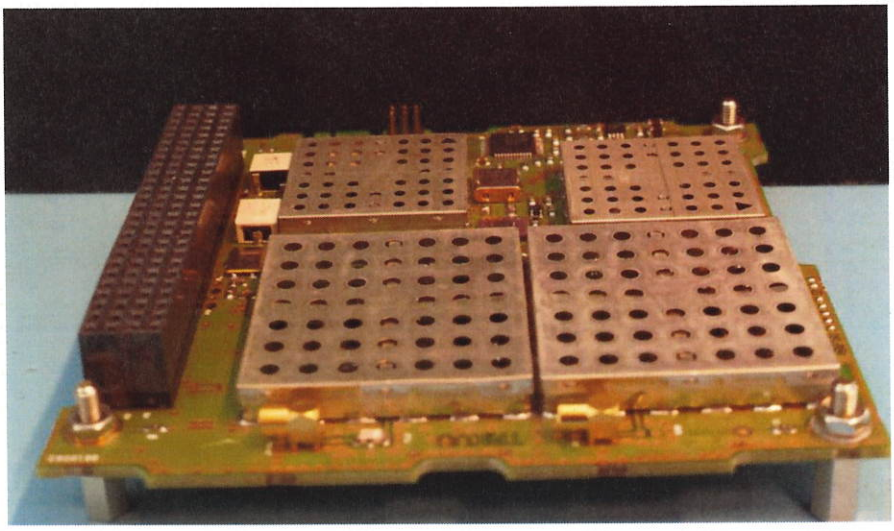
TRXVU Interface Control Document

ISIS.TRXVU.ICD.001



Issue 1.3

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		E. Timmer	§3.1, §3.2	Default connector types updated.
		R. Fernandez	§1.1, §2, §4.2	Clarification regarding document applicability added. Comments from I. Ibañez implemented. General document template update

Applicable Documents

#	Document ID	Title	Version
AD01	ISIS.TRXVU.OS.001	TRXVU Option Sheet	

Reference Documents

#	Document ID	Title	Version

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List of Acronyms

AFSK	Audio Frequency Shift Keying
ASCII	American Standard Code for Information Interchange
AX.25	Amateur X.25
BPSK	Binary Phase Shift Keying
COTS	Commercial off the shelf
CSKB	CubeSat Kit Bus
DC	Direct current
GND	Ground (reference electrical potential)
GPIO	General purpose Input / Output
HDLC	High-Level Data Link Control
I^2C	Inter integrated circuit communication bus.
ICD	Interface Control Document
IF	Intermediate Frequency
ISIS	Innovative Solutions In Space BV.
MCU	Micro Controller Unit
PLL	Phase-Lock Loop
RF	Radio Frequency
RX	Receiver
TBC	To Be Confirmed
TBD	To Be Determined
TBW	To Be Written
TRXVU	ISIS Transceiver, UHF Transmitter and VHF Receiver
TX	Transmitter
UHF	Ultra High Frequency (400 – 450 MHz)
UI	Unnumbered Information
VHF	Very High Frequency (130 – 170 MHz)
VSWR	Voltage Standing Wave Ratio

Table of Contents

ISIS.TRXVU.ICD.001 ..... *1*

1 Introduction **1**

1.1 Purpose and Scope of Document *1*

2 System Description **2**

3 Electrical interfaces **3**

3.1 VHF Receiver input *3*

3.2 UHF Transmitter output *4*

3.3 CubeSat Kit Bus interface *5*

3.4 Grounding *7*

4 RF interface **8**

4.1 Downlink *8*

4.2 Uplink *9*

5 Mechanical interface **10**

6 Thermal interface **12**

7 Software interface **13**

7.1 Description *13*

7.2 Parameter / response length *13*

7.3 Format specification *14*

7.4 Telemetry and Command Definition *14*

7.4.1 Receiver unit 14

7.4.2 Transmitter 18

7.5 Telemetry conversion formulas *26*

7.5.1 Receiver telemetry 26

7.5.2 Transmitter telemetry 26

Table of Figures

Figure 2-1 TRXVU Functional Block diagram 2
Figure 2-2 TRXVU board top and bottom view 2
Figure 3-1 TRXVU external interfaces (top view) 3
Figure 3-2 Receiver input interface schematic 3
Figure 3-3 Transmitter output interface schematic 4
Figure 3-4 CubeSat Kit Bus interface connectors 5
Figure 3-5 CSKB connector pin-out. 5
Figure 3-6 Mounting holes 7
Figure 5-1 TRXVU drawing 10
Figure 5-2 TRXVU overview drawing. 11

Table of Tables

Table 3-1 TRXVU External Interfaces 3
Table 3-2 Receiver input connector pin out 4
Table 3-3 Receiver input electrical characteristics 4
Table 3-4 Transmitter output connector pin out 4
Table 3-5 Transmitter output electrical characteristics 4
Table 3-6 CSKB connector pin-out. 6
Table 3-7 CSKB interface electrical characteristics 6
Table 4-1 Downlink RF, modulation and protocol parameters 8
Table 4-2 Uplink modulation and protocol parameters 9
Table 6-1 Thermal parameters 12
Table 7-1 Receiver telemetry conversion formulas 26
Table 7-2 Transmitter telemetry conversion formulas 26
Table 7-3 Forward and reflected power conversion table to dBm 27
Table 7-4 Forward and reflected power conversion table to milliWatts 28

1 Introduction

The ISIS TRXVU is a CubeSat standard compatible transceiver module designed specifically for nano-satellite applications. The transmitter frequency is programmable at UHF frequencies from 430 MHz to 450 MHz and supports BPSK. The receiver frequency is programmable at VHF frequencies from 140 MHz to 150 MHz and supports AFSK. Frequencies outside the above mentioned ranges are available upon request.

Unless otherwise noted, this document is applicable from TRXVU revision B and onwards.

1.1 Purpose and Scope of Document

This document is created to provide a concise overview of the various interfaces of the ISIS TRXVU for prospective users.

This document is valid until it is declared obsolete or replaced with a succeeding version. Changes with respect to the previous version will be clear from the revision. As this document may be updated without prior notice, it is advised to check the ISIS website "http://www.isispace.nl" or ask us for the latest version at "support@isispace.nl" before using this document as reference.

2 System Description

The internal structure is shown in Figure 2-1 and it can be split in three parts: a receiver, a transmitter and a shared section. The shared section interfaces with the rest of the satellite while receive and transmit sections communicate with the ground radio.

Receive and transmit sections are independent and each feature a dedicated MCU and an RF synthesizer.

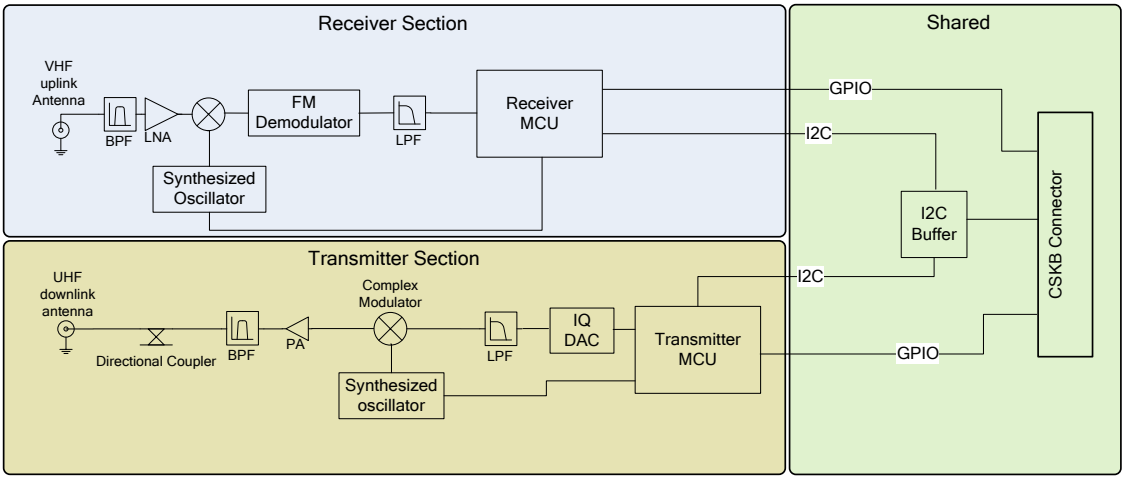


Figure 2-1 TRXVU Functional Block diagram

The board is shown in Figure 2-2 where both the top and the bottom side are visible. The top side contains the RF sections encased in shielding cans for protection against interference. The bottom side contains the power and control sections.

