User Manual
Communication System

Document change log

Rev.	Date	Author	Pages	Description
0	2014-06-27	Artur Scholz	All	Created
1	2014-12-23	Artur Scholz	All	Major revision

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1 Introduction

The LC-2301a Communication System is a half-duplex communication system for UHF band operation with radio output power of up to 31 dBm (>1 W). The output power, the frequency and the frequency separation are user-programmable, allowing large flexibility in operation. The main function of the device is the receiving of telecommands and sending of telemetry over the space link and exposing this to the UART interface. The space link implements ECSS/CCSDS telecommand and telemetry frames (namely, CLTUs and CADUs). The physical layer of the space link uses binary FSK modulation at a default data rate of 1200 bps (user-programmable). Further, a mechanism to support antenna deployment is included.

Features:

- CubeSat and CubeSat Kit compatible with PC/104 form factor
- Industrial temperature range
- RF output power up to 31 dBm
- ECSS/CCSDS frame protocol for telecommands and telemetry
- Transceiver completely programmable
- Binary FSK at 1200 bps
- Operates in the UHF band (amateur radio band)
- Includes provisions for antenna deployment

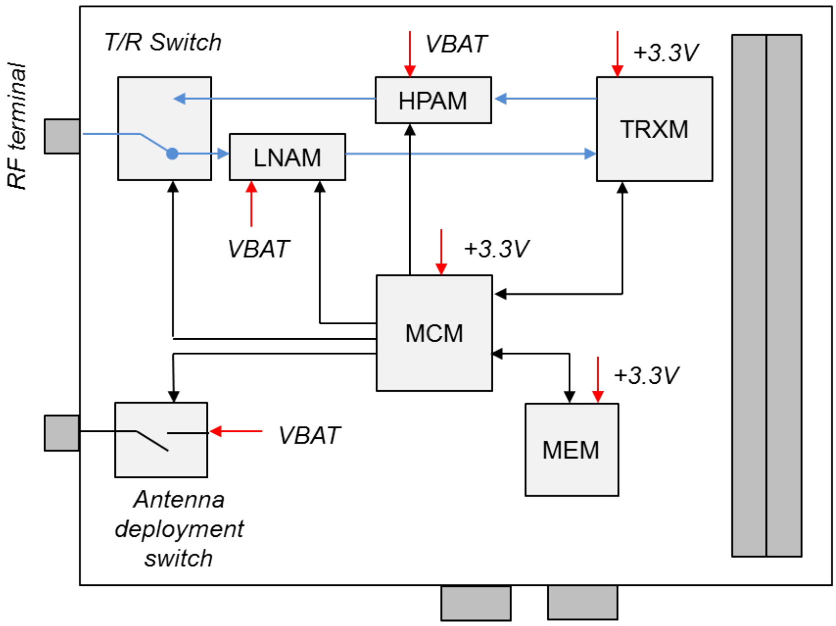


Illustration 1: System block diagram

2 Applicable and reference documents

Reference	Title	Issue
AD01	LibreCube Board Specification	1

3 Definitions and abbreviations

Abbreviation	Definition
ASM	Attached sync marker
CCSDS	Consultative Committee for Space Data Systems
CLTU	Communications link transmission unit
ECSS	European Cooperation on Space Standardization
HPAM	High power amplifier module
LNAM	Low noise amplifier module
MCM	Microcontroller module
MEM	Memory module
MSB	Most significant bit
RF	Radio frequency
RSSI	Received signal strength indication
TC	Telecommand
TM	Telemetry
TNC	Terminal node controller
TRXM	Transceiver module
WPM	Words per minute

4 Specification

4.1 Absolute maximum ratings

Parameter	Min	Max	Unit
Operational temperature range	-40	85	°C
Supply voltage on +3.3V		3.6	V
Supply voltage on VBAT		4.5	V

Exceeding the limits specified in the table above may result in permanent damage to the device and harm to products and personal.

4.2 Physical characteristics

Parameter	Min	Nom	Max	Unit
Total mass		62.7		g
Height above PCB			5	mm
Height below PCB			9.6	mm
PCB width		95.9		mm
PCB length		90.2		mm
PCB thickness		1.6		mm

4.3 Electrical characteristics

Parameter	Min	Nom	Max	Unit
Supply voltage on +3.3V	3.0	3.3	3.6	V
Supply voltage on VBAT*	3.2	3.6	4.0	V
Power consumption on +3.3V (idle)			50	mW
Power consumption on +3.3V (active)	56		66	mW
Power consumption on VBAT (active)	1.2		4.2	W
I2C node address (7 bit, hex)		0x13		-
I2C operating frequency		50	100	kHz
Microcontroller operating frequency		6.125		MHz
Measurement resolution		12		bit
UART baud rate		9600		bps

