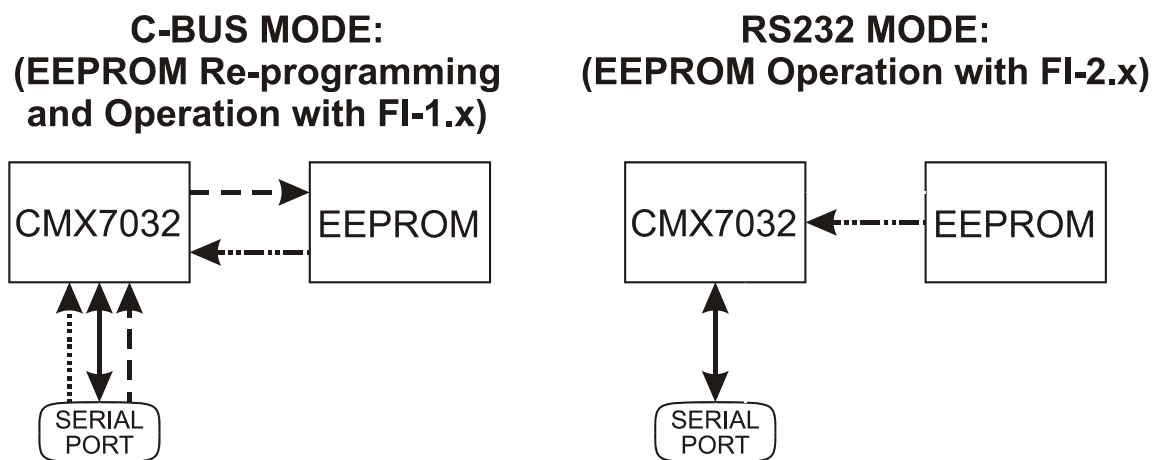
Please refer to the CML website for descriptions of the latest Function Images™ that can be used with the DE70321(T). References to EEPROM also include serial Flash memory, which may be fitted as an alternative. Function Images™ can handle either type of memory, automatically.

### 7.4.1 Changing the Function Image™

The DE70321(T) comes with FI-2.x (version current at time of shipping from CML) pre-installed into the EEPROM. Either a different FI can be programmed into the EEPROM or the FI can be loaded directly into the CMX7032 from the C-BUS serial port (FI-1.x only). See the CMX7032 data sheet for instructions on loading the FI directly into the CMX7032.

Please note that any attempt to load FI-2.x directly into the CMX7032, when in RS232 mode, will only be possible if the RS232 interface can operate at 360,000 baud. This method is not recommended. If successful, the FI-2.x will reconfigure the RS232 port to 38,400 baud for normal operation.

Figure 7 shows the recommended options for FI loading and operation, diagrammatically.



#### KEY:

- ..... Load FI directly from the Serial Port
- ..... Load FI from EEPROM
- - - Program FI into EEPROM
- Operation with the Serial Port (FI-1.x and FI-2.x)

**Figure 7 Function Image™ Loading and EEPROM Re-programming**

### 7.4.2 To Update the EEPROM with FI-1.x (Tx/Rx)

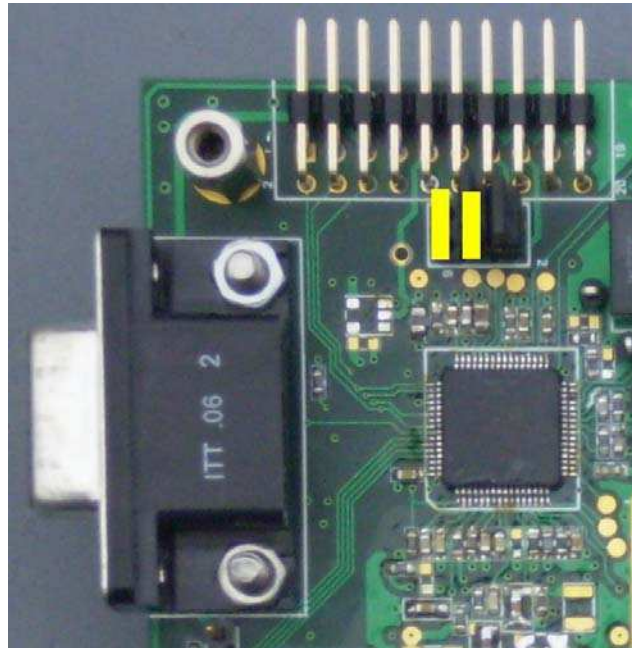
Follow the instructions in section 7.4.3 (for a PE0002) or section 7.4.4 (for a PE0001); but (in both cases) leave the DE70321T configured to C-BUS mode.