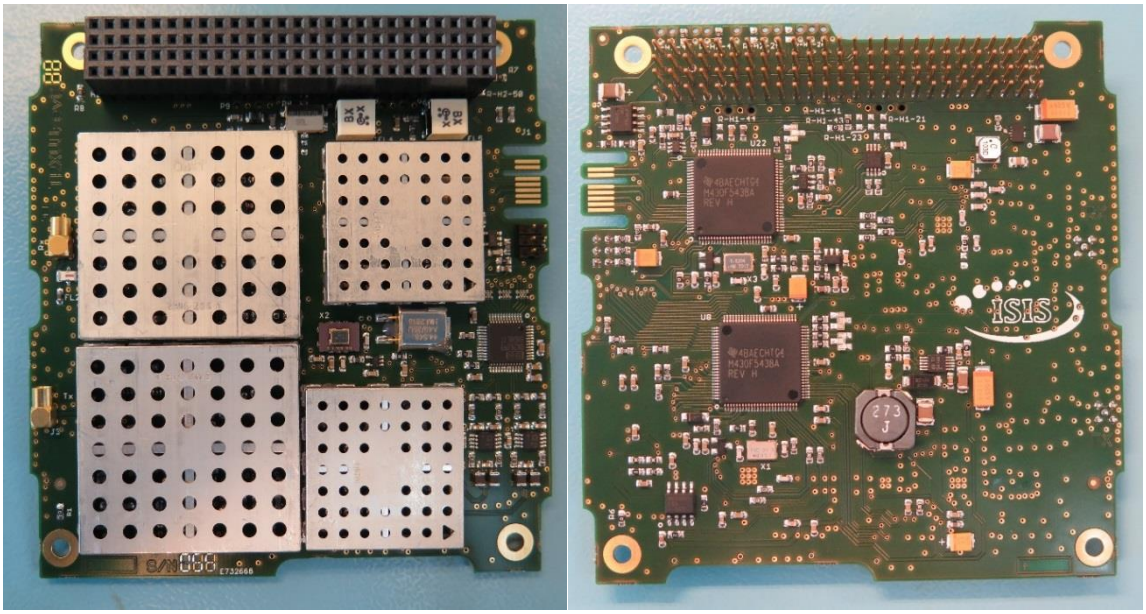


Figure 2-2 TRXVU board top and bottom view

3 Electrical interfaces

This section describes the electrical interfaces that are used to connect to the system and are divided into three groups: CubeSat Kit Bus, RF receiver and RF transmitter interface.

Table 3-1 and Figure 3-1 show how to identify the different electrical interface on the board.

Table 3-1 TRXVU External Interfaces

Source - destination	Signal	Comments
Antenna System	RX – VHF Receiver input	MMCX plug
Antenna System	TX – UHF Transmitter output	MMCX plug
System Bus	CubeSat Kit Bus	

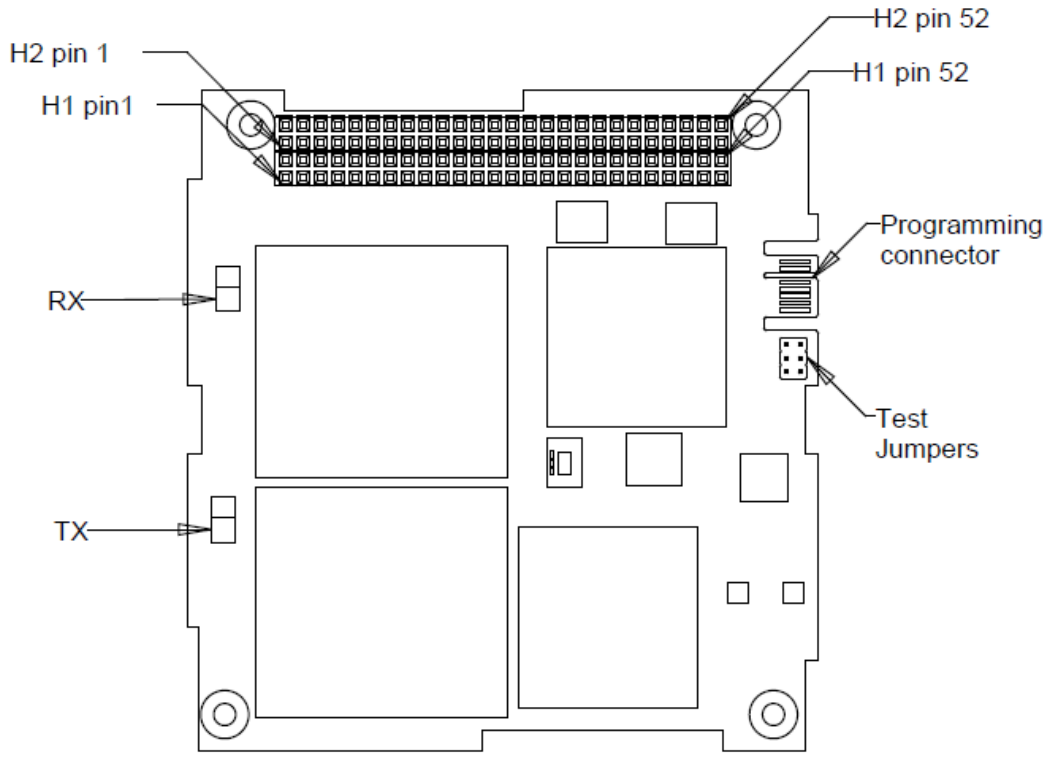


Figure 3-1 TRXVU external interfaces (top view)

The following paragraphs describe the different interfaces as seen from the board connector side, providing more details on the internal electrical connections.

3.1 VHF Receiver input

Figure 3-2 shows the VHF receiver input schematic to provide an indication of the internal structure.

The connector used to connect to a VHF antenna is by default an MMCX straight plug, top mount (other orientations are available upon request). Connector pin-out can be seen in Table 3-2.

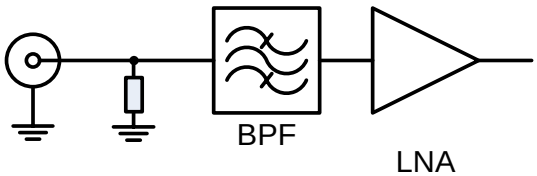


Figure 3-2 Receiver input interface schematic

Table 3-2 Receiver input connector pin out

Connector	Pin	Name	Remarks
RX (VHF)	Center pin	RF in	50 ohm RF input
	Shield	GND	RF ground (common with power ground)

Table 3-3 shows the electrical characteristics of the receiver.

Table 3-3 Receiver input electrical characteristics

Parameter	Value	Notes
Maximum input level	0 dBm	Values above the specified limit may cause permanent damage to the device.
VSWR	< 1:1.3	
DC Resistance to GND	< 1 Ω	

3.2 UHF Transmitter output

Figure 3-3 shows the UHF transmitter output schematic to provide an indication of the internal structure.

The connector used to connect to a UHF antenna, is by default an MMCX straight plug, top mount (other orientations are available upon request). Connector pin-out can be seen in Table 3-4.

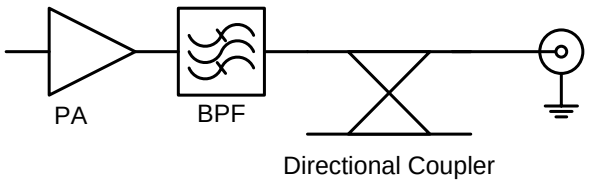


Figure 3-3 Transmitter output interface schematic

Table 3-4 Transmitter output connector pin out

Connector	Pin	Name	Remarks
TX (UHF)	Centre pin	RF out	50 ohm RF output
	Shield	GND	RF ground (common with power ground)

Table 3-5 shows the electrical characteristics of the transmitter.

