Interface Control Document

ISIS-TRXVU-ICD-0001

Version: 1.1

CI Number: SS-001-005-002 | TRXVU

Release Information

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Change Log

Version	Date	Affects	Description
1.0	2023-04-04	All	First Release
1.1	2023-07-07	1.3 3.1 7.2 7.3 7.4 Annex A	Corrected maximum vertical dimension from 10.5mm to 11.0mm to match Mechanical Envelope Drawing in Annex A Added minimum RF downlink output power level and corrected maximum level. Corrected current sense formula in Table 10 - Receiver telemetry conversion formulas Added additional dimension to Mechanical Envelope Drawing in Annex A Added note over reported serial number. Removed Section 1.3 Revision Changes

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Acronyms

Name	Description
BPF	Band-Pass Filter
BPSK	Binary Phase-Shift Keying
CSKB	CubeSat Kit Bus
DC	Direct Current
FM	Frequency Modulation
FSK	Frequency-Shift Keying
GFSK	Gaussian pulse-shaped FSK
GPIO	General Purpose I/O
I2C	Inter-Integrated Circuit
ICD	Interface Control Document
LPF	Low-Pass Filter

Name	Description
LNA	Low-Noise Amplifier
MCU	Micro Controller Unit
MPN	Manufacturer Part Number
NRZ-I	Non-Return-to-Zero Inverted
NRZ-S	Non-Return-to-Zero Space
OBC	On-Board Computer
PA	Power Amplifier
RF	Radio Frequency
RSSI	Receive Signal Strength Indication
TRXVU	Transmitter Receiver VHF - UHF
UHF	Ultra-High Frequency
VHF	Very High Frequency

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 435 MHz to 438 MHz and supports BPSK. The receiver frequency is programmable at VHF frequencies from 145.8 MHz to 146.0 MHz and supports (G)FSK. Frequencies outside these ranges are available upon request.

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

1.1 Applicable Documents

The table below contains documents which applicability is required. The contents of the present document follow the standards, guidelines and requirements here mentioned.

Table 1 - Applicable Documents

Reference	Name	Version
ISIS-TRXVU-OS-0001	RevE Option Sheet	3.0
ISIS-TRXVU-ICD-0002	Transponder Mode ICD	1.0

1.2 Reference Documents

The table below contains documents that are not fully applicable and will provide supplementary information relevant for the present document.

Table 2 - Reference Documents

Reference	Name	Version
ISIS-TRXVU-CAD-0001	CAD model	1.0

2 System description

The TRXVU hardware is divided in four sections:

1. Power conditioning: Integrated Load switch, Current, Voltage and Power Sensing, DC/DC Converters.
2. Digital electronics: Receive and Transmit Microcontroller, I^2C Buffer, two temperature sensors and two watchdog timers.
3. RF Receive section: Front end, Digital FSK Demodulator and FM demodulator for transponder mode.
4. RF Transmit section: DAC, Mixer, Power amplifier.

Receive and transmit sections are independent and each feature a dedicated MCU and Local Oscillator.

2.1 System Block Diagram

A detailed block diagram is provided in Figure 1.

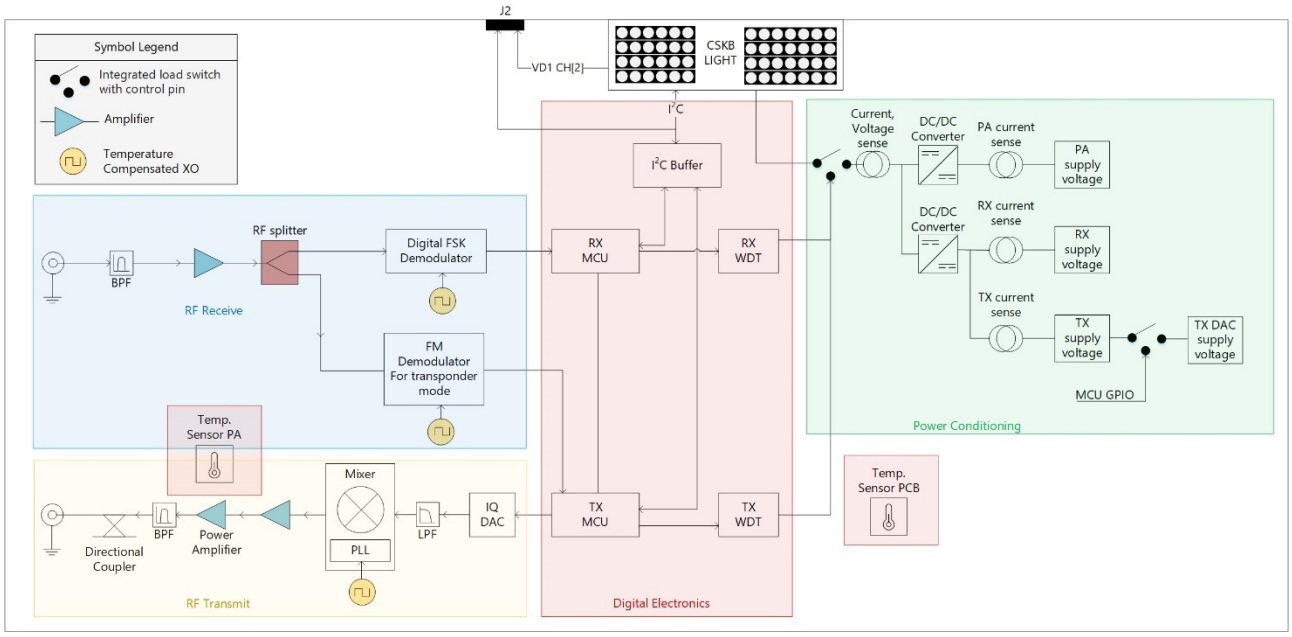


Figure 1 - TRXVU Functional Block diagram

2.2 Power Conditioning

The input power, as supplied from the CSKB, first goes through an integrated load switch. This load switch is enabled by default unless the control pin is triggered, see section 2.3.4 for details. After the integrated load switch the voltage and current is measured and read out by both microcontrollers.

The supply voltage is down converted to the power amplifier supply voltage level. This converter is only enabled if the power amplifier voltage is required, i.e., during transmission. The current going to the power amplifier current measured and read out by both microcontrollers.

A second downconverter is used for the last voltage domain, the voltage supply of all other components on the board. The output power is split into two sections, RX power and TX power. Both will be always enabled, unless there is a board reset. Current is readout individually for each section by both microcontrollers. A last load switch is used to enable the power supply for the transmit DAC. This supply will only be enabled during transmission. It is switched on and off together with the power amplifier voltage line.