**VBAT powers the LNAM and the HPAM*

4.4 RF and interface characteristics

Parameter	Min	Nom	Max	Unit
Antenna impedance (SMA connector)		50		Ohm
Centre frequency	300	437	500	MHz
Frequency programming steps		250		Hz
Frequency separation	0	9.6	65	kHz
Frequency sep. programming steps		250		Hz
RF baudrate		1200		bps
Transmit power	-17		31	dBm
Receiver sensitivity (BER = 10^{-3})	-95	-105		dBm
Size of telecommand data buffer		65536		Byte
Size of telemetry data buffer		65536		Byte

5 Interfaces

5.1 Mechanical interfaces

The mechanical layout of the device is shown in Illustration 2. Four ø3.2 mm holes are located on the corners for mounting with M3 screws. The CubeSat connector is available in stack-through (as shown) and non-stack-through option.

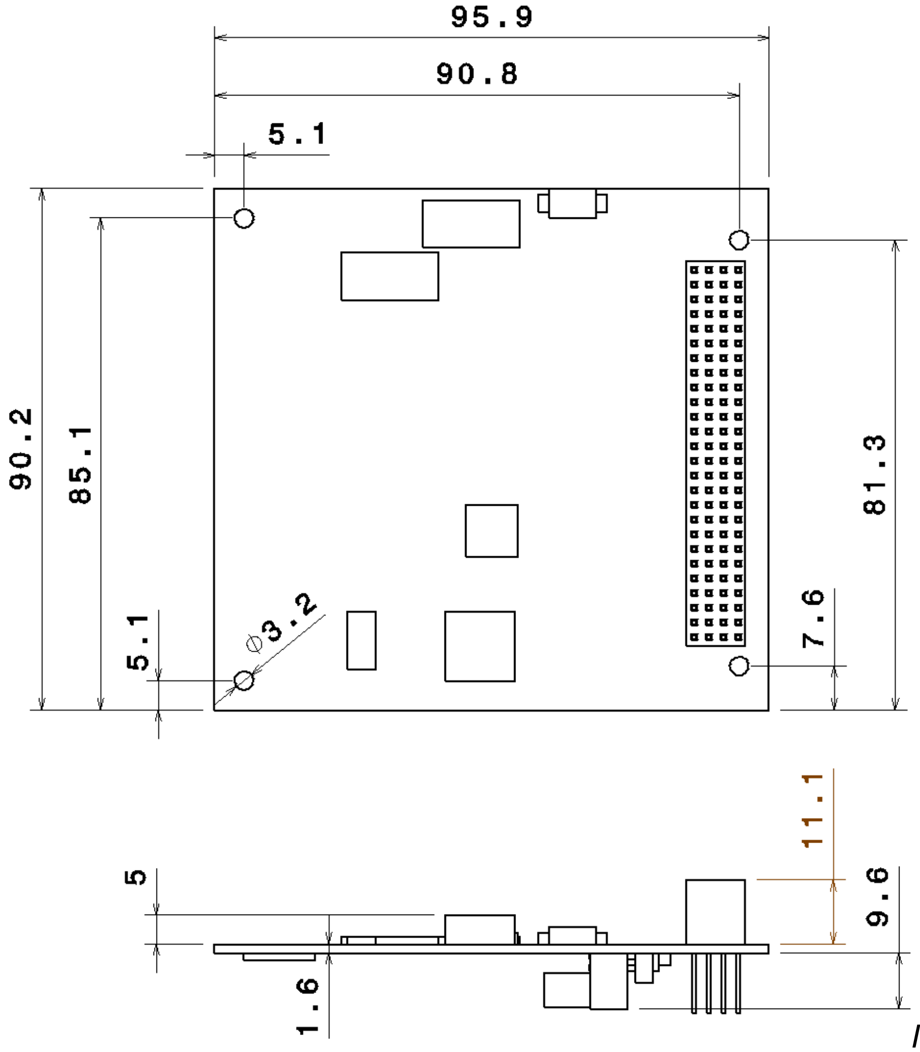


Illustration 2: Mechanical layout

5.2 Electrical interfaces

All available connectors on the top and bottom of the board are shown in Illustration 3. Note that the arrow points to the location of pin 1 for each connector. The signals of each connector are described in Table 1 to Table 4.