Table 3-5 Transmitter output electrical characteristics

Parameter	Value	Notes
Peak output power	27 dBm	
Maximum input power	15 dBm	Values above the specified limit may cause permanent damage to the device.
VSWR	< 1:1.3	
DC Resistance to GND	< 1 Ω	

3.3 CubeSat Kit Bus interface

The system is designed to be fully compatible with the CubeSat Kit Bus interface, composed of two Samtec connectors of 52 pins each. As it can be seen in Figure 3-4, several options are available depending on customer requirements. The system is fitted by default with an SSQ-126-23-G-D connector to allow fitting the board in the middle of one stack, while an SSQ-126-21-G-D (to be used if mounted at the bottom of a stack) or a TSW-126-07-G-D (to be used if mounted at the bottom of a stack) can be fitted upon request. An ESQ-126-38-G-D or ESQ-126-39-G-D can also be used to fit the system in the middle of one stack. Alternative Samtec connectors can be fitted but these have to be approved by ISIS before order confirmation.

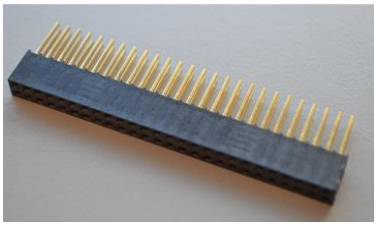
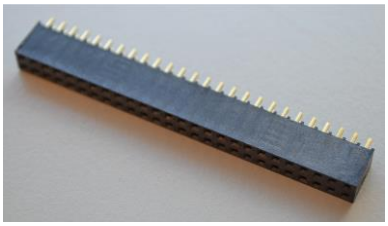
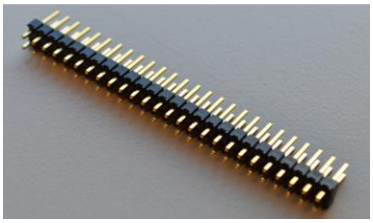
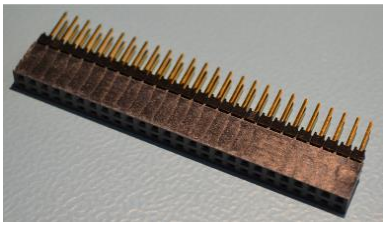
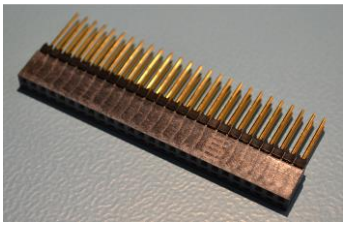
Standard Stack Thru	Stack termination bottom	Stack termination top
		
SSQ-126-23-G-D	SSQ-126-21-G-D	TSW-126-07-G-D
Stack Thru	**Stack Thru**	**Alternative**
		This option has to be approved by ISIS before order confirmation.
ESQ-126-38-G-D	ESQ-126-39-G-D	

Figure 3-4 CubeSat Kit Bus interface connectors

The pin-out of the stack connector and the definition of the channels are explained in the following figures and tables:

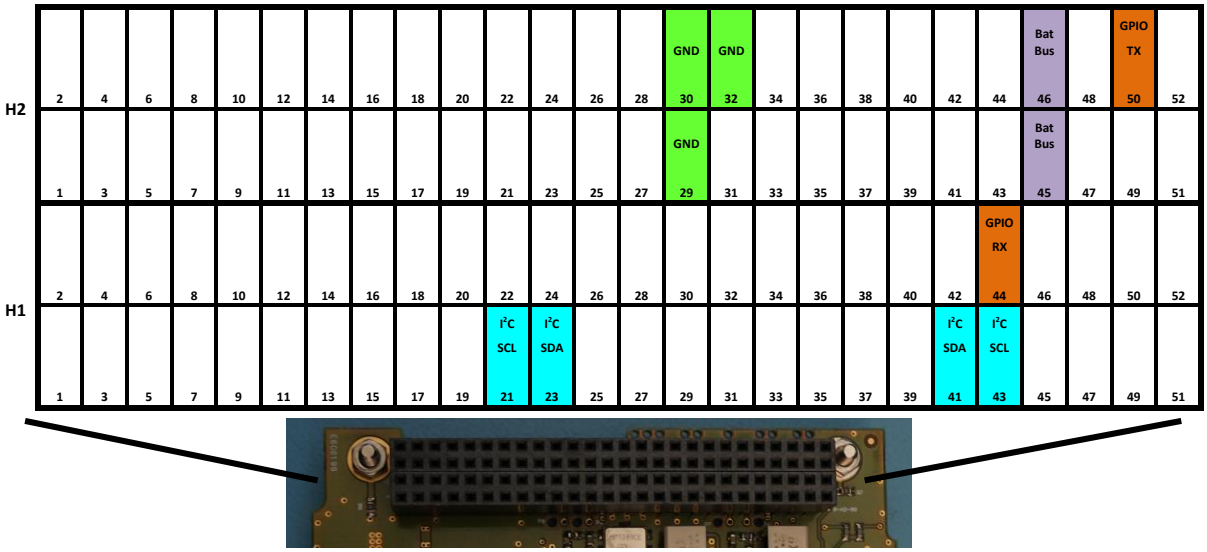


Figure 3-5 CSKB connector pin-out.

Table 3-6 CSKB connector pin-out.

CSKB Pin	Name	Signal Description	Value	Remarks
H1-21	ALT_SCL	I²C clock signal	0- 3.3 V	Available upon request
H1-23	ALT_SDA	I²C data signal	0- 3.3 V	Available upon request
H1-41	SDA	I²C data signal	0- 3.3 V	Default
H1-43	SCL	I²C clock signal	0- 3.3 V	Default
H1-44	GPIO_RX	Receiver general purpose digital I/O	0- 3.3 V	Available upon request. Functionality to be defined by customer and agreed upon by ISIS
H2-29	GND	Ground		
H2-30	GND	Ground		
H2-32	GND	Ground		
H2-45	BAT_BUS	Battery bus	6.0 – 20 V	
H2-46	BAT_BUS	Battery bus	6.0- 20 V	
H2-50	GPIO_TX	Transmitter general purpose digital I/O	0- 3.3 V	Available upon request. Functionality to be defined by customer and agreed upon by ISIS

Table 3-7 describes the electrical characteristics of the system bus.

Table 3-7 CSKB interface electrical characteristics

Parameter	Value	Notes
Power Supply		
Supply Voltage	6.0- 20 V	DC
Supply Max current	60 mA	Receiver only 8V supply
Supply Max current	600 mA	Receiver and Transmitter ON 8V supply
Supply Typical current	50 mA	Receiver only 8V supply
Supply Typical current	410 mA	Receiver and Transmitter ON 8V supply
I2C		
Bus logic low-level voltage	0.47 V	For further details please see here
Bus logic high-level voltage	2.3 V	For further details please see here
Supported I2C modes	Standard-mode (100 kbit/s) Fast-mode (400 kbit/s)	
I2C node type	Slave only	
I2C general call supported	Yes	
Supported address types	7 bits	
GPIO		
Input low-level voltage	0.8 V	
Input high-level voltage	2.3 V	
Maximum input current	1 mA	
Output low-level voltage	0.3 V	
Output high-level voltage	3 V	
Maximum output current	5 mA	

3.4 Grounding

The system is designed to have one single ground potential, which comes from the CubeSat Kit Bus connector (see section 3.3 for further details). The RF connectors (see section 4 for further details) share the ground connection with the CubeSat Kit Bus connector.

The four mounting holes in (shown in Figure 3-6) can be grounded (See [AD01] for further details) to the satellite structure.