2.2.1 Grounding

The power ground, data interface ground as well as the RF ground are internally connected. The TRXVU internal ground may be connected to the satellite structure ground by means of impedance networks labelled "Z" see Figure 2. These networks are placed between each of the four mounting holes and the TRXVU internal ground. By default, a broadband RF capacitor is placed for each "Z" network. Alternative "Z" network components can be accommodated, refer to the TRXVU option sheet [ISIS-TRXVU-OS-0001] for the available options.

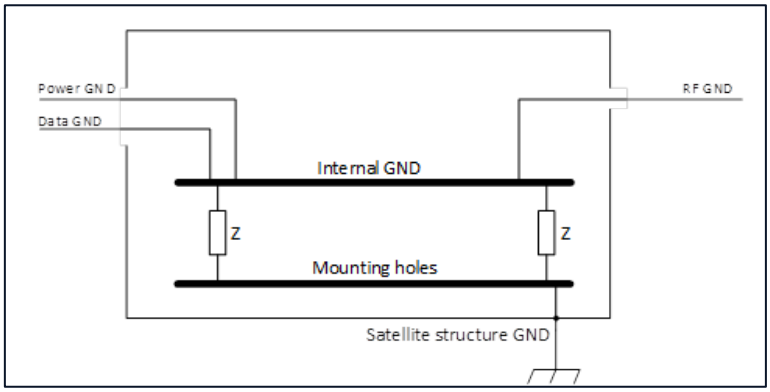


Figure 2 - TRXVU grounding scheme representation.

2.3 Digital electronics

The TRXVU has two microcontrollers, one is dedicated for the transmit section, one for the receive section. Both microcontroller readout all power telemetry and temperature sensors. Each microcontroller has a dedicated hardware windowed watchdog timer. There is a single I^2C buffer connected to both microcontrollers.

2.3.1 I2C Interface

The TRXVU data interface with the platform is over I^2C. I^2C SCL and DATA can be connected to CSKB default and to CSKB alternative position, see Figure 7 for details on CSKB pinout. For selection between I^2C default or alternative refer to the option sheet [ISIS-TRXVU-OS-0001].

The buffer utilized frequently at ISISPACE is the NXP PCA9517A. Texas Instruments has the same IC in their portfolio. The NXP PCA9517A I^2C buffer is bi-directional and utilizes a bias voltage on side-B. This offset allows the IC to detect buffer itself. The side-B offset results in a restriction that the side-B of one buffer cannot be connected to the side-B of another buffer, as this will impair bi-directional bus communication across the side-B to side-B I^2C section.

The buffer side-A connection does not have a bias voltage and can be connected to other buffers on their side-A or side-B. As such the side-A supports a star point network topology. For the TRXVU the side-A is connected to the CSKB.

Note: Some flavours of I^2C buffers, other that the PCA9517A, use the A/B designations in reverse, meaning that for those the side-B is star connectable. Verify the correct orientation in the datasheet when using a different buffer type.

Note: For more details on the I^2C bus timings and operations, please refer to the *I2C-bus specification and user manual* from Phillips – NXP (UM10204, Rev. 03, 19 June 2007, https://www.nxp.com/docs/en/user-guide/UM10204.pdf).

2.3.2 GPIO

The TRXVU offers two GPIOs on the CSKB. One GPIO is used for RX DATA ready indication. By default, this GPIO is connected to the CSKB. The second GPIO (GPIO2) is a generic GPIO. The GPIO is not connected to the CSKB by default. Both GPIO connect to the receive microcontroller. For alternative connections refer to the option sheet [ISIS-TRXVU-OS-0001].

2.3.3 Temperature sensors

The TRXVU offers two temperature sensors. One sensor is located close to the transmit power amplifier. The other sensor is located roughly in the centre of the board, see Figure 3. The temperature as measured by the temperature sensor is readout by both microcontrollers. The power amplifier temperature sensor is used a safeguard against a power amplifier overtemperature event.

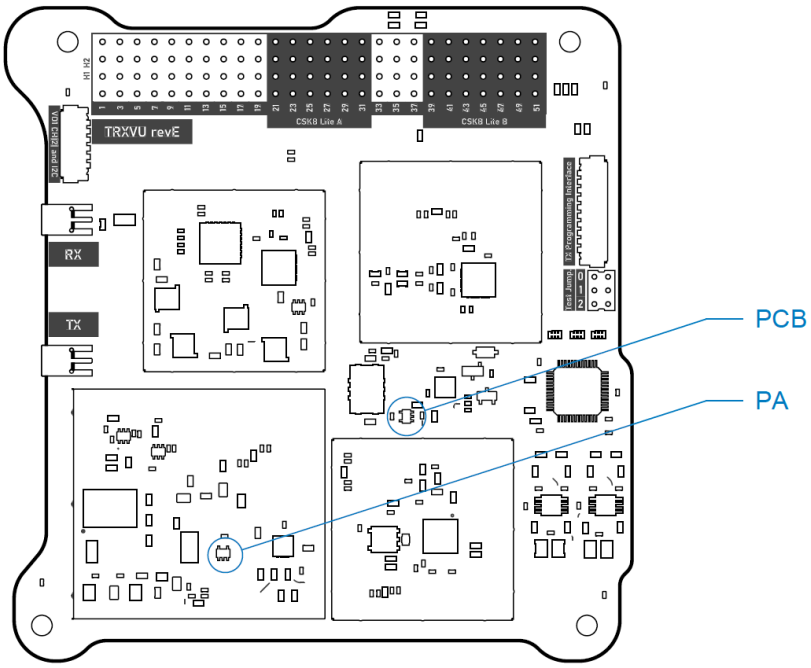


Figure 3 - Temperature sensor locations

2.3.4 Watchdog Timer

Both microcontrollers have an external windowed watchdog timer. If a time out or multiple signal (double pulse) fault occurs in the MCU, the watchdog will reset the entire board by switching the main load switch off. After less than 1 second the board will start up again. The software command “Hardware system reset” (see section 7.2.1.15 and 0) will have the same effect.

2.3.5 Test mode jumpers

By placing jumpers on J1 (See section 4.2.2) the TRXVU can be put in test beacon mode. The TRXVU keeps transmitting until jumpers are removed.

2.4 RF Transmit

Figure 4 shows the UHF transmitter output schematic to provide an indication of the internal structure. Connector pin-out can be seen in Section 4.2.5.

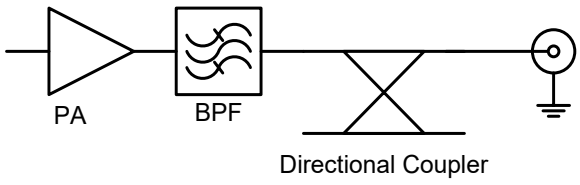


Figure 4 - Transmitter output interface schematic

The Band Pass Filter at the Power Amplifier output attenuates transmitter spurious and harmonics to a very low level. This ensures successful full-duplex operation even when the transmit and receive antennas are physically close. The rejection of the BPF extends into L-Band, S-Band and above. This allows successful co-existence with receivers in these bands in close proximity on the same spacecraft, even while the transmitter is active.