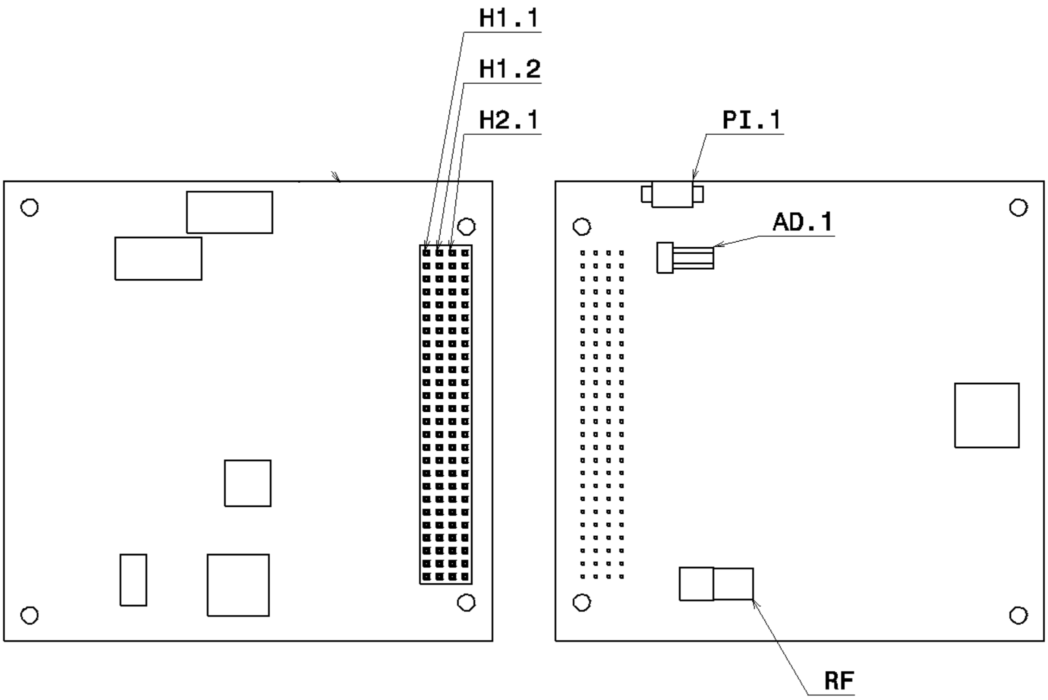


Illustration 3: Connector layout

Table 1: Antenna deployment connector

Pin	Description
AD.1	Connects to battery supply during deployment. Otherwise open.
AD.2	Ground

Table 2: RF interface connector

Pin	Description
-	RF signal
-	Ground (shielding)

Table 3: Programming interface connector

Pin	Signal	Description
PI.1	+3.3V	+3.3V power supply
PI.2	TMS	JTAG TMS signal
PI.3	TCK	JTAG TCK signal
PI.4	TDI	JTAG TDI signal
PI.5	TDO	JTAG TDO signal
PI.6	GND	Ground.

⚠ The programming interface is used for updating the firmware.

Table 4: CubeSat connector

Pin	Signal	Description
H1.29	-RESET	System reset line. Active low. Causes MCU to reboot.
H1.39	TX0	TX of UART0 for data to be transmitted via communication system.
H1.40	RX0	RX of UART0 for data received via communication system.
H1.41	SDA0	I2C system bus data
H1.43	SCL0	I2C system bus clock
H2.27, 28	+3.3V	+3.3V power supply
H2.29, 30, 32	DGND	Ground
H2.45, 46	VBAT	Battery power supply (3.2 V – 4.0 V)

H1

	1	2	
	3	4	
	5	6	
	7	8	
	9	10	
	11	12	
	13	14	
	15	16	
	17	18	
	19	20	
	21	22	
	23	24	
	25	26	
	27	28	
-RESET	29	30	
	31	32	
	33	34	
	35	36	
	37	38	
TX0	39	40	RX0
SDA0	41	42	
SCL0	43	44	
	45	46	
	47	48	
	49	50	
	51	52	

H2

	1	2	
	3	4	
	5	6	
	7	8	
	9	10	
	11	12	
	13	14	
	15	16	
	17	18	
	19	20	
	21	22	
	23	24	
	25	26	
+3.3V	27	28	+3.3V
DGND	29	30	DGND
AGND	31	32	DGND
	33	34	
	35	36	
	37	38	
	39	40	
	41	42	
	43	44	
VBAT	45	46	VBAT
	47	48	
	49	50	
	51	52	

Illustration 4: CubeSat connector pin layout

5.3 Software interfaces

Interfacing for monitoring and control is accomplished via I2C bus. The device always operates as slave. A master can read and write the values of the internal registers of the device. The following paragraphs describe how to read and write the registers.

5.3.1 Write operation

The master initiates a write operation by issuing a START condition followed by the device's slave address and a WRITE bit (0). When the master receives an ACKNOWLEDGE from the device it can transmit the 8-bit register address. The device will respond with a second ACKNOWLEDGE. The master then transmits the 8-bit value that shall be loaded into this register. The slave will respond with a third ACKNOWLEDGE. The write operation is then completed when the master issues a STOP condition or a second START condition.