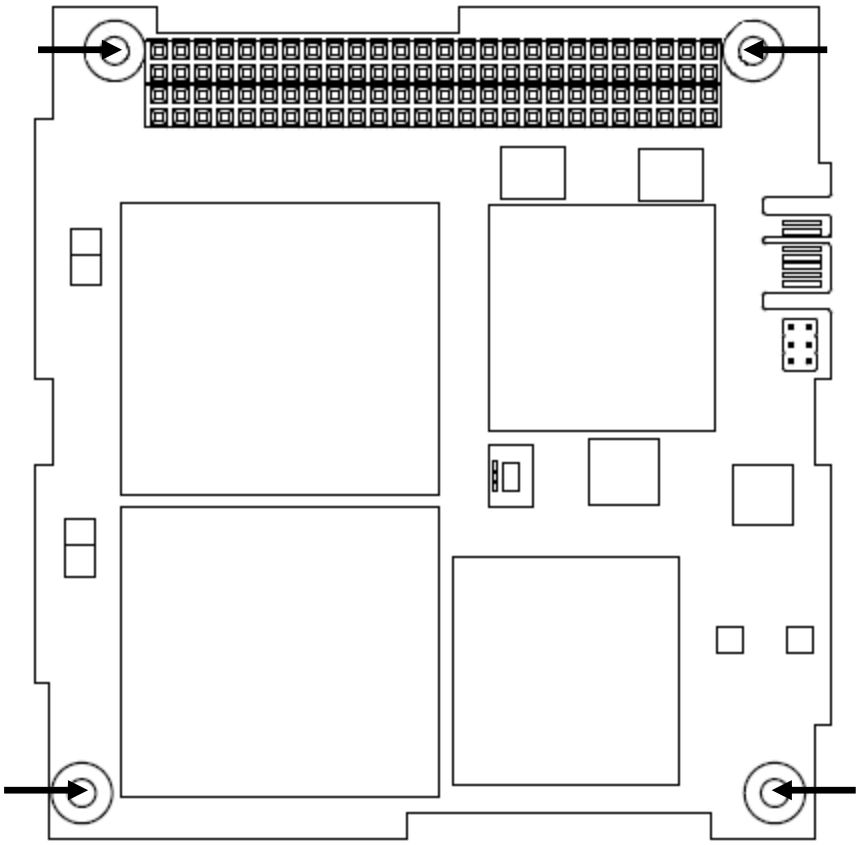


Figure 3-6 Mounting holes

4 RF interface

This section describes the uplink and downlink RF, modulation and protocol parameters.

4.1 Downlink

The downlink RF, modulation and protocol parameters are summarized in Table 4-1.

Table 4-1 Downlink RF, modulation and protocol parameters

Parameter	Value	Notes
Frequency range:	430 – 450 MHz	Other values available upon request
Total frequency error	100 Hz	Worst case, aging and temperature drift
Peak output power	27 dBm	
Modulation	BPSK	
Pulse shaping	Square Root Raised Cosine	
Roll-off factor	0.5	
Data rate	1200- 9600 bit/s	Other values available upon request
Necessary bandwidth	15 kHz	99% emitted power, 9600 bit/s
ITU emission class	15K0G1DAN	For further details please see Appendix 1 of the 2012 ITU Radio Regulations which can be found here. Note: Appendix 1 can be found in volume 2..
Power spectral density	-44.7 dBW / Hz	Maximum
Spurious suppression:	> 50dBc	
Scrambling polynomial	$x^{17} + x^{12} + 1$	G3RUH
Encoding	NRZ-I	
Protocol	AX.25 connectionless or HDLC	AX.25: Only UI frames supported. See [AD01] for further details.
Maximum frame payload size	235	Default value. See [AD01] for further details.

4.2 Uplink

The uplink RF, modulation and protocol parameters are summarized in Table 4-2.

Table 4-2 Uplink modulation and protocol parameters

Parameter	Value	Notes
Frequency range	140 – 150 MHz	Other values available upon request
Total frequency error	1 kHz	Worst case, aging and temperature drift
Modulation	AFSK	
Frequency deviation	3.5 kHz	
Data rate	1200 bit/s	
ITU emission class	12K5F1DBN	For further details please see Appendix 1 of the 2012 ITU Radio Regulations which can be found here. Note: Appendix 1 can be found in volume 2.
First IF	45 MHz	
Second IF	455kHz	
IF bandwidth	30 kHz	
Baseband bandwidth	5.3 kHz	
Local oscillator frequency	Receive frequency – 45 MHz	
Receiver sensitivity	-104 dBm +/-1dB	Bit Error Rate = 10^{-5}
Required E_b/N_0	20 dB	Bit Error Rate = 10^{-5}
System noise temperature	2000 K	
Scrambling polynomial	None	No scrambling employed
Protocol	AX.25 connectionless or HDLC	AX.25: Only UI frames supported. See [AD01] for further details.
Maximum frame payload size	200	Default value. See [AD01] for further details.

5 Mechanical interface

The board should be mounted in the satellite structure by means of the four 3.2 mm mounting holes on the PCB. This interface is compatible with ISIS structures. It is not recommended to mount the board by any other means than this mounting interface. The mass of the complete system (including all the default options as specified in [AD01]) is **75 grams**. The total weight can vary by up to **± 10 grams** due to the different options populated on the board and device-to-device variations.