The Directional Coupler is used to provide instantaneous forward and reverse power measurements. This can be requested over the I2C interface (see section 7.3.1.11)

2.5 RF Receive

Figure 5 shows the VHF receiver input schematic to provide an indication of the internal structure.

Connector pin-out can be seen in Section 4.2.6.

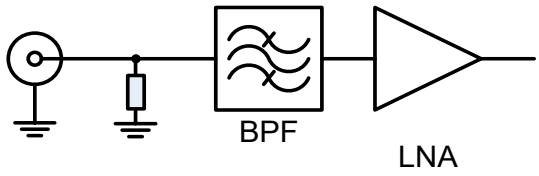


Figure 5 - Receiver input interface schematic

An inductor with high impedance at RF frequencies is used to provide a DC path to ground. If a customer application requires DC bias, an external DC block must be fitted between the TRXVU and an external bias-tee.

The TRXVU features a carefully designed Band Pass Filter designed to strongly reject out-of-band signals whilst maximising in-band performance. The -3dB bandwidth of the BPF is approximately 25MHz, centred on the Receive Frequency range. The filter provides in excess of -50dB rejection below 100MHz and in excess of -30dB rejection above 200MHz.

2.6 Transponder mode

Transponder mode is only available if the option is selected in the Option Sheet [ISIS-TRXVU-OS-0001]. Details on transponder mode can be found in the Transponder Mode Annex [ISIS-TRXVU-ICD-0002][1].

2.7 Point-to-point connector J2

The point-to-point connector J2 is used only to break out VD1_CH2 and I^2C from the CSKB. It does not influence the functionalities of the TRXVU. By default (depending on the power system connected to the CSKB) the VD1_CH2 supply line will of 5V. J2 could be used to power the ISISPACE Antenna system.

[1] If Transponder Mode was selected but the Transponder Mode Annex [ISIS-TRXVU-ICD-0002] is not included with the delivery, contact your ISISPACE representative.

3 Performance

3.1 Specifications

Table 3 - General Specifications

Parameter			Min	Typ	Max	Unit
Environmental Characteristics						
Operating temperature			-20		60	°C
Storage temperature			-40		85	°C
Storage lifetime (at relative humidity < 60%)				12		months
Electrical Characteristics						
Supply voltage			6.0[2]		20.0	V
Supply current at **8V** input voltage	Receiver only		22	30	40	mA
	Receiver and transmitter		310	350	400	mA
Supply current at **16V** input voltage	Receiver only		12	18	24	mA
	Receiver and transmitter		160	180	220	
Static power dissipation				240		mW
Power amplifier dissipation during transmission[3]				2.7	3.1	W
Input current limit				1.01		A
Voltage sense accuracy				1		%
Current sense accuracy				10		%
Temperature sensor range			-50		150	°C
Temperature sensor error	T = +20°C to +40°C		-1.5		1.5	°C
	T = -50°C to +70°C		-1.8		1.8	°C
Power Up Time[4]	After power-on			0.2	1.0	s
	After watchdog or hard reset			0.2	1.0	s
Digital Characteristics						
I²C Interface	Bus logic low-level input voltage		0		1.0	V
	Bus logic low-level output voltage		0.47		0.6	V
	Bus logic high-level voltage		2.3		3.3	V
	Supported I²C modes	Standard-mode			100	kbit/sec
		Fast-mode			400	
	Supported address types		7 bits			-
	I²C node type		Slave only			-
	I²C general call supported		No			-
	I²C repeated start condition supported		No			-

[2] Lower minimum supply available if build option H2-25 H2-26 VD1 CH0 is selected in option sheet [ISIS-TRXVU-OS-0001].

[3] At maximum transmit power

[4] Duration until the radio responds to I2C commands

Parameter		Min	Typ	Max	Unit
GPIO	Input Logic low-level voltage	0		0.75	V
	Input Logic high-level voltage	2.3		3.3	V
	Output Logic low-level voltage	0		0.3	V
	Output Logic high-level voltage	3		3.3	V
	Input current			1	mA
	Output current			5	mA
Physical Characteristics					
Volume (excluding CSKB connector)		91.9 x 95.9 x 11.0			mm^3
Mass (excluding CSKB connector)		40	48	56	gram
RF, Uplink modulation and protocol parameters					
Input level				0	dBm
VSWR				1:1.3	-
DC resistance to RF Ground				1	Ω
Frequency range[5]		140		150	MHz
Total frequency error				1	kHz
Modulation		FSK or GFSK			-
Frequency deviation			3.5		kHz
Data rate		9600			Bit/s
ITU emission class		12K5F1DBN[6]			-
Receiver bandwidth			12		kHz
Reference oscillator frequency		30.72			MHz
Receiver sensitivity		-101	-102	-103	dBm[7]
Required E_b/N_0			20[7]		dB
System noise temperature			2000		K
Scrambling polynomial[8]		$x^{17} + x^{12} + 1$			-
Encoding		NRZ-S [9]			
Protocol[10]		AX.25 connectionless			-
Frame payload size				200	-
RF, Downlink modulation and protocol parameters					
Output power		25		27.5	dBm
Input power				15	dBm

[5] Alternative VHF frequencies available on request. See Option Sheet [ISIS-TRXVU-OS-0001] for further details.

[6] 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.

[7] Bit Error Rate = 10^{-5}

[8] G3RUH

[9] NRZ-S is the subset of NRZ-I encoding where Serializer mapping 0 = toggle; 1 = constant

[10] AX.25: Only UI frames supported. See [ISIS-TRXVU-OS-0001] for further details.

Parameter	Min	Typ	Max	Unit
VSWR			1:1.3	-
DC resistance to ground			1	Ω
Frequency range[11]	400		440	MHz
Total frequency error			100	Hz
Modulation	BPSK or GMSK[12]			-
Pulse shaping	Square Root Raised Cosine			
Roll-off factor	0.5			-
Data rate	1200	9600	9600	Bit/s
Necessary bandwidth[13]		15		kHz
ITU emission class[6]	15K0G1DAN			-
Power spectral density			-44.7	dBW / Hz
Spurious suppression	50			dBc
Scrambling polynomial[8]	$x^{17} + x^{12} + 1$			-
Encoding	NRZ-S [14]			
Protocol[15]	AX.25 connectionless			-
Frame payload size			235	-

[11] Alternative UHF frequencies available on request. See Option Sheet [ISIS-TRXVU-OS-0001] for further details.