### 7.4.3 To Update the EEPROM with FI-2.x (Rx-only) if using a PE0002

The CMX7032 FI-2.x Datasheet and User Manual contain details of how to load and upgrade the EEPROM Function Image: this upgrade cannot be done directly, however, as the EEPROM is soldered in place and the RS232 interface would need to operate at 360,000 baud (because the DE70321 uses a 19.2MHz clock oscillator module). To overcome these limitations, the following method may be used. It requires the DE70321 to be reconfigured into C-BUS mode for the purposes of EEPROM programming:

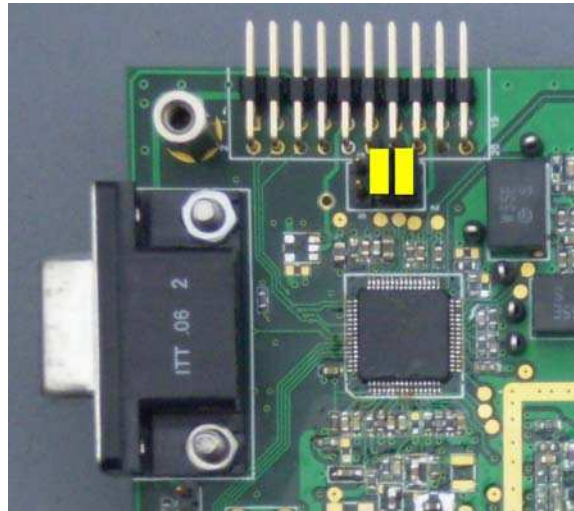
- Plug a PE0002 (available from CML) into the C-BUS interface of the DE70321 (J11) and connect the PE0002 USB port to the PC. The PE0002 requires its own power supply.

- Set the J4 links on the DE70321 for C-BUS operation (3-4 and 5-6 connected, no jumper across 1-2), as shown in *Figure 8*.



**Figure 8 J4 Links 3-4 and 5-6 for C-BUS Operation and Re-programming**

- Apply 7.2V to the DE70321 (J1).
- Apply 5.0V to the PE0002 kit.
- Run the program ES0002xx.exe (available from CML).
- Click on the tab “Program Serial Memory”.
- Browse to select the “thick stub” file FI\_FLASH\_10.h and open it. (This can be downloaded from the CML Portal by using the “CMX7032 and CMX7042 AIS Data Processors” link).
- Browse to select the “Function Image” file and open it.
- Ensure that the frequency selected is 19.2MHz (the clock divider setting will be set to E0C8).
- Select the correct C-BUS header for the target board.
- Click on Load.
- Click ok on the message “Thick Stub loaded”.
- The Function Image™ should download. Click ok on the message “Program serial memory complete”.
- Switch the power off (both DE70321 [7.2V] and PE0002 [5.0V]), disconnect the PE0002 from the DE70321 and connect the serial port cable to the DE70321 connector (J6).
- Close the ES0002xx application.
- Set the J4 links on the DE70321 to RS232 operation (3-4 and 1-2 connected, no jumper across 5-6, see *Figure 9*).
- Open HyperTerminal or a similar serial communications application. Settings are 38,400 baud, 8-bit data, no parity, 1 stop bit, no flow control.
- Apply 7.2V to the DE70321 (J1).
- Check that the DE70321 sends “\$PCML” at switch-on. This confirms that FI-2.x has been successfully installed / updated. Note that the FI-2.x firmware version number is not returned in FI-2.0.0.2, although it will be returned in future FI releases.