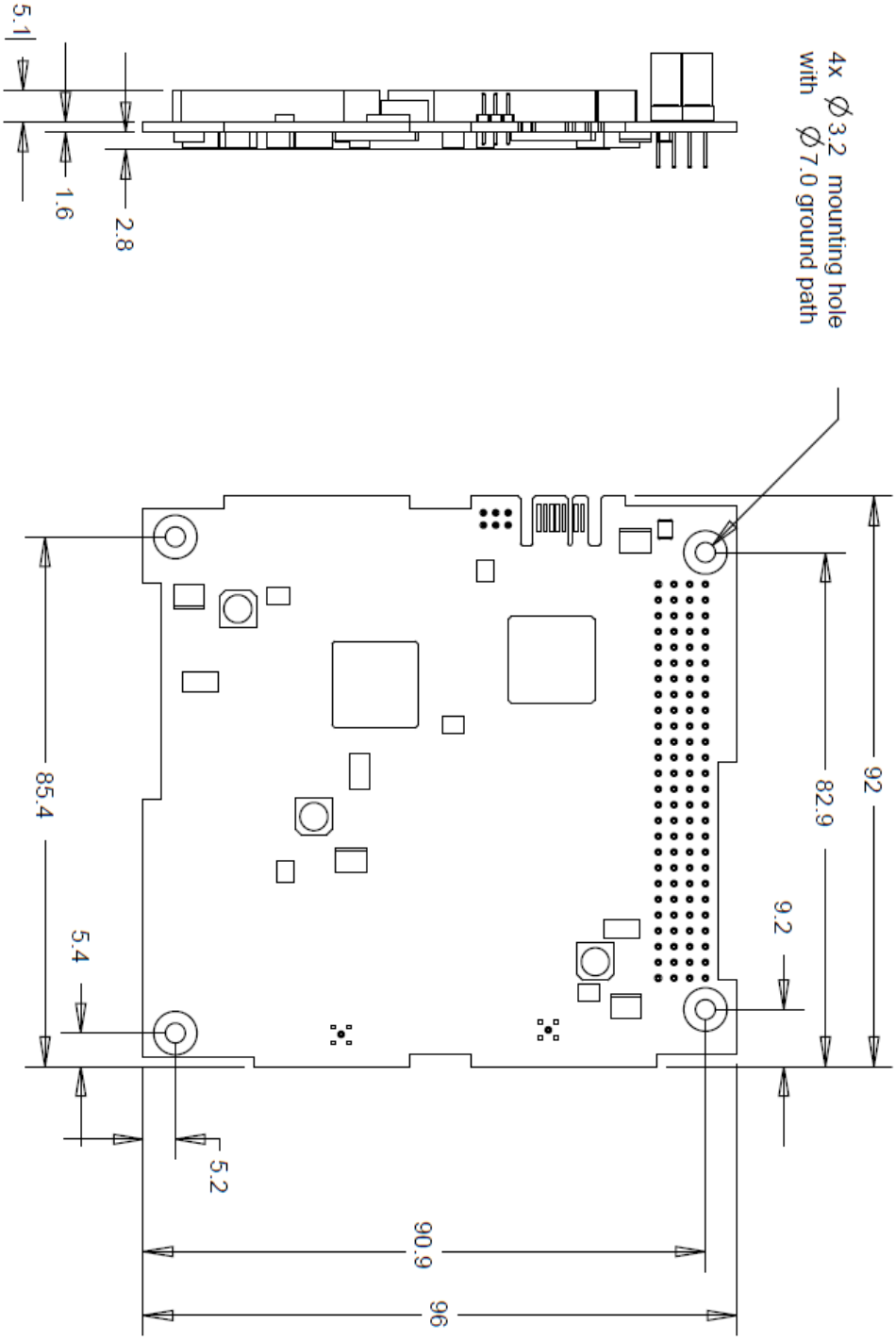


Figure 5-1 TRXVU drawing

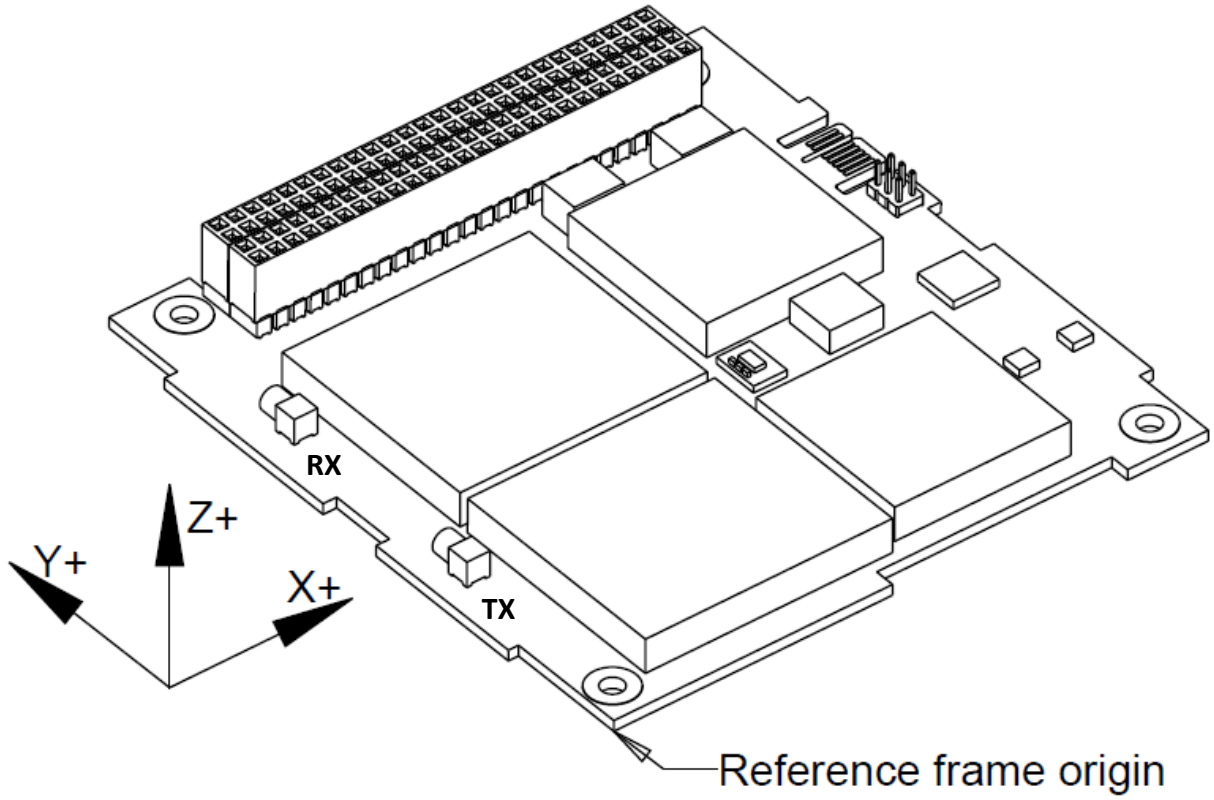


Figure 5-2 TRXVU overview drawing.

6 Thermal interface

The system should be connected to the CubeSat bus by means of four rods with spacers and the CubeSatKit connector. The connector together with the spacers constitutes the biggest thermal path to the board and this ensures sufficient thermal conductance for safe operations within the operating temperature range. No other thermal connection is required to dissipate the heat produced on the PCB.

The system is intended to be operated connected to a satellite structure that acts as heat sink: operations in a lab environment should be carefully planned and verified to ensure that the hardware never goes outside the specified temperature ranges. Continuous operations without any thermal connection to a structure may cause overheating and damage the system. Please verify continuously the board temperature.

Thermally the board can be modelled by two sources, one spread over the whole volume which represents the power dissipation of the components active when the receiver is on and the transmitter is idle. The second heat source can be modelled by a hot spot corresponding to the RF power amplifier and active when as RF signal is being transmitted.

The transmitter power amplifier is encased in a tin shielding can for RF reasons and this limits the thermal transfer by radiation. As a result, conduction through the PCB can be considered the dominant transfer mode.

The parameters required to model the thermal behaviour of the system are summarized in Table 6-1.

Table 6-1 Thermal parameters

Parameter	Value	Notes
Minimum operating temperature	-40 °C	
Maximum operating temperature	+60 °C	
Maximum PA temperature	+95 °C	
Static power dissipation	400 mW	
Transmitter max power dissipation	3.1 W	Only during transmission
Transmitter typical power dissipation	2.7 W	Only during transmission
Maximum power amplifier temperature	100 °C	
Thermal resistance amplifier to PCB	9 °C / W	
Power amplifier mass	0.6 g	50% epoxy 50% copper
Power amplifier location	[26.1 15.2] mm	[x y] of the center, referred to Figure 5-2
Power amplifier size	[2.6 4.6 1.6] mm	[x y z]
PCB material	FR4	
PCB thickness	1.55 mm	
Layers	4	
Copper thickness	35 um	For all layers
Shielding can emissivity	0.05	

7 Software interface

7.1 Description

Commands are used to set the TRXVU parameters. Additionally, some of them can have responses (return values). These responses need to be retrieved from the controller using a separate data transfer (master read) following the data transfer that contained the command (master write). The response of a command will be generated at the time of reception of the command and not at the time the response is retrieved from the transceiver. This applies for example to the commands requesting telemetry values: the measurements are performed when the command is received by the TRXVU. The response to a command will be available until another command that has a response is executed. The commands are listed in the following section.

Please find the format specification for all the commands below.

Command Name	Command Code
Name of the command	Command code in binary

Description

Extended description of the command.

Parameters

[000 – 000] format

Specification of the parameters required after the command.

Response

[000 – 000] format

Specification of the response that the antenna system will generate for this command.

The parameter and response descriptions contain specifications per byte or sequence of bytes. There can be several parameters or responses associated with a command and each have its own specification. Please note that parameters always start at byte 001, as byte 000 contains the command code. These specifications contain the following items:

7.2 Parameter / response length

This specifies the length and the location in the byte sequence of the parameter or response of the command. Several examples are provided below to explain the possible options.

[001 - 001]

Parameter / response has a fixed length of 1 byte and is located in byte 001

[001 - 020]

Parameter / response has a fixed length of 20 bytes and is located in bytes 001 through 020

[001 - 020*]

Parameter / response has an arbitrary length between 1 byte and 20 bytes and is located in the corresponding number of bytes starting at byte 001

7.3 Format specification

This specifies the format of the byte(s) of the parameter or response. Several examples are provided below to explain the possible options.

0000xxxx	The four most significant bits contain zeroes, while the four least significant ones contain the relevant bits
xxxxxxxx 000000xx	All bits of the first (and least significant) byte are relevant, while of the second byte only the two least significant bits are relevant
n/a, binary	All bits in all the bytes are relevant and are interpreted as binary content, i.e. no interpretation will take place
n/a, ASCII	All bits in all the bytes are relevant and are interpreted as ASCII content, specific interpretation depends on the command
_ _ _ _ _ _01	The two least significant bits have the specific value of '01', while the other bits can be either a 1 or a 0 (don't care)

7.4 Telemetry and Command Definition

7.4.1 Receiver unit

7.4.1.1 Functionality overview

The receiver controller contains the following functionalities:

- Tele-command decoding and buffering
- Instantaneous telemetry (measurement and report)
  - Total supply current
  - Power amplifier temperature
  - Local oscillator temperature
  - Received signal Doppler offset at the receiver port
  - Received signal strength at the receiver port
  - Supply voltage
- Telemetry synchronized with last packet received (measurement and report)
  - Received signal Doppler offset at the receiver port
  - Received signal strength at the receiver port
- Uptime monitoring
- System reset
  - Software reset
  - Hardware reset
- Watchdog reset

7.4.1.2 Data interface specification

7.4.1.2.1 Watchdog reset

Command Name	Command Code
Watchdog Reset	11001100 (0xCC)

Description

Performs a reset of the I2C watchdog without performing any other operation.