[12] GMSK is only available if the option is selected in the Option Sheet [ISIS-TRXVU-OS-0001]

[13] 99% emitted power, 9600 bit/s

[14] NRZ-S is the subset of NRZ-I encoding where Serializer mapping 0 = toggle; 1 = constant

[15] AX.25: Only UI frames supported.

4 Electrical and RF interface

4.1 Connector locations

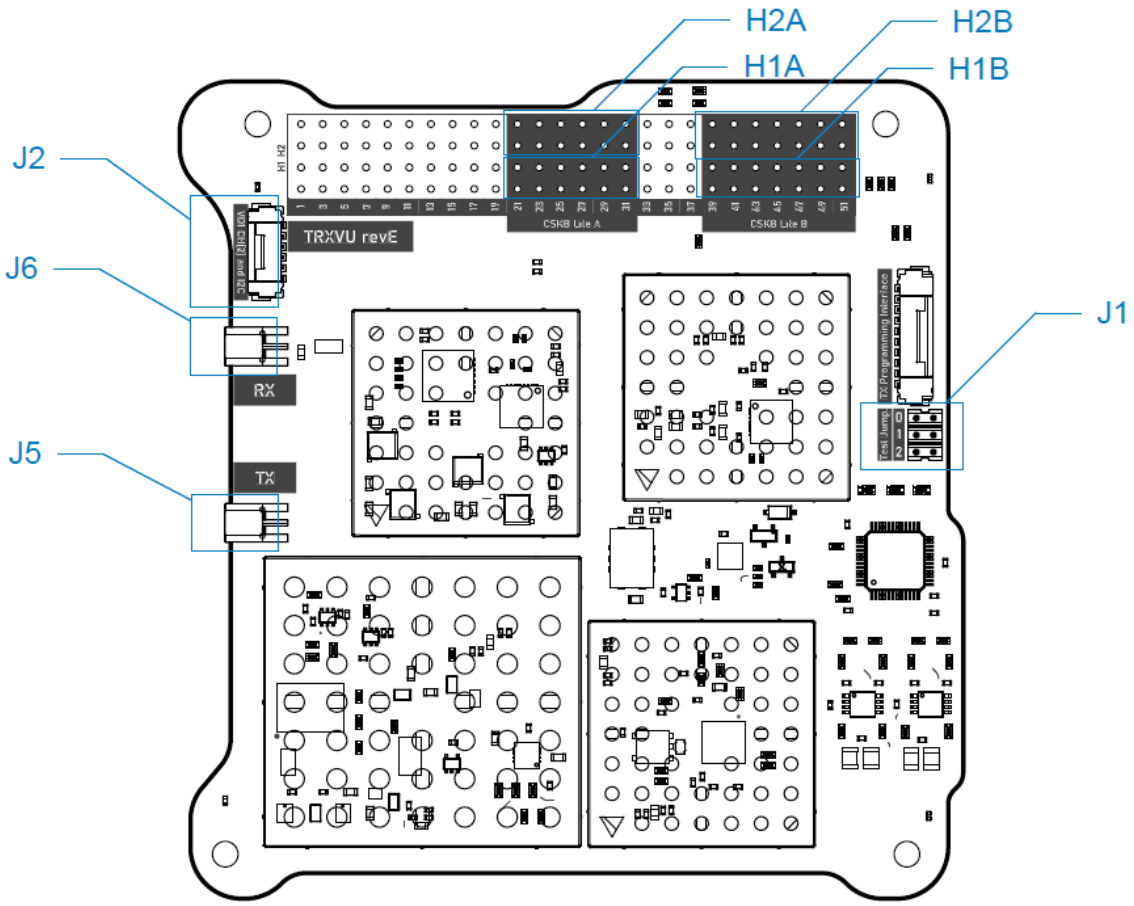


Figure 6 - Connector Location

4.2 Connector pinout

4.2.1 CSKB H1 H2

The TRXVU has a CSKB interface located at the "top" edge of the board (Figure 6). The TRXVU makes electrical connections only within the pin ranges 21-32 and 39-52. In the TRXVU Option Sheet [ISIS-TRXVU-OS-0001] the customer may select to only populate connectors within this range, which is referred to as "CSKB-Lite". H1 and H2 are 2.54 mm through hole pin connectors.

H2						VD1 CH[0]		GND	GND				GND	GND	GND	VD0 CH[0]			GPIO2 RX
	2	-	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52
						VD1 CH[0]		GND					GND	GND	GND	VD0 CH[0]			
	1	-	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51
H1				GND	GND	VD0 CH[1]	GND	VD0 CH[2]	GND							DATA READY			
	2	-	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52
				I2C SCL ALT	I2C SDA ALT	VD0 CH[1]	GND	VD0 CH[2]	GND				GND	I2C SDA DEF	I2C SCL DEF			VD1 CH[2]	
	1	-	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51

Figure 7 - H1 H2 CSKB layout

Table 4 - H2 CSKB light pinout

Pin	Name	Description	Remarks
H2_25, H2_26	VD1_CH[0]	5V permanent	Alternative supply pin
H2_29, H2_30, H2_32,	GND	GND return path	
H2_39, H2_40, H2_41, H2_42, H2_43, H2_44	GND	GND return path (non-standard CSKB)	
H2_45, H2_46	VD0_CH[0]	Rail voltage[16], permanent	Default input voltage
H2_52	GPIO2	General Purpose I/O	Not connected by default.

Table 5 - H1 CSKB light pinout

Pin	Name	Description	Remarks
H1_21	CSKB_I2C_SCL_ALT_H1_21	Alternative I^2C SCL	
H1_22	GND	GND return path (non-standard CSKB)	
H1_23	CSKB_I2C_SDA_ALT_H1_23	Alternative I^2C SDA	
H1_24	GND	GND return path (non-standard CSKB)	
H1_25, H1_26	VD0_CH[1]	Rail voltage[16], switchable 1	Alternative supply pin
H1_27, H1_28,	GND	GND return path (non-standard CSKB)	
H1_29, H1_30	VD0_CH[2]	Rail voltage[16], switchable 2	Alternative supply pin
H1_31, H1_32	GND	GND return path (non-standard CSKB)	
H1_39	GND	GND return path (non-standard CSKB)	Path could be disconnected if required.
H1_41	CSKB_I2C_SDA_H1_41	I^2C SCL	
H1_43	CSKB_I2C_SCL_H1_43	I^2C SDA	
H1_46	RX DATA READY		Connected by default.
H1_49	VD1_CH[2]	5V switched 2	Used to breakout on J2.

4.2.2 Test Mode Jumpers J1

Jumpers for test mode.