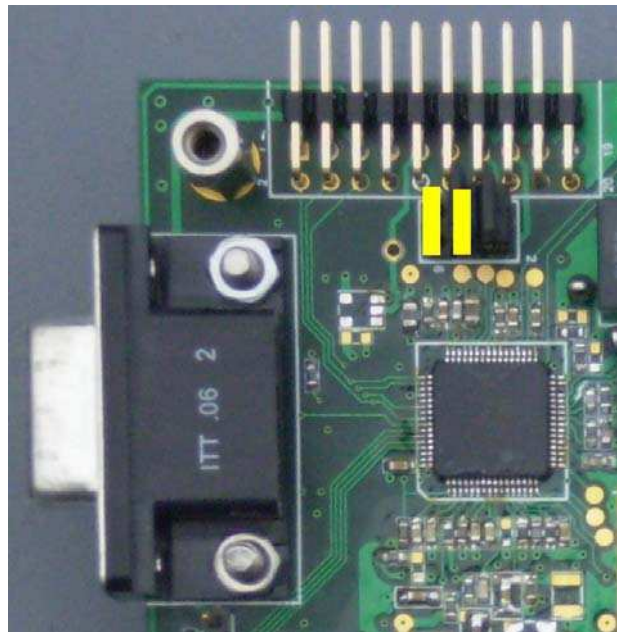


**Figure 9 J4 Links 1-2 and 3-4 for RS232 Operation**

#### **7.4.4 To Update the EEPROM with FI-2.x (Rx-only) if using a PE0001**

The CMX7032 FI-2.x Datasheet and User Manual contain details of how to load and upgrade the EEPROM Function Image: this upgrade cannot be done directly, however, as the EEPROM is soldered in place and the RS232 interface would need to operate at 360,000 baud (because the DE70321 uses a 19.2MHz clock oscillator module). To overcome these limitations, the following method may be used. It requires the DE70321 to be reconfigured into C-BUS mode for the purposes of EEPROM programming:

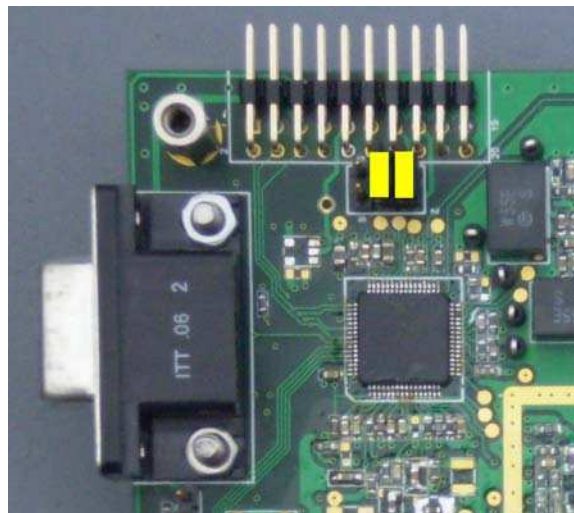
- Plug a PE0001 (available from CML) into the C-BUS interface of the DE70321 (J11) and connect the PE0001 serial port to the PC. The PE0001 derives its power supply from the J11 connector.
- Set the J4 links on DE70321 for C-BUS operation (3-4 and 5-6 connected, no jumper across 1-2) as shown in *Figure 10*.



**Figure 10 J4 Links 3-4 and 5-6 for C-BUS Operation and Re-programming**

- Apply 7.2V to the DE70321 (J1).

- Run the program ES0001xx.exe (available from CML). Select the correct Com port and click OK at the prompt.
- Press and release the RESETN button as instructed.
- Click on the tab “EEPROM load”.
- Browse to select the “thick stub” file and open it.
- Browse to select the “function image” file and open it.
- Ensure that the frequency selected is 19.2MHz and the clock divider setting is E0C8.
- Click on Load.
- Click ok on the message “Thick Stub loaded”
- It should respond “EEPROM load was successful”. Click OK.
- Switch the power off, disconnect the PE0001 from the DE70321 and transfer the serial port cable to the DE70321 connector J6.
- Close the ES0001xx application.
  
- Set the J4 links on DE70321 to RS232 operation (3-4 and 1-2 connected, no jumper across 5-6, see *Figure 11*).
- Apply 7.2V to the DE70321 (J1).
- Open HyperTerminal or a similar serial communications application. Settings are 38,400 baud, 8-bit data, no parity, 1 stop bit, no flow control.
- Check that the DE70321 sends “\$PCML” at switch-on. This confirms that FI-2.x has been successfully installed / updated. Note that the FI-2.x firmware version number is not returned in FI-2.0.0.2, although it will be returned in future FI releases.



**Figure 11 J4 Links 1-2 and 3-4 for RS232 Operation**

## 7.5 Application Information

The DE70321(T) is a technology demonstrator and has been designed to meet the requirements for AIS class B (IEC 62287) and AIS Rx-only products. However the DE70321(T) itself is a demonstration PCB and has not been approved to any product standards. The user is advised to use caution whilst transmitting, so as to ensure that the integrity of the live AIS system is not compromised and to comply with the local regulatory requirements.

## 7.6 Evaluation Tests

The DE70321(T) is intended to allow demonstration of CMX7032 RF synthesiser and baseband modem performance. The following is a list of tests from the IEC AIS standards (see below) along with the typical DE70321(T) performance.