Parameters

None

Response

None

7.4.1.2.2 Software reset

Command Name	Command Code
Software Reset	10101010 (0xAA)

Description

Performs a software reset of the receiver processor.

Parameters

None

Response

None

7.4.1.2.3 Hardware system reset

Command Name	Command Code
Hardware Reset	10101010 (0xAB)

Description

Power cycles the full board (transmitter and receiver will be both reset).

Parameters

None

Response

None

7.4.1.2.4 Get number of frames in receive buffer

Command Name	Command Code
Get number of frames in receive buffer	00100001 (0x21)

Description

Retrieves the number of frames that are currently stored in the receiver buffer.

Parameters

None

Response

[000 - 001] xxxxxxxx xxxxxxxx

Number of frames in receive buffer. This number has a minimum value of 0 and a maximum value of the maximum number of frames that can be in the buffer. The latter is specified in the device configuration (see [AD01] for further details).

7.4.1.2.5 Get frame from receive buffer

Command Name	Command Code
Get frame from receive buffer	00100010 (0x22)

Description

Retrieves the contents of the oldest frame in the receive buffer. The contents of the frame are preceded by two bytes that indicate the frame size in number of bytes. This size can be used by the OBC to terminate the transmission after all the relevant bytes have been received (when the actual size is less than the maximum size). It can also be used for easier processing of the frame contents by the OBC's command processor. If there are 0 frames in the receive buffer the response is undefined.

Parameters

None.

Response

[000 - 001] xxxxxxxx xxxxxxxx

Frame contents size. This size has a minimum value of 1 and the maximum can be as specified in the device configuration (see [AD01] for further details.). The least significant byte is transmitted first (little endian).

[002 - 003] xxxxxxxx 0000xxxx

Doppler frequency. This field contains the measured Doppler shift on the packet at the reception time. The least significant byte is transmitted first (little endian).

[004 - 005] xxxxxxxx 0000xxxx

RSSI. This field contains the measured Received Signal Strength Indicator (RSSI) at the reception time. The least significant byte is transmitted first (little endian).

[006 – 6 + N] n/a, binary

Frame contents. The size of the data block depends on the received frame length and on the maximum frame size (see [AD01] for further details).

7.4.1.2.6 Remove frame from buffer

Command Name	Command Code
Remove frame from receive buffer	00100100 (0x24)

Description

Removes the oldest frame from the receive buffer. This is the same frame that can be retrieved from the receiver buffer command. If there are 0 frames in the receive buffer this command has no effect.

Parameters

None.

Response

None.

7.4.1.2.7 Measure all telemetry channels

Command Name	Command Code
Measure all telemetry channels	00011010 (0x1A)

Description

Measures all the available telemetry channels:

- Total supply current
- Power amplifier temperature
- Local oscillator temperature
- Instantaneous received signal Doppler offset at the receiver port
- Instantaneous received signal strength at the receiver port
- Supply voltage

Parameters

None.

Response

[000 - 001] xxxxxxxx 0000xxxx

Raw measurement value of the instantaneous Doppler offset of the signal at the receiver port.

[002 - 003] xxxxxxxx 0000xxxx

Raw measurement value of the total supply current.

[004 - 005] xxxxxxxx 0000xxxx

Raw measurement value of the power bus voltage.

[006 - 007] xxxxxxxx 0000xxxx

Raw measurement value of the local oscillator temperature.

[008 - 009] xxxxxxxx 0000xxxx

Raw measurement value of the power amplifier temperature.

[010 - 011] xxxxxxxx 0000xxxx

Raw measurement value of the instantaneous signal strength of the signal at the receiver.

The least significant byte is transmitted first (little endian) for all the telemetry values.

All the measurements have a minimum value of 0 and a maximum value of 4095. Please refer to Section 0 for the conversion formulas.

7.4.1.2.8 Report receiver uptime

Command Name	Command Code
Report receiver uptime	01000000 (0x40)

Description

Reports the amount of time the transmitter MCU has been active since the last reset, also known as up- time. The uptime is reported with a resolution of 1 second. The maximum supported uptime is 4294967295 seconds, after which the uptime will overflow and the reported uptime will be 0 seconds.

Parameters

None.

Response

[000 - 003] xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx

Seconds uptime value.

7.4.2 Transmitter

7.4.2.1 Functionality overview

The transmitter controller contains the following functionality:

- Transmission of AX.25 / HDLC frames
- Configuration of AX.25 parameters
- Autonomous transmission of beacon in AX.25 / HDLC
- Configuration of beacon parameters
- Instantaneous telemetry (measurement and report)
    - RF reflected power from TX port
    - RF forward power from TX port
    - Supply voltage
    - Total supply current
    - Power amplifier temperature
    - Local oscillator temperature
- Telemetry synchronized with last packet transmission (measurement and report)
    - RF reflected power from TX port
    - RF forward power from TX port
    - Supply voltage
    - Total supply current
    - Power amplifier temperature
    - Local oscillator temperature
- Uptime monitoring
- System reset
    - Software reset
    - Hardware reset
- Watchdog reset

7.4.2.2 Data interface specification

7.4.2.2.1 Watchdog reset

Command Name	Command Code
Watchdog Reset	11001100 (0xCC)

Description

Performs a reset of the I2C watchdog without performing any other operation.

Parameters

None

Response

None

7.4.2.2.2 Software reset

Command Name	Command Code
Software Reset	10101010 (0xAA)

Description

Performs a software reset of the transmitter processor.

Parameters

None

Response

None

7.4.2.2.3 Hardware system reset

Command Name	Command Code
Hardware Reset	10101010 (0xAB)

Description

Power cycles the full board (transmitter and receiver will be both reset).

Parameters

None

Response

None

7.4.2.2.4 Send frame

Command Name	Command Code
Send a frame	00010000 (0x10)

Description

Adds a frame (AX.25 UI or HDLC frame, according to [AD01]) to the frame buffer of the transmitter. If the radio mode is AX.25 (as specified in [AD01]), the AX.25 frame will contain the default callsigns as they are set in the controller at the time this command is received. This command will disable any beacon that is currently being transmitted by the transceiver. The frame will not be added to the frame buffer if:

- The frame buffer is full
- The content size is 0 bytes
- The content size is larger than the maximum size (specified in [AD01])

Parameters

[001 - N] n/a, binary

Contents of the AX.25 frame's INFO field or HDLC payload field. The contents have a minimum size of 1 byte and a maximum size specified in [AD01] (default value is 235 bytes).

Response

[000 - 000] xxxxxxxx

Number of remaining available 'slots' in the transmission buffer of the transmitter after this frame has been added. The minimum value of this response is 0 (meaning the buffer is full) and the maximum value of this response is the transmission frame buffer size as specified in the device configuration (This configuration is defined in the Test Report document delivered with this manual). If the response has a value of 255 (or 0xFF in hexadecimal) then the frame was not added to the buffer.

7.4.2.2.5 Send AX.25 frame with override callsigns

Command Name	Command Code
Send AX.25 frame with override callsigns	00010001 (0x11)

Description

Adds an AX.25 UI frame to the frame buffer of the transmitter. This AX.25 frame will contain the callsigns as specified in the command, ignoring the default callsigns set in the transmitter. This command will disable any beacon that is currently being transmitted by the transceiver. The AX.25 frame will not be added to the frame buffer if:

- The frame buffer is full
- The content size is 0 bytes
- The content size is larger than the maximum size (specified in [AD01])

This command is only available if the radio is set in AX.25 mode in [AD01].

Parameters

[001 - 007] n/a, ASCII & binary

AX.25 TO callsign to be used when transmitting this AX.25 frame. The first 6 bytes should be ASCII characters, while the 7th byte should be a number (binary encoded between 0 and 15, usually 0).