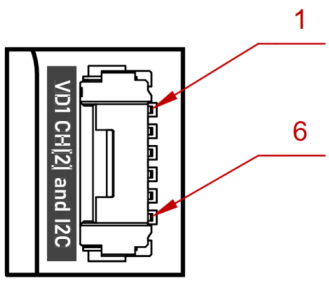
Mode	Selection
TC_NOMINAL_OPS, normal operation. No jumpers placed.	
TC_TESTBEACON_AX25 All jumpers placed.	

[16] Rail voltage is the voltage of the EPS internal power rail. The rail voltage, with a battery attached, is close to the battery voltage.

4.2.3 Point-to-point connector J2

J2 connector type is a Molex Microlock, part number 505567-0681 and mates with 505565-0601. The connector is rated for 30 mating cycles.

Table 6 - J2 CH[3] and I2C

Pin	Name	Description	Remarks	Pinout
1	VD1_CH[2]	VD1_CH[2]	Same as on the CSKB	
2, 6	GND	Ground return		
3	EXT_SDA	I^2C SDA	Same signal as on CSKB	
4	EXT_SCL	I^2C SCL	Same signal as on CSKB	
5	N.C.	Not connected		

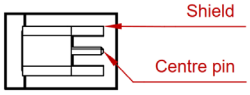
4.2.4 Programming connector J3, J4

Intended for internal use only.

4.2.5 RF Transmit J5

RF connector type: MMCX female, Edge Mount.

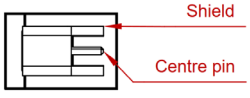
Table 7 - J5 RF pinout

Pin	Name	Description	Pinout
Centre pin	RF out	50Ω RF output	
Shield	GND	RF ground (common with power ground)	

4.2.6 RF Receive J6

RF connector type: MMCX female, Edge Mount.

Table 8 - J6 RF pinout

Pin	Name	Description	Pinout
Centre pin	RF out	50Ω RF input	
Shield	GND	RF ground (common with power ground)	

5 Mechanical Interface

The TRXVU should be mounted in the satellite structure by means of the four 3.2 mm mounting holes on the PCB, using four rods with spacers. This interface is compatible with ISIS structures. Also, the system should be connected to the CubeSat bus by means of the four rods with spacers and the CubeSat Kit connector (CSKB). It is not recommended to mount the board by any other means than this mounting interface. For the board envelope refer to ISIS-TRXVU-CAD-0001 and the CAD module [ISIS-TRXVU-CAD-0001].

6 Thermal Interface

The system should be connected to the CubeSat bus by means of four rods with spacers and the CubeSat Kit connector. The connector, together with the spacers constitutes the biggest thermal path to the board in addition to the CSKB connector and both ensure sufficient thermal coupling for safe operations and remaining within the operating and surviving 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 measure and verify continuously the board temperature.

Thermally the board can be modelled by two heat sources, one spread over the whole volume which represents the power dissipation of the components active when the receiver is active 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 an RF signal is being transmitted. Typical values for Static and Transmitter power dissipation are given in Table 3.

The transmitter power amplifier is encased in a shielding can to provide RF shielding. This impacts the radiative heat transfer, though conduction can be assumed as the dominant heat transfer mechanism.

The parameters required to model the thermal behaviour of the system are summarized in Table 9.

Table 9 - Thermal parameters

Parameter	Value	Notes
Maximum PA temperature	+95 °C	
Thermal resistance amplifier to PCB	9 °C / W	
Power amplifier mass	0.6 g	50% epoxy 50% copper
Power amplifier location	[26.5, 16.7] mm	[x, y] of the centre of PA, referred as in ISIS-TRXVU-CAD-0001.
Power amplifier size	[2.6, 4.6, 1.6] mm	[x, y, z]
Power amplifier dissipation	*See Table 3*	
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

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 sections.

7.1 Command format

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:

7.1.1 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

7.1.2 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)

7.2 Receiver Telemetry and Command Definition

The receiver controller contains the following functionalities:

- Telecommand 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
- I^2C Watchdog reset

7.2.1 Data interface specification

7.2.1.1 0x1A Measure all telemetry channels

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

Description

Measures all the available telemetry channels:

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

Parameters

None

Response

[000 - 001] xxxxxxxx xxxxxxxx

Raw measurement value of the instantaneous Doppler offset of the signal at the receiver port. 16-bit twos complement.

[002 - 003] xxxxxxxx xxxxxxxx

This field contains the measured Received Signal Strength Indicator (RSSI) at the reception time. 16-bit twos complement.

[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 transmitter current.

[010 - 011] xxxxxxxx 0000xxxx

Raw measurement value of the receiver current.

[012 - 013] xxxxxxxx 0000xxxx

Raw measurement value of the power amplifier current.

[014 - 015] xxxxxxxx 0000xxxx

Raw measurement value of the power amplifier temperature.

[016 - 017] xxxxxxxx 0000xxxx

Raw measurement value of the local oscillator temperature.

[018 - 019] xxxxxxxx xxxxxxxx

Last packed received Doppler offset at the receiver port. 16-bit twos complement.

[020 - 021] xxxxxxxx xxxxxxxx

Last packed received Received Signal Strength Indicator (RSSI) at the receiver port. 16-bit twos complement.

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

Please refer to Section Telemetry conversion formulas 7.4 for the conversion formulas.

7.2.1.2 0x21 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 least significant byte is transmitted first (little endian).

7.2.1.3 0x22 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 first two bytes of the response indicate the size in number of bytes. This size can be used by the OBC to terminate the transaction 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 is the maximum frame size. The least significant byte is transmitted first (little endian).

[002 - 003] xxxxxxxx xxxxxxxx

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 xxxxxxxx

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.

7.2.1.4 0x23 Get full frame from receive buffer

Command Name	Command Code
Get full frame from receive buffer	00100011 (0x23)

Description

Retrieves the header and contents of the oldest frame in the receive buffer. In contrast to 0x22 Get frame from receive buffer, this command returns an additional 18 bytes of AX.25 frame header before the frame contents. These may be used by the OBC to implement various functionalities, for example a Digipeater function.

The first two bytes of the response indicate the size in number of bytes. This size can be used by the OBC to terminate the transaction 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

Full Frame size. This size has a minimum value of 19 and the maximum is the maximum frame size plus 18. The least significant byte is transmitted first (little endian).

[002 - 003] xxxxxxxx xxxxxxxx

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 xxxxxxxx

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 header and contents. The size of the data block depends on the received frame length and on the maximum frame size.

7.2.1.5 0x24 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

7.2.1.6 0x25 Get length telecommands

Command Name	Command Code
Get length telecommands	00100101 (0x25)

Description

Retrieves the number and lengths of the frames in the receive buffer. If there are 0 frames in the receive buffer the response is undefined. The response is determined by an array of bytes where every 2 bytes the length of a specific frame length is defined. The size of this array is determined by the size of the receiver buffer multiplied by 2 and it will keep exactly the same order as the frames 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 least significant byte is transmitted first (little endian).