S	Device Address	W	A	Register Address	A	Value	A	P

5.3.2 Read operation

The master initializes a read operation with a START condition followed by the device's slave address and a WRITE bit (0). When the master receives an ACKNOWLEDGE from the device it can transmit the 8-bit register address. The device will respond with a second ACKNOWLEDGE. The master must then issue a new START condition followed by the device's slave address and a READ bit (1). The sensor will respond with an ACKNOWLEDGE followed by the value of the register. The master must issue a NOT ACKNOWLEDGE followed by a STOP condition to terminate the operation.

S	Device Address	W	A	Register Address	A	S	Device address	R	A	Value	NA	P

5.3.3 Bit operations

The read and write operations operate on the basis of single bytes. In order to set or clear single bits from the internal register without changing the other bits of that register, the register must be first read out, then be subjected to AND/OR operation for clearing/setting a single or multiple bits, and finally the result must be written back to the register.

5.3.4 Device register

Writing and reading of the device registers allows full control and knowledge about the device. The content of the register is shown in Table 5. It is divided into segments that group related registers together.

Table 5: Device register

Add (hex)	Register name	Default	Read / Write	Note	Segment
0x00	null	-	-		Main
0x01	cmd	-	W	Command input	
0x02	hkperiod	1 Hz	R/W	Sets HK period	Settings
0x03	measure	All	R/W	Sets measurement mode	
0x04	tm_power	26 dBm	R	FM transmit power	
0x05	frx_l	436.850 MHz	R	Receive frequency	
0x06	frx_m		R		
0x07	frx_h		R		
0x08	ftx_l	436.995 MHz	R	Transmit frequency minus half of frequency separation	
0x09	ftx_m		R		
0x0A	ftx_h		R		
0x0B	fsep_l	9.6 kHz	R	Frequency separation	
0x0C	fsep_h		R		
0x0D	flag	-	R	System flags	Flags
0x0E	mcutemp_l	-	R	MCU temperature	Values
0x0F	mcutemp_h	-	R		
0x10	hpatemp_l	-	R	HPA temperature	
0x11	hpatemp_h	-	R		
0x12	rssi_l	-	R	RSSI level	
0x13	rssi_h	-	R		
0x14	tc_byte_counter_l	-	R	Counter of received TC bytes	
0x15	tc_byte_counter_m	-	R		
0x16	tc_byte_counter_h				
0x17	tm_byte_counter_l			Counter of transmitted TM bytes	
0x18	tm_byte_counter_m				
0x19	tm_byte_counter_h				

Table 6 provides detailed information about all of the not self-explanatory registers listed in Table 5. Each register is 8 bit, and as structured as shown below.

<register name>							
Bit 7 MSB	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 LSB

Table 6: Detailed description of registers

<table>
<tr><th>Register</th><th>Description</th></tr>
<tr><td>cmd</td><td>Command input register. The following commands are defined:
<table>
<tr><th>Opcode</th><th>Mnemonic</th><th>Description</th></tr>
<tr><td>0x01</td><td>RESET</td><td>Triggers a microcontroller reset.</td></tr>
<tr><td>0x02</td><td>MEASURE</td><td>Triggers a manual refreshment of measurements.</td></tr>
<tr><td>0x03</td><td>UPDATE_TRX</td><td>Updates the transceiver to the settings given in registers 0x08 to 0x0F.</td></tr>
<tr><td>0x04</td><td>DEPLOY_ANT</td><td>Powers the antenna deployment circuit for a fixed duration of one second.</td></tr>
<tr><td>0x05</td><td>TX_ENABLE</td><td>Enable the transmission of data over the space link.</td></tr>
<tr><td>0x06</td><td>TX_DISABLE</td><td>Disabled the transmission of data over space link.</td></tr>
</table></td></tr>
<tr><td>hkperiod</td><td>Sets the refreshment cycle of measurements for the housekeeping data, in steps of 1/10 seconds. Set to zero to disable automatic refreshment.</td></tr>
<tr><td>measure</td><td>Defines which of the measurement types are updated when a measurement is triggered (manual or via automatic refreshment). Set or clear the following bits:

Bit 0: temperature
Bit 1: rssi</td></tr>
<tr><td>tm_power</td><td>Adjusts the RF output power of telemetry frames. Settings are not linear and must be calibrated. Changes have immideate effect.</td></tr>
</table>