[008 - 014] n/a, ASCII & binary

AX.25 FROM callsign to be used when transmitting this AX.25 frame. The first 6 bytes should be ASCII characters, while the 7th byte should be a number (binary encoded between 0 and 15, usually 0).

[015 - N] n/a, binary

Contents of the AX.25 frame's INFO field. The contents have a minimum size of 1 byte and a maximum size specified in [AD01] (default value is 235 bytes).

Response

[000 - 000] xxxxxxxx

Number of remaining available 'slots' in the transmission buffer of the transmitter controller after this frame has been added. The minimum value of this response is 0 (meaning the buffer is full) and the maximum value of this response is the transmission frame buffer size as specified in the device configuration (This configuration is defined in the Test Report document delivered with this manual). If the response has a value of 255 (or 0xFF in hexadecimal) then the frame was not added to the buffer.

7.4.2.2.6 Set beacon

Command Name	Command Code
Set beacon	00010100 (0x14)

Description

Sets the transceiver to autonomously repeat transmission of a beacon message contained in an AX.25 UI frame or HDLC frame (mode is specified in [AD01]. The AX.25 frame will contain the default callsigns as they are set in the transmitter at the time this command is received. This command will remove any frame that is stored in the frame buffer waiting for transmission. The first transmission of the beacon message will take place when this command is received. If the transceiver is not in nominal telemetry mode, this command will have no effect.

Parameters

[001 - 002] xxxxxxxx 0000xxxx

Repeat interval of the beacon in seconds. This is the interval between the starts of two transmissions of the beacon. This interval has a minimum value of 0 and a maximum value of 3000. If an interval of more than 3000 seconds is specified, the interval will automatically be set to 3000. The least significant byte should be sent first (little endian).

[003 – N] n/a, binary

Contents of the AX.25 frame's INFO field. The contents have a minimum size of 1 byte and a maximum size specified in [AD01] (default value is 235 bytes).

Response

None.

7.4.2.2.7 Set AX.25 beacon with override callsigns

Command Name	Command Code
Set AX.25 beacon with override callsigns	00010101 (0x15)

Description

Sets the transceiver to autonomously repeat transmission of a beacon message contained in an AX.25 UI frame. This AX.25 frame will contain the callsigns as specified in the command, ignoring the default callsigns set in the transmitter. This command will remove any AX.25 frames that are stored in the frame buffer waiting for transmission. The first transmission of the beacon message will take place when this command is received. If the transceiver is not in nominal telemetry mode, this command will have no effect. This command is only available if the radio is set in AX.25 mode in [AD01].

Parameters

[001 - 002] xxxxxxxx 0000xxxx

Repeat interval of the beacon in seconds. This is the interval between the starts of two transmissions of the beacon. This interval has a minimum value of 0 and a maximum value of 3000. If an interval of more than 3000 seconds is specified, the interval will automatically be set to 3000.

[003 - 009] n/a, ASCII & binary

AX.25 TO callsign to be used when transmitting this AX.25 frame. The first 6 bytes should be ASCII characters, while the 7th byte should be a number (binary encoded between 0 and 15, usually 0).

[010 - 016] n/a, ASCII & binary

AX.25 FROM callsign to be used when transmitting this AX.25 frame. The first 6 bytes should be ASCII characters, while the 7th byte should be a number (binary encoded between 0 and 15, usually 0).

[017 – N] n/a, binary

Contents of the AX.25 frame's INFO field. The content has a minimum size of 1 byte and a maximum size specified in [AD01] (default value is 235 bytes).

Response

None.

7.4.2.2.8 Clear beacon

Command Name	Command Code
Clear beacon	00011111 (0x1F)

Description

Clears any beacon that is currently set in the transceiver. If a beacon transmission is currently in progress, this transmission will be completed.

Parameters

None.

Response

None.

7.4.2.2.9 Set default AX.25 TO callsign

Command Name	Command Code
Set default AX.25 TO callsign	00100010 (0x22)

Description

Sets the default AX.25 TO callsign in the transmitter. This callsign is included in AX.25 frames and AX.25 beacon transmissions that are transmitted using the default callsigns (see sections 6.2.2.2 and 6.2.2.5).

This command is only available if the radio is set in AX.25 mode in [AD01].

Parameters

[001 - 007] n/a, ASCII & binary

AX.25 TO callsign to be used for AX.25 frames. The first 6 bytes should be ASCII characters, while the 7th byte should be a number (binary encoded between 0 and 15, usually 0).

Response

None.

7.4.2.2.10 Set default AX.25 FROM callsign

Command Name	Command Code
Set default AX.25 FROM callsign	00100011 (0x23)

Description

Sets the default AX.25 FROM callsign in the transmitter. This callsign is included in AX.25 frames and AX.25 beacon transmissions that are transmitted using the default callsigns.

This command is only available if the radio is set in AX.25 mode in [AD01].

Parameters

[001 - 007] n/a, ASCII & binary

AX.25 FROM callsign to be used for AX.25 frames. The first 6 bytes should be ASCII characters, while the 7th byte should be a number (binary encoded between 0 and 15, usually 0).

Response

None.

7.4.2.2.11 Set transmitter idle state

Command Name	Command Code
Set transmitter idle state	00100100 (0x24)

Description

Sets the state of the transmitter when it's idle. The transmitter can either be set to either remain or switch off when it's idle. When it's set to switch off, this will happen when there are no frames in the frame buffer or no beacon transmission is scheduled to occur. As soon as the transmitter needs to transmit a beacon or data it will switch on again. When the transmitter is idle but is set to remain on, it will transmit an idle sequence to help the ground receiver to lock.

Parameters

[001 - 001] 0000000x

The idle state of the transmitter to be set. The values listed below correspond to the available states. If another value is specified this command will have no effect.

00000000 - transmitter is turned off when idle

00000001 - transmitter remains on when idle

Response

None.

7.4.2.2.12 Measure all the telemetry channels

Command Name	Command Code
Measure all the telemetry channels	00100101 (0x25)

Description

Measures all the telemetry channels:

- Instantaneous RF reflected power from transmitter port
- Instantaneous RF forward power from transmitter port
- Supply voltage
- Total supply current
- Power amplifier temperature
- Local oscillator temperature

Parameters

None.

Response

[000 - 001] xxxxxxxx 0000xxxx

Raw measurement value of the instantaneous RF reflected power at the transmitter port. This field is valid only during transmission.

[002 - 003] xxxxxxxx 0000xxxx

Raw measurement value of the instantaneous RF forward power at the transmitter port. This field is valid only during transmission.

[004 - 005] xxxxxxxx 0000xxxx

Raw measurement value of the power bus voltage.

[006 - 007] xxxxxxxx 0000xxxx

Raw measurement value of the total supply current.

[008 - 009] xxxxxxxx 0000xxxx

Raw measurement value of the power amplifier temperature. This field is valid only during transmission.

[010 - 011] xxxxxxxx 0000xxxx

Raw measurement value of the local oscillator temperature.
The least significant byte is transmitted first (little endian) for all the telemetry values.
All these measurements have a minimum value of 0 and a maximum value of 4095. Please refer to Section 0 for the conversion formulas.

7.4.2.2.13 Get telemetry channels during the last transmission

Command Name	Command Code
Get the stored telemetry channels during the last transmission	00100110 (0x26)

Description

Provides the telemetry channels that were sampled during the last frame transmission:

- Instantaneous RF reflected power from transmitter port
- Instantaneous RF forward power from transmitter port
- Supply voltage
- Total supply current
- Power amplifier temperature
- Local oscillator temperature

Parameters

None.

Response

[000 - 001] xxxxxxxx 0000xxxx
Raw measurement value of the instantaneous RF reflected power during the last transmission.

[002 - 003] xxxxxxxx 0000xxxx
Raw measurement value of the instantaneous RF forward during the last transmission.

[004 - 005] xxxxxxxx 0000xxxx
Raw measurement value of the power bus voltage during the last transmission.

[006 - 007] xxxxxxxx 0000xxxx
Raw measurement value of the total supply current during the last transmission.

[008 - 009] xxxxxxxx 0000xxxx
Raw measurement value of the power amplifier temperature during the last transmission.