... xxxxxxxx xxxxxxxx

Frame contents size. This size has a minimum value of 1 and the maximum the maximum is the maximum frame size. The least significant byte is transmitted first (little endian).

7.2.1.7 0x26 Remove all frames from buffer

Command Name	Command Code
Remove all frames from receive buffer	00100110 (0x26)

Description

Removes all frames from the receive buffer. If there are 0 frames in the receive buffer this command has no effect.

Parameters

None

Response

None

7.2.1.8 0x32 Set receiver frequency

Command Name	Command Code
Set receiver frequency	00110010 (0x32)

Description

Sets the receiver carrier frequency in kHz. The acceptable range of receive carrier frequencies is determined by the configuration of the unit. Use command 0x33 Get receiver frequency to confirm the new receive carrier frequency.

Parameters

[001 - 004] xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx

Frequency value in kHz. The least significant byte should be sent first (little endian).

Response

None

7.2.1.9 0x33 Get receiver frequency

Command Name	Command Code
Get receiver frequency	00110011 (0x33)

Description

Gets the receiver carrier frequency in kHz.

Parameters

None

Response

[000 - 003] xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx

Frequency value in kHz. The response is least significant byte first (little endian).

7.2.1.10 0x34 Get receiver PLL error counter

Command Name	Command Code
Get PLL error counter	00110100 (0x34)

Description

Gets two different PLL error counters. First a counter of PLL lock errors and second a PLL frequency value errors.

Parameters

None

Response

[000 - 001] xxxxxxxx xxxxxxxx

PLL error counter showing the amount of PLL lock errors.

[002 - 003] xxxxxxxx xxxxxxxx

PLL error counter showing the amount of PLL frequency value errors.

7.2.1.11 0x40 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.

7.2.1.12 0x42 Get firmware information

Command Name	Command Code
Get firmware information	01000010 (0x42)

Description

Reports firmware information string. It can contain product name, version, revision number and board serial number. Example: “ISISPACE TRXVU REVE RC V1.4.0.0 REV12348 SN000”.

7-digital serial numbers allocated by ISISPACE will be reported in truncated form (last 5 digits).

Parameters

None

Response

[000 - 079] xxxxxxxx … xxxxxxxx

Firmware information zero-terminated string, max length 80 bytes.

7.2.1.13 0x50 Get last reset cause

Command Name	Command Code
Get last reset cause	01010000 (0x50)

Description

Gets last reset cause. It is technical information from the MCU SYSRSTIV register. This register can contain the following: Reset interrupt vector. Generates a value that can be used as address offset for fast interrupt service routine handling to identify the last cause of a reset (BOR, POR, PUC) . Writing to this register clears all pending reset source flags.

00h = No interrupt pending

02h = Brownout (BOR) (highest priority)

04h = RST/NMI (BOR)

06h = PMMSWBOR (BOR)

08h = Wakeup from LPMx.5 (BOR)

0Ah = Security violation (BOR)

0Ch = SVSL (POR)

0Eh = SVSH (POR)

10h = SVML_OVP (POR)

12h = SVMH_OVP (POR)

14h = PMMSWPOR (POR)

16h = WDT time out (PUC)

18h = WDT password violation (PUC)

1Ah = Flash password violation (PUC)

1Ch = Reserved

1Eh = PERF peripheral/configuration area fetch (PUC)

20h = PMM password violation (PUC)

22h to 3Eh = Reserved

Parameters

None

Response

[000 - 001] xxxxxxxx

Last reset cause byte.

7.2.1.14 0xAA No operation

Command Name	Command Code
Software Reset	10101010 (0xAA)

Description

The command was a software reset command in Revision D and earlier. It is now a no-operation.

Parameters

None

Response

None

7.2.1.15 0xAB Hardware system reset

Command Name	Command Code
Hardware Reset	10101011 (0xAB)

Description

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

Parameters

None

Response

None

7.2.1.16 0xCC 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

7.3 Transmitter Telemetry and Command Definition

The transmitter controller contains the following functionality:

- Transmission of AX.25 frames
- Configuration of AX.25 parameters
- Autonomous transmission of beacon in AX.25
- 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
- I^2C Watchdog reset

Note that this section does not contain commands related to transponder mode. If transponder mode is enabled on your unit, details on transponder mode can be found in the Transponder Mode Annex [ISIS-TRXVU-ICD-0002].

7.3.1 Data interface specification

7.3.1.1 0x10 Send frame

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

Description

Adds an AX.25 UI frame to the frame buffer of the transmitter. 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

Parameters

[001 - 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 of 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. If the response has a value of 255 (or 0xFF in hexadecimal) then the frame was not added to the buffer.

7.3.1.2 0x11 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 [ISIS-TRXVU-OS-0001])
- This command is only available if the radio is set in AX.25 mode in [ISIS-TRXVU-OS-0001].

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 [ISIS-TRXVU-OS-0001] (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. If the response has a value of 255 (or 0xFF in hexadecimal) then the frame was not added to the buffer.

7.3.1.3 0x14 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. 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 [ISIS-TRXVU-OS-0001] (default value is 235 bytes).

Response

None

7.3.1.4 0x15 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.

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 [ISIS-TRXVU-OS-0001] (default value is 235 bytes).

Response

None

7.3.1.5 0x1F 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

7.3.1.6 0x20 Get current AX.25 TO callsign

Command Name	Command Code
Get current AX.25 TO callsign	00100000 (0x20)

Description

Retrieves the current 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).

Parameters

None

Response

[000 - 005] xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx

Six ASCII characters containing the AX.25 TO callsign currently set in the transmitter.

[006] xxxxxxxx

The secondary station ID byte from the AX.25 TO callsign set in the transmitter (binary encoded between 0 and 15, usually 0).

7.3.1.7 0x21 Get current AX.25 FROM callsign

Command Name	Command Code
Get current AX.25 FROM callsign	00100001 (0x21)

Description

Retrieves the current 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 (see sections 6.2.2.2 and 6.2.2.5).

Parameters

None

Response

[000 - 005] xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx

Six ASCII characters containing the AX.25 FROM callsign currently set in the transmitter.

[006] xxxxxxxx

The secondary station ID byte from the AX.25 FROM callsign set in the transmitter (binary encoded between 0 and 15, usually 0).

7.3.1.8 0x22 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).

Parameters

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

7.3.1.9 0x23 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.

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

7.3.1.10 0x24 Set transmitter idle state

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

Description

Sets the idle state of the transmitter. The transmitter can either be set to either remain or switch off when idle. When set to switch off, the transmitter will switch off 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 off when idle

00000001 - transmitter remains on when idle

Response

None

7.3.1.11 0x25 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
- Transmitter current
- Receiver current
- Power amplifier current
- Power amplifier temperature
- PCB 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 transmitter current.