<table>
<tr><td>frx_[l/m/h]</td><td>Receiver frequency setting.</td></tr>
<tr><td>ftx_[l/m/h]</td><td>Transceiver frequency setting.</td></tr>
<tr><td>fsep_[l/h]</td><td>Frequency separation setting.</td></tr>
<tr><td>flag</td><td>This register holds the flags of system events.
<table>
<tr><th>Bit</th><th>Name</th><th>Description</th></tr>
<tr><td>0</td><td>busy</td><td>Flag is set when device is not idle, that is when doing measurements for the housekeeping, or transmitting/receiving data over the space link.</td></tr>
<tr><td>1</td><td>complete</td><td>Flag is set when the recent measurements for the housekeeping have completed.</td></tr>
<tr><td>2</td><td>sending_tm_data</td><td>This bit is set during the transmission of TM frame over the space link.</td></tr>
<tr><td>3</td><td>receiving_tc_data</td><td>This bit is set whenever the device has found the CLTU start sequence in the received space link, and is busy with processing the incoming frame.</td></tr>
<tr><td>4</td><td>antenna_deploying</td><td>This flag is set when the antenna deployment is ongoing.</td></tr>
<tr><td>5</td><td>rf_bitlock</td><td>Same as bit 3.</td></tr>
<tr><td>6</td><td>tx_enabled</td><td>This bit is set when TX is enabled.</td></tr>
<tr><td>7</td><td>tx_on</td><td>This bit is set when TX is on. Same as bit 2.</td></tr>
</table></td></tr>
<tr><td>mcutemp_l/h</td><td>Contains low byte and high byte of temperature measurement code (at microcontroller). Convert to Celsius according to[1]:
Temperature [Celsius] = gain * code + offset</td></tr>
<tr><td>hpatemp_l/h</td><td>Contains low byte and high byte of temperature measurement code (at HPA). Convert to Celsius according to[1]:
Temperature [Celsius] = gain * code + offset</td></tr>
<tr><td>rssi_l/h</td><td>Contains low byte and high byte of RSSI measurement code. Convert to Celsius according to[1]:
P[dBm] = gain * code + offset</td></tr>
</table>

[1] The values for gain and offset are determined during calibration.

6 Design description

6.1 Hardware

6.1.1 Transceiver module (TRXM)

The transceiver is a single-chip UHF transceiver IC (CC1000 from Texas Instruments). A block diagram of the chip is given in Illustration 5.

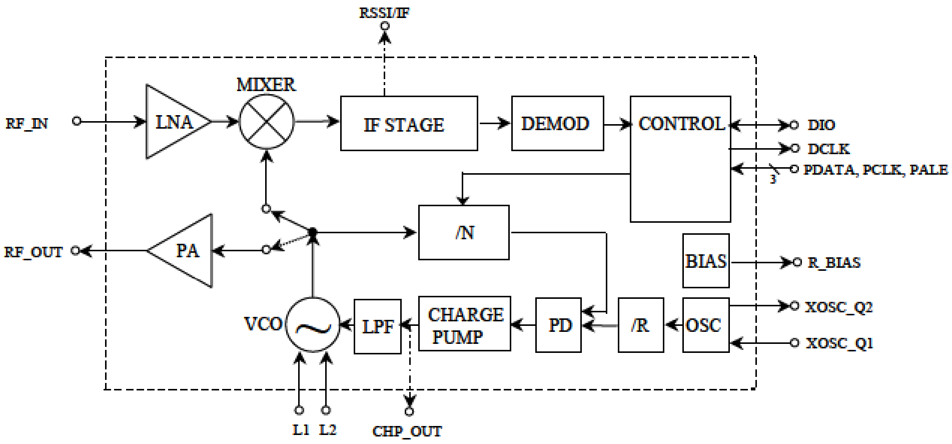


Illustration 5: Block diagram of CC1000 transceiver

The receiver part is built as a traditional super-heterodyne down-conversion receiver (Illustration 6). The incoming RF signal is amplified in the LNA and then fed into the mixer. The mixer takes the input frequency f_{IN} from the LNA and the frequency f_{LO} from the local oscillator (which is a voltage controlled oscillator tuned to a specific frequency as described later) and produces the sum and difference frequencies (and harmonics), $f_{IN} + f_{LO}$ and $f_{IN} – f_{LO}$ respectively. The CC1000 uses an intermediate frequency (IF) of 150 kHz, and to achieve low-side injection (where the digital output data will not be inverted as for high-side injection) the LO is tuned to $f_{IN} – f_{IF}$. The result is that the original FSK signal with centre frequency of f_{RF} is converted to a fixed centre frequency f_{IF}, while retaining the frequency deviation (e.g. ±5 kHz) between ‘0’ and ‘1’. The output of the mixer is band-pass filtered to remove $f_{IN} + f_{LO}$ and reduce harmonics. This signal is filtered and amplified and then fed to the demodulator. The data and clock are provided at DIO and DCLK respectively. The data at DIO is valid at the rising edge of DCLK.