[010 - 011] xxxxxxxx 0000xxxx
Raw measurement value of the local oscillator temperature during the last transmission.
The least significant byte is transmitted first (little endian) for all the telemetry values.
All these measurements have a minimum value of 0 and a maximum value of 4095. Please refer to Section 0 for the conversion formulas.

7.4.2.2.14 Set transmission bitrate

Command Name	Command Code
Set AX.25 transmission bitrate	00101000 (0x28)

Description

Changes the bitrate used: the modification will take effect immediately, possibly in the middle of transmitting a frame.

Parameters

[001 - 001] 0000xxxx
Transmission bitrate. The values listed below correspond to the available bitrates. If another value is specified this command will have no effect.
00000001- 1200 bits per second
00000010- 2400 bits per second
00000100- 4800 bits per second
00001000- 9600 bits per second

Response

None.

7.4.2.2.15 Report transmitter uptime

Command Name	Command Code
Report transmitter uptime	01000000 (0x40)

Description

Reports the amount of time the transmitter MCU has been active since the last reset, also known as up- time. The uptime is reported with a resolution of 1 second. The maximum supported uptime is 4294967295 seconds, after which the uptime will overflow and the reported uptime will be 0 seconds.

Parameters

None.

Response

[000 - 003] xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx

Seconds uptime value.

7.4.2.2.16 Report transmitter state

Command Name	Command Code
Report transmitter state	01000001 (0x41)

Description

Reports general information about the state the transmitter is currently in.

Parameters

None.

Response

[000 - 000] 0xxxxxxx

Status of the transmitter. The following information is contained in this value:

- Transmitter idle state

xxxxxxx0 - transmitter is turned off when idle

xxxxxxx1 - transmitter remains on when idle

- Beacon active

xxxxxx0x - no beacon has been set

xxxxxx1x - a beacon is active

- Transmitter bit rate

xxxx00xx - 1200 bits per second

xxxx01xx - 2400 bits per second

xxxx10xx - 4800 bits per second

xxxx11xx - 9600 bits per second

7.5 Telemetry conversion formulas

This section contains the telemetry conversion formulas required to convert the raw measurements provided by the system. The formulas contain the typical values including error for the different parameters: FM boards are shipped with a test report containing calibration values to improve the accuracy over the numbers provided in this document.

7.5.1 Receiver telemetry

Table 7-1 Receiver telemetry conversion formulas

Parameter	Conversion	Unit	Error
Power bus voltage	ADC * 0.00488	V	±55 mV
Total current consumption	ADC * 0.16643964	mA	±4 mA
Power amplifier temperature	ADC *-0.07669 + 195.6037	°C	±1 °C
Local oscillator temperature	ADC *-0.07669 + 195.6037	°C	±1 °C
Received signal Doppler offset	ADC * 13.352- 22300	Hz	±1 kHz
Received signal strength	ADC * 0.03 – 152	dBm	±3 dB

7.5.2 Transmitter telemetry

The RF forward and reflected power sensors output can be expressed in dBm or mW and both conversion formulas are shown. Due to the non linear nature of this sensor, the output is also provided in Table 7-3 and Table 7-4.

Table 7-2 Transmitter telemetry conversion formulas

Parameter	Conversion	Unit	Error
Power bus voltage	ADC * 0.00488	V	±55 mV
Total current consumption	ADC * 0.16643964	mA	±4 mA
Power amplifier temperature	ADC *-0.07669 + 195.6037	°C	±1 °C
Local oscillator temperature	ADC *-0.07669 + 195.6037	°C	±1 °C
RF reflected power	20 * log10(ADC * 0.00767)	dBm	±1.5 dB
	ADC * ADC * 5.887 10^{-5}	mW	±150 mW
RF forward power	20 * log10(ADC * 0.00767)	dBm	±1.5 dB
	ADC * ADC * 5.887 10^{-5}	mW	±150 mW

7.5.2.1 Forward and reflected power conversion to dBm

To simplify the conversion from raw ADC value to measured power, Table 7-3 can be used. The table reports the tabulated conversion to dBm, based on Table 7-2.

Table 7-3 Forward and reflected power conversion table to dBm

ADC	Power (dBm)	ADC	Power (dBm)	ADC	Power (dBm)	ADC	Power (dBm)
1	-42.3	1054	18.2	2107	24.2	3160	27.7
40	-10.3	1093	18.5	2146	24.3	3199	27.8
79	-4.3	1132	18.8	2185	24.5	3238	27.9
118	-0.9	1171	19.1	2224	24.6	3277	28.0
157	1.6	1210	19.4	2263	24.8	3316	28.1
196	3.5	1249	19.6	2302	24.9	3355	28.2
235	5.1	1288	19.9	2341	25.1	3394	28.3
274	6.5	1327	20.2	2380	25.2	3433	28.4
313	7.6	1366	20.4	2419	25.4	3472	28.5
352	8.6	1405	20.7	2458	25.5	3511	28.6
391	9.5	1444	20.9	2497	25.6	3550	28.7
430	10.4	1483	21.1	2536	25.8	3589	28.8
469	11.1	1522	21.3	2575	25.9	3628	28.9
508	11.8	1561	21.6	2614	26.0	3667	29.0
547	12.5	1600	21.8	2653	26.2	3706	29.1
586	13.1	1639	22.0	2692	26.3	3745	29.2
625	13.6	1678	22.2	2731	26.4	3784	29.3
664	14.1	1717	22.4	2770	26.5	3823	29.3
703	14.6	1756	22.6	2809	26.7	3862	29.4
742	15.1	1795	22.8	2848	26.8	3901	29.5
781	15.6	1834	23.0	2887	26.9	3940	29.6
820	16.0	1873	23.1	2926	27.0	3979	29.7
859	16.4	1912	23.3	2965	27.1	4018	29.8
898	16.8	1951	23.5	3004	27.3	4057	29.9
937	17.1	1990	23.7	3043	27.4	4095	29.9
976	17.5	2029	23.8	3082	27.5		
1015	17.8	2068	24.0	3121	27.6		

7.5.2.2 Forward and reflected power conversion to milliWatts

To simplify the conversion from raw ADC value to measured power, Table 7-4 can be used. The table reports the tabulated conversion to milliWatts, based on Table 7-2.

Table 7-4 Forward and reflected power conversion table to milliWatts

ADC	Power (mW)	ADC	Power (mW)	ADC	Power (mW)	ADC	Power (mW)
1	0.0	1054	65.4	2107	261.3	3160	587.8
40	0.1	1093	70.3	2146	271.1	3199	602.4
79	0.4	1132	75.4	2185	281.1	3238	617.2
118	0.8	1171	80.7	2224	291.2	3277	632.2
157	1.5	1210	86.2	2263	301.5	3316	647.3
196	2.3	1249	91.8	2302	312.0	3355	662.6
235	3.3	1288	97.7	2341	322.6	3394	678.1
274	4.4	1327	103.7	2380	333.5	3433	693.8
313	5.8	1366	109.8	2419	344.5	3472	709.7
352	7.3	1405	116.2	2458	355.7	3511	725.7
391	9.0	1444	122.7	2497	367.0	3550	741.9
430	10.9	1483	129.5	2536	378.6	3589	758.3
469	12.9	1522	136.4	2575	390.3	3628	774.9
508	15.2	1561	143.4	2614	402.3	3667	791.6
547	17.6	1600	150.7	2653	414.3	3706	808.5
586	20.2	1639	158.1	2692	426.6	3745	825.6
625	23.0	1678	165.8	2731	439.1	3784	842.9
664	26.0	1717	173.6	2770	451.7	3823	860.4
703	29.1	1756	181.5	2809	464.5	3862	878.0
742	32.4	1795	189.7	2848	477.5	3901	895.9
781	35.9	1834	198.0	2887	490.7	3940	913.9
820	39.6	1873	206.5	2926	504.0	3979	932.0
859	43.4	1912	215.2	2965	517.5	4018	950.4
898	47.5	1951	224.1	3004	531.2	4057	968.9
937	51.7	1990	233.1	3043	545.1	4095	987.2
976	56.1	2029	242.4	3082	559.2		
1015	60.6	2068	251.8	3121	573.4		