[010 - 011] xxxxxxxx 0000xxxx

Raw measurement value of the receiver current.

[012 - 013] xxxxxxxx 0000xxxx

Raw measurement value of the power amplifier current.

[014 - 015] xxxxxxxx 0000xxxx

Raw measurement value of the power amplifier temperature.

[016 - 017] xxxxxxxx 0000xxxx

Raw measurement value of the PCB 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 Telemetry conversion formulas 7.4 for the conversion formulas.

7.3.1.12 0x26 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
- Transmitter current
- Receiver current
- Power amplifier current
- Power amplifier temperature
- PCB 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 transmitter current.

[010 - 011] xxxxxxxx 0000xxxx

Raw measurement value of the receiver current.

[012 - 013] xxxxxxxx 0000xxxx

Raw measurement value of the power amplifier current.

[014 - 015] xxxxxxxx 0000xxxx

Raw measurement value of the power amplifier temperature.

[016 - 017] xxxxxxxx 0000xxxx

Raw measurement value of the PCB 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 Telemetry conversion formulas 7.4 for the conversion formulas.

7.3.1.13 0x28 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

7.3.1.14 0x32 Set transmitter frequency

Command Name	Command Code
Set transmitter frequency	00110010 (0x32)

Description

Sets the transmitter carrier frequency in kHz.

Parameters

[001 - 004] xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx

Frequency value in kHz. The least significant byte should be sent first (little endian).

Response

None

7.3.1.15 0x33 Get transmitter frequency

Command Name	Command Code
Get transmitter frequency	00110011 (0x33)

Description

Gets the transmitter carrier frequency in kHz.

Parameters

None

Response

[000 - 003] xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx

Frequency value in kHz. The response is least significant byte first (little endian).

7.3.1.16 0x34 Get transmitter PLL error counter

Command Name	Command Code
Get PLL error counter	00110100 (0x34)

Description

Gets two different PLL error counters. First a counter of PLL lock errors and second a PLL frequency value errors.

Parameters

None

Response

[000 - 001] xxxxxxxx xxxxxxxx

PLL error counter showing the number of PLL lock errors.

[002 - 003] xxxxxxxx xxxxxxxx

PLL error counter showing the number of PLL frequency value errors.

7.3.1.17 0x35 Set PLL power output

Command Name	Command Code
Set PLL power output	00110101 (0x35)

Description

Sets the modulator output power level. The command takes a 16-bit value that is written into a register of the modulator component.

Parameters

[001 - 002] xxxxxxxx xxxxxxxx

Raw value to be set on the modulator register. The value must be sent Little Endian.

Power Level	Value
Power Level 4	0xFFCF
Power Level 5	0xEFCF

Response

None

7.3.1.18 0x40 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.

7.3.1.19 0x41 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

7.3.1.20 0x42 Get firmware information

Command Name	Command Code
Get firmware information	01000010 (0x42)

Description

Reports firmware information string. It can contain product name, version, revision number, board serial number and modulation. Example: "ISISPACE TRXVU REVE TC V1.4.0.0 REV12349 SN000 BPSK RRC G3RUH".

7-digital serial numbers allocated by ISISPACE will be reported in truncated form (last 5 digits).

Parameters

None

Response

[000 - 079] xxxxxxxx ... xxxxxxxx

Firmware information zero-terminated string, max length 80 bytes.

7.3.1.21 0x50 Get last reset cause

Command Name	Command Code
Get last reset cause	01010000 (0x50)

Description

Gets last reset cause. It is technical information from the MCU SYSRSTIV register. This register can contain the following: Reset interrupt vector. Generates a value that can be used as address offset for fast interrupt service routine handling to identify the last cause of a reset (BOR, POR, PUC) . Writing to this register clears all pending reset source flags.

00h = No interrupt pending

02h = Brownout (BOR) (highest priority)

04h = RST/NMI (BOR)

06h = PMMSWBOR (BOR)

08h = Wakeup from LPMx.5 (BOR)

0Ah = Security violation (BOR)

0Ch = SVSL (POR)

0Eh = SVSH (POR)

10h = SVML_OVP (POR)

12h = SVMH_OVP (POR)

14h = PMMSWPOR (POR)

16h = WDT time out (PUC)

18h = WDT password violation (PUC)

1Ah = Flash password violation (PUC)

1Ch = Reserved

1Eh = PERF peripheral/configuration area fetch (PUC)

20h = PMM password violation (PUC)

22h to 3Eh = Reserved

Parameters

None

Response

[000 - 001] xxxxxxxx

Last reset cause byte.

7.3.1.22 0x60 Get PA overtemperature flag

Command Name	Command Code
Get PA overtemperature flag	01100000 (0x60)

Description

Gets PA overtemperature flag.

Parameters

None

Response

[000 - 000] 0000000x

PA overtemperature flag (0: no issue, 1: overtemperature reached at least once)

7.3.1.23 0x61 Clear PA overtemperature flag

Command Name	Command Code
Clear PA overtemperature flag	01100001 (0x61)

Description

Clears PA overtemperature flag, after this command the flag is set to initial value 0.

Parameters

None

Response

None

7.3.1.24 0xAA No operation

Command Name	Command Code
Software Reset	10101010 (0xAA)

Description

The command was a software reset command in Revision D and earlier. It is now a no-operation.

Parameters

None

Response

None

7.3.1.25 0xAB Hardware system reset

Command Name	Command Code
Hardware Reset	10101011 (0xAB)

Description

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

Parameters

None

Response

None

7.3.1.26 0xCC 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 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.

7.4.1 Receiver telemetry

Receiver telemetry conversion formulas are shown in Table 10.

Table 10 - Receiver telemetry conversion formulas

Parameter	Conversion	Unit
Received signal Doppler offset	ADC * 38.15	Hz
Received signal strength	ADC * -0.5 - 22	dBm
Power bus voltage	ADC * 0.00488	V
Total current consumption	ADC * 0.3152	mA
Transmitter current consumption	ADC * 0.3152	mA
Receiver current consumption	ADC * 0.3152	mA
Power amplifier current consumption	ADC * 0.3152	mA
Power amplifier temperature	ADC * -0.07669 + 195.6037	°C
Local oscillator temperature	ADC * -0.07669 + 195.6037	°C

7.4.2 Transmitter telemetry

Transmitter telemetry conversion formulas are shown in Table 11. The RF forward and reflected power sensors output can be expressed in dBm or mW and both conversion formulas are shown. Due to the nonlinear nature of this sensor, the output is also provided in Table 12 and Table 13.