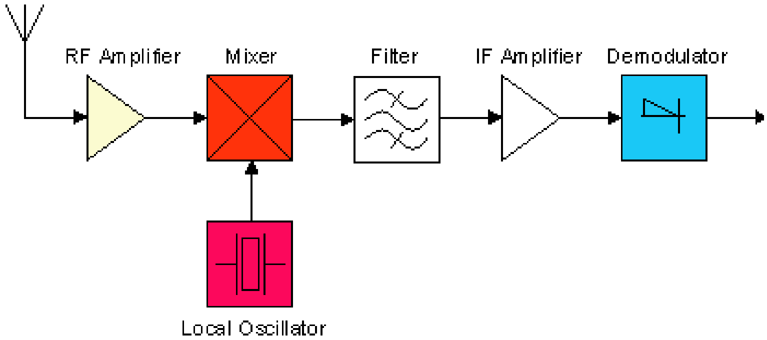


Illustration 6: Concept of super-heterodyne receiver

During transmit mode the timing clock is provided at DCLK (whose frequency is defined by the baud rate setting). The data at DIO is latched at the rising edge of DCLK. The VCO signal is directly fed to the internal power amplifier (PA). The RF output is frequency shift keyed (FSK). The VCO is the f_0 frequency for a ‘0’ and $f_0 + f_{SEP}$ is a ‘1’. The frequency separation f_{SEP} can be programmed in steps of 250 Hz. Illustration 7 pictures the relevant frequencies for receive and transmit mode.

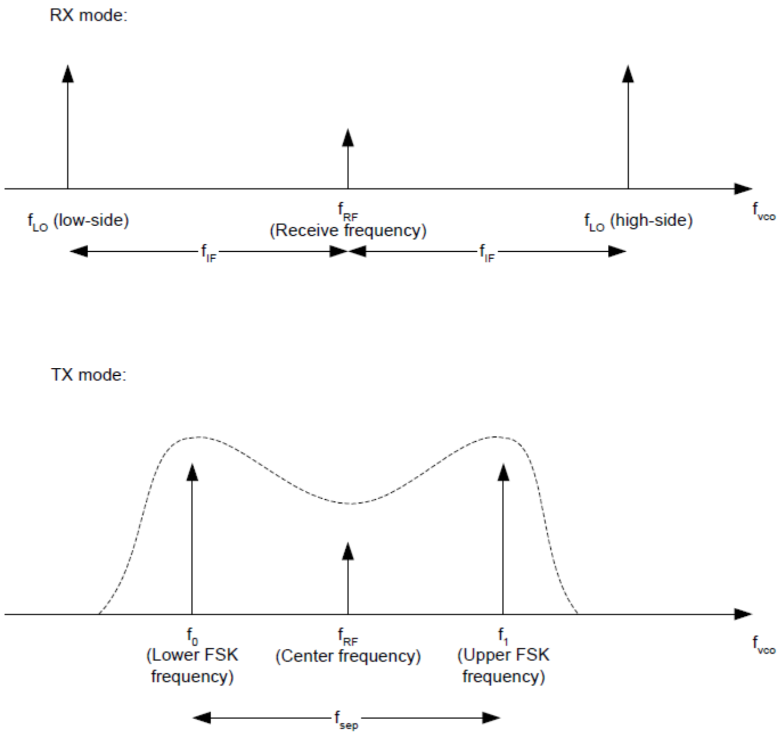


Illustration 7: Frequency settings for TX and RX

The key blocks in the transceiver are described in the following in more detail.

The demodulator block samples the frequency and converts it to a voltage level. This level is (after quantization and filtering) compared to the value of the average filter to generate the data output. The average filter is used to find the average value of the incoming data.

The VCO uses an external inductor, which determines the operating range of the circuit. The tuning range limits can be tested as described in AN018 page 2. The frequency of operation should be ideally located somewhere near the center of this range.

The wide tuning range of a VCO is combined with an inherently high frequency stable crystal oscillator (XOSC) to do frequency synthesis in form of a phase-locked loop (PLL).

The phase detector compares the (R-divided) XOSC reference input with the feedback of the (N-divided) VCO and produces an error signal which is proportional to their phase difference. The error signal is then low-pass filtered (to remove AC variations and noise) and used to drive a VCO which creates an output phase. If the output phase drifts, the error signal will increase, driving the VCO phase in the opposite direction so as to reduce the error. Thus the output phase is locked to the phase at the reference input.

The matching of the RF input and output pins for the CC1000 is accomplished as described in the data sheet.

6.1.2 High power amplifier module (HPAM)

The fully matched (50 Ohm) high power amplifier IC provides high gain of 35 dB and an output power of P_{1dB} = 32.5 dBm. The power is taken directly from the battery supply to support the high current of I_{CC} = 1.3 A at maximum RF output. The PA gets very hot during operation and needs appropriate cooling in form of a large ground plane The PA block diagram is shown in Illustration 8. A current limiting IC is included in the supply line of the HPA to limit maximum current to about 1.3 Ampere, for safety reasons. The HPA is only powered when TX is enabled.