Performance standards:

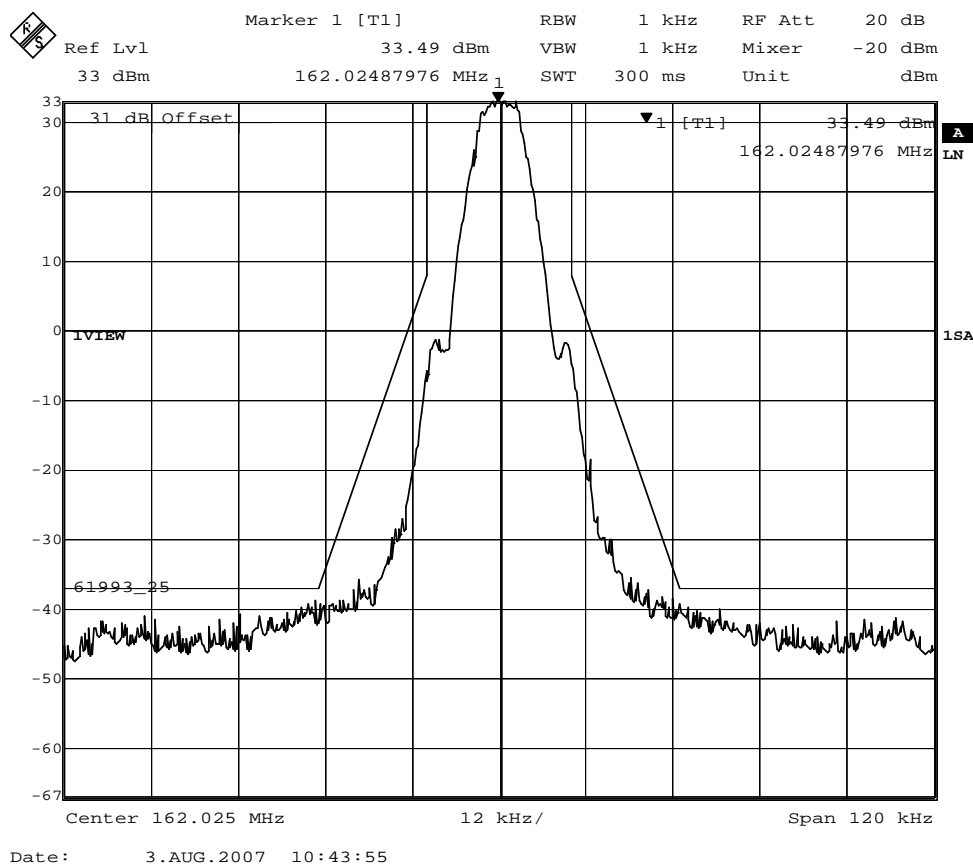
- IEC62287-1 AIS Class B
- IEC61193-2 AIS Class A

### 7.6.1 Frequency Error

Compliant, based on a selected 19.2MHz VCTCXO.

### 7.6.2 Tx Adjacent Channel Power (ACP)

The transmitter easily meets the stringent  $-70\text{dBc}$  mask for continuous transmission defined for AIS Class A (see *Figure 12*). Note that the Class B standard is relaxed to  $-60\text{dBc}$  but is for slotted transmission, so includes switching transients. To evaluate the Class B mask, real-time control by a host micro-controller is recommended.



**Figure 12 Continuous PRBS Modulated Tx Spectral Mask at the PA Output (+33dBm, 162.025MHz)**

### 7.6.3 Spurious Emissions

DE70321(T) meets the Tx spurious emissions requirements by at least 5dB.

### 7.6.4 Maximum Usable Sensitivity

Typically  $-112\text{dBm}$  for less than 20% Packet Error Rate (PER).

**7.6.5 Errors at High Input Levels**

Both receivers are error free at the test limits of  $-7$  and  $-77$ dBm.

**7.6.6 Co-channel Rejection**

With an interferer on the same frequency this is typically  $-9$ dB for less than 20% PER.

**7.6.7 Adjacent Channel Rejection (ACR)**

ACR performance is limited by local oscillator phase-noise. If configured to use the separate Rx PLL synthesiser, the performance of the DE70321(T) meets the Class B requirement of 70dB for less than 20% PER. The VCO sections should also be screened to reduce pick up that can induce sidebands onto the LO. If the CMX7032 SYSCLK outputs are used to generate the 2<sup>nd</sup> LO signals, performance is limited to around 65dB.

**7.6.8 Spurious Response Rejection**

Front-end SAW filters are provided on the DE70321(T) to limit out of band responses. This provides good performance for receive only applications, however some additional screening is required to meet the exacting demands of the class B standard (70dB for less than 20% PER). In particular, screening is required between the two halves of the crystal filter to reduce the 2<sup>nd</sup> image response.

**7.6.9 Intermodulation Response Rejection**

The DE70321(T) meets the Class B requirement of 65dB for less than 20% PER.

**7.6.10 Blocking or Desensitisation**

Blocking performance is excellent and is virtually error free at the test limits.