Table 11 - Transmitter telemetry conversion formulas

Parameter	Conversion	Unit
RF reflected power	20 * log10(ADC * 0.00767)	dBm
	ADC * ADC * 5.887 10^{-5}	mW
RF forward power	20 * log10(ADC * 0.00767)	dBm
	ADC * ADC * 5.887 10^{-5}	mW
Power bus voltage	ADC * 0.00488	V
Total current consumption	ADC * 0.3152	mA
Transmitter current consumption	ADC * 0.3152	mA
Receiver current consumption	ADC * 0.3152	mA
Power amplifier current consumption	ADC * 0.3152	mA
Power amplifier temperature	ADC * -0.07669 + 195.6037	°C
Local oscillator temperature	ADC * -0.07669 + 195.6037	°C

7.4.2.1 Forward and reflected power conversion to dBm

To simplify the conversion from raw ADC value to measured power, Table 12 can be used. The table reports the tabulated conversion to dBm, based on Table 11.

Table 12 - 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

ADC	Power (dBm)	ADC	Power (dBm)	ADC	Power (dBm)	ADC	Power (dBm)
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		

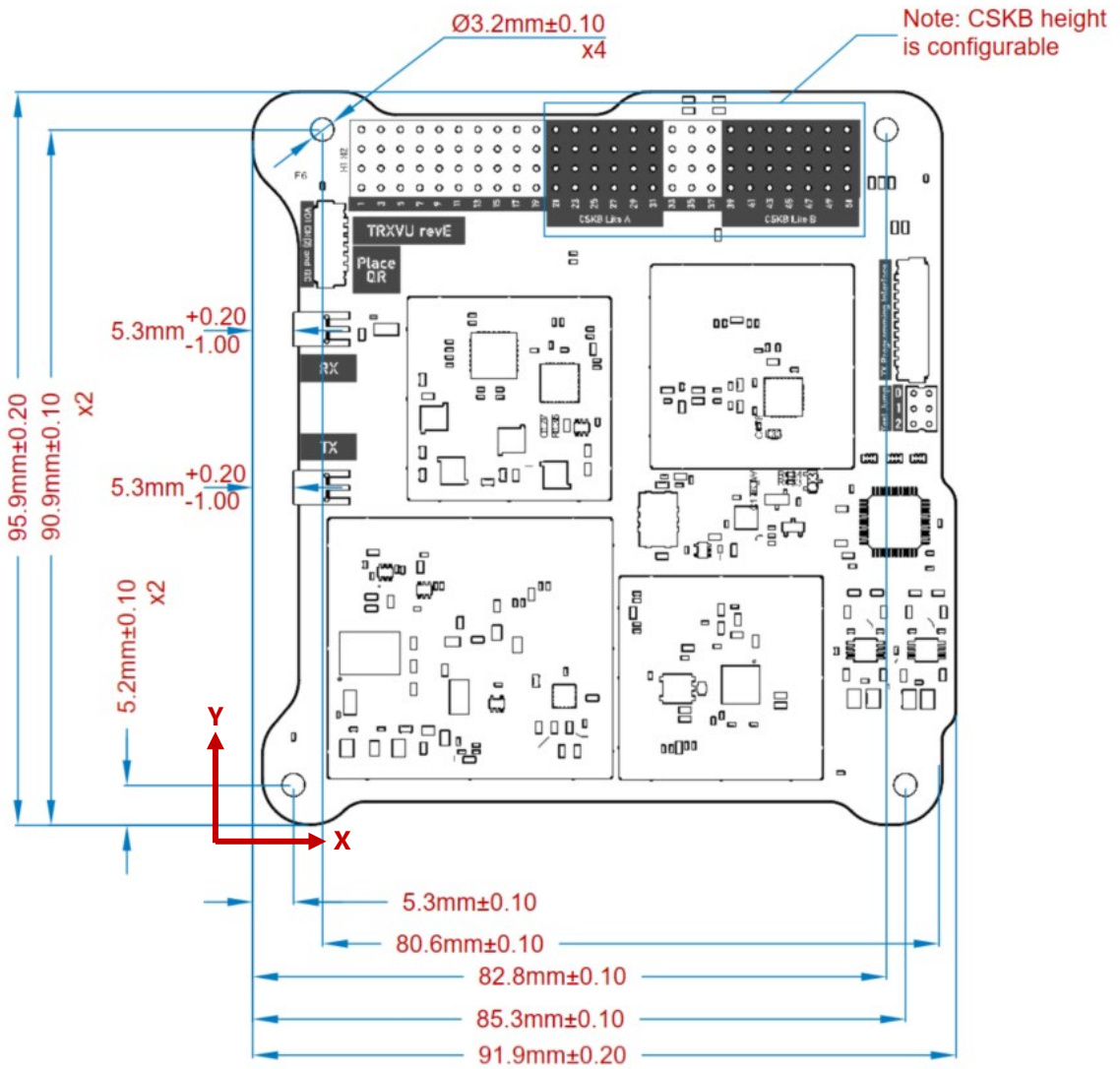
7.4.2.2 Forward and reflected power conversion to milliWatts

To simplify the conversion from raw ADC value to measured power, Table 13 can be used. The table reports the tabulated conversion to milliWatts, based on Table 11.

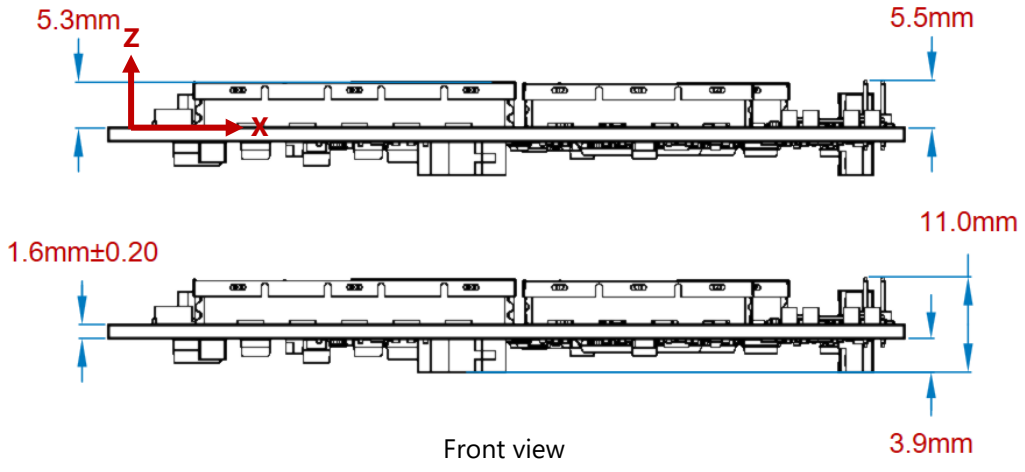
Table 13 - Forward and reflected power conversion table to milliWatts

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		

Annex A Mechanical Envelope



Top view



Front view