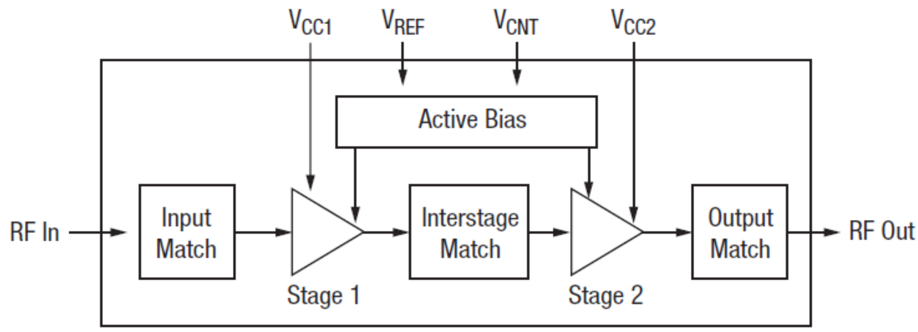


Illustration 8: Block diagram of HPA

6.1.3 Low noise amplifier module (LNAM)

A low noise amplifier IC is used to improve the signal quality of the received signal before going into the transceiver. The LNA is constantly powered.

6.1.4 Filter

The output of transceiver contains harmonics (integer multiples of the operating frequency), that should be filtered out before the power amplifier stage. A simple Pi-type low-pass filter as shown in Illustration 9 is utilized.

A band-pass filter to reject out-of-band signals at the receiver front-end is usually not necessary for space applications, as the problem of IDM (intermodulation distortion) or image noise is not dominant (because this would require other ground stations to actively transmit signals to the receiver system).

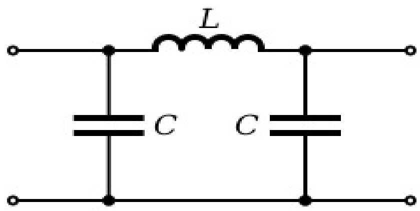


Illustration 9: Pi-type low-pass filter

6.1.5 Duplexer

The duplexer is used for switching the antenna between the TX output and RX input of the transceiver, as the device only operates on a single frequency, and must therefore use half-duplex communication.

6.1.6 Antenna deployment module (ADM)

The antenna deployment module is simply a power switch that connects the VBATT voltage to the antenna deployment mechanisms (an external coil). A low-value resistor is inserted in the path to allow current limiting.

6.1.7 Memory module (MEM)

The memory module is a volatile SRAM, which us used as a buffer. It buffers a single beacon/frame coming in via the UART data bus before it is transmitted over the space link. It also buffers the received CLTUs coming from the space link.

6.1.8 Microcontroller module (MCM)

The microcontroller is a 8051 device. The MCU runs at 6.1256 MHz, which is enough for the baud rate of 1200 bps (high baud rate may require the MCU to run at higher speeds).

6.2 Software description

6.2.1 Functional overview

The functionality of the device is to:

- constantly search the incoming bit stream from the receiver for telecommands (in form of CLTUs), and buffer them
- route completely received telecommands to UART
- receive telemetry data from UART and send over the space link
- provide antenna deployment support
- produce housekeeping data

6.3 Software implementation

6.3.1 Main loop

Following initialization, the main loop checks for received commands (from a I2C master device) and periodically refreshes its housekeeping information (unless disabled). Then it looks if there are telecommand data bytes in the FIFO, and routes them to the UART, one byte per loop iteration. The last step of the loop is to check if there is telecommand data in the FIFO. If so, it will send it over the space link, one byte per loop iteration. It also takes care of activating TX at start of transfer and deactivation when the FIFO is emptied.

6.3.2 Telecommand reception

A timer (Timer 0) interrupt is triggered every 50 microseconds, which checks if a new bit has arrived. If so, this bit is shifted into a 16 bit buffer. This buffer is then compared to the CLTU start sequence (0xEB90). If it matches, a function for buffering the incoming CLTU is called. The structure of a CLTU is as shown:

CLTU – Command Link Transmission Unit					
Start Sequence 0xEB90	1st Codeblock	2nd Codeblock	...	n-th Codeblock	Tail sequence
2 byte	8 byte	8 byte		8 byte	8 byte

Valid tail sequence: `0xC5 0xC5 0xC5 0xC5 0xC5 0xC5 0xC5 0x79`
or: `0x55 0x55 0x55 0x55 0x55 0x55 0x55 0x55`

The device does not check any of the payload data for errors, it solely looks for the start sequence, incoming data, and finally the tail sequence, and pushes all of it in the telecommand FIFO buffer.