## 7.7 Troubleshooting

The CMX7032 is a complex RF and Baseband system. If incorrectly programmed or modified, results will be at variance from datasheet performance. Please study the CMX7032 datasheet, this manual and the associated schematics and layout drawings carefully when troubleshooting. This section provides suggestions to help users resolve application issues they might encounter.

### 7.7.1 Receiver Operation

Error Observed – FI-1.x	Possible Cause	Remedy
Received data is not provided by the receiver	BOOTEN pins have been set incorrectly	Set BOOTEN pins for EEPROM load as shown in <i>Table 3</i> and <i>Table 4</i> . Ensure EEPROM contains FI-1.x firmware. Alternatively, set BOOTEN pins (J4) for C-BUS loading (3-4 and 5-6 connected, no jumper across 1-2)
	FI not loaded	Reset by cycling power. Check Activation codes and Checksums.
Rx synthesiser not locked.	Incorrect configuration components	Check that the separate Rx PLL synthesiser programming data is correct.
Error Observed – FI-2.x	Possible Cause	Remedy
\$PCML not received	BOOTEN pins have been set incorrectly	Set BOOTEN pins for EEPROM load as shown in <i>Table 3</i> and <i>Table 4</i> . Ensure EEPROM contains FI-2.x firmware.
	FI not loaded	Reset by cycling power.
	RS232 terminal incorrectly configured	Set terminal for 38,400 baud, 8, N, 1, no flow control
Received data is not provided by the receiver	Insufficient RF signal	Increase RF level by changing antenna, location or signal source.
Rx synthesiser not locked.	Incorrect configuration components	Check against <i>Table 9</i> and <i>Table 10</i> above.

### 7.7.2 Transmitter Operation

Error Observed	Possible Cause	Remedy
Tx synthesiser not locked.	Incorrect configuration components	Check against <i>Table 9</i> and <i>Table 10</i> above. Also check that power to the TXVCO is enabled (VCC_TX).
Poor Tx modulation spectrum	Modulation levels incorrect	Enter config mode and transmit PRBS whilst observing the demodulated GMSK waveform. Adjust the mod levels to both the VCTCXO and VCO accordingly. Note that these levels may need to be different across the frequency band and from unit to unit.
Low power	PIN diode not enabled	Check that the TXEN+V power supply is enabled. Also check that the RAMDAC output is being enabled.

## Performance Specification

### 7.8 Electrical Performance

#### 7.8.1 Absolute Maximum Ratings

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

	<b>Min.</b>	<b>Max.</b>	<b>Units</b>
Supply Voltage ( $V_{IN} - V_{SS}$ )	0.0	7.6	V
Current into or out of $V_{IN}$ and $V_{SS}$ pins	0	+2.0	A
Current into or out of any other connector pin	-20	+20	mA

#### 7.8.2 Operating Limits

Correct operation of the DE70321(T) Demonstration Kit outside these limits is not implied.

	<b>Notes</b>	<b>Min.</b>	<b>Max.</b>	<b>Units</b>
Supply Voltage ( $V_{IN} - V_{SS}$ )		5.25	7.6	V
Xtal/External Clock Frequency		9.6	19.2	MHz

### 7.8.3 Operating Characteristics

For the following conditions unless otherwise specified:

Device Xtal Frequency = 19.2MHz, Bit Rate = 9.6kbps,  
 $V_{IN} - V_{SS} = 7.2V$ ,  $T_{amb} = +25^{\circ}C$ .

	Notes	Min.	Typ.	Max.	Units
<b>DC Parameters</b> (Excluding PA Supply)					
$I_{DD}$ (CMX7032 powersaved)	1	–	25	–	mA
$I_{DD}$ (Tx)	1	–	1500	–	mA
$I_{DD}$ (Rx, LNA enabled)	1	–	260	–	mA
<b>AC Parameters</b>					
<b>Tx Output</b>					
Tx Output Impedance		–	50	–	$\Omega$
Tx Output Power		–	33	–	dBm
<b>Rx Input</b>					
Rx Input Impedance		–	50	–	$\Omega$
Rx Sensitivity	2	–	-112	–	dBm
Maximum Input Level - without damage		–	–	0	dBm
<b>Xtal/Clock Input</b>					
Reference Clock Frequency		–	19.2	–	MHz
Reference Clock Level	3	1	–	–	Vp-p
<b><math>\mu C</math> Interface</b>					
See CMX7032 Datasheet					

- Notes:**
1. PCB current consumption, not current consumption of the CMX7032
  2. 20% Packet Error Rate (PER)
  3. Typically clipped sine wave

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