Note that CLTUs can have variable length, therefore the tail sequence is needed for detecting the end of each CLTU. However, there is a maximum allowed CLTU length defined in software, for the purpose of preventing a corrupted or lost tail sequence to cause a buffer overflow.

6.3.3 Telemetry transmission

For sending telemetry over the space link, an attached device simply needs to write the data to the UART connection. The data is received via the UART interrupt service routine byte for byte and added to the telemetry FIFO buffer.

Basically the telemetry data frame can have any structure and format, and hence any downlink protocol can be implemented by the master. Nonetheless, the device is supposed to use CCSDS telemetry frames, and therefore the data should be structured (as provided by the master device) as follows:

CADU – Channel Access Data Unit	
Attached Synch Marker 0x1ACFFC1D	Data
4 byte	Fixed, max. 2048 byte

Note that telemetry frames (and hence CADUs), have a defined fixed length throughout the mission. This is needed in order to help the ground segment to synchronize.

7 Handling and storage

When handling the device make sure that it is powered off. To do so, disconnect all power lines from the device. For transportation put the device into an ESD protective bag and a box. For storage of the device ensure that it is in powered off. Store the device in an ESD protective bag in a dry, clean environment preferably at room temperature.

Be careful when making modifications to the board electronics. Avoid touching the board circuitry when handling. Mistreatment may result in damage.

8 Experimental usage

8.1 Set up for testing

1. When setting up the device for in-lab operation, place it on a horizontal surface that is preferably covered by an ESD mat. Make sure that the device is powered off.

2. Attach antenna to the device via a coax cable.

3. Attach power supply cables to the 3.3V land VBAT pin. Alternatively, stack a power supply board (such as LC-2201a or similar) onto it. Make sure that at this step the device is not yet powered.

4. To connect the device to a computer for monitoring and control use an I2C-UART bridge (LC-3101a or similar). Use the CubeSat board connector for connecting the SDA0, SCL0, +3.3V, and GND pins.

5. To connect the device to a computer for transfer of data use a UART adapter (LC-3102a or similar). Connect the TX0, RX0, +3.3V, and GND pins from the device's CubeSat connector to the adapter. See Illustration 10.

6. Power the device by switching on the external power supply.

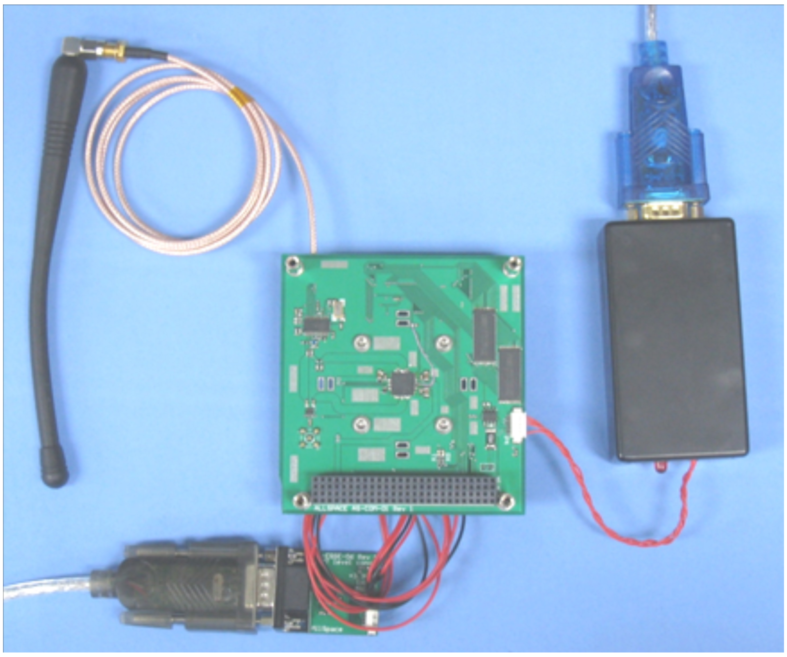


Illustration 10: In-lab set-up (power supply not shown)

8.2 Test procedures

8.2.1 Reading from the device via I2C bus

For example, to read the housekeeping setting of the device, send the following two bytes via the terminal program: 0x27 0x02. The first byte is the device 7 bit I2C address appended by 1 bit for the read operation. The second byte is the register address from which to read. The device will respond with the default value of 0x0A.

8.2.2 Writing to the device via I2C bus

As another example, to set the housekeeping refresh rate to every 2 seconds, send the following: 0x26 0x02 0x14. The first is the 7 bit I2C address shifted to left one bit, followed by the register address, and the value to be written (20 decimal).

8.2.3 Sending telemetry

To send telemetry, simply write data to the TX0 port of the CubeSat board connector.

8.2.4 Receiving telecommands

When valid telecommands (i.e. CLTUs) are received, they are automatically routed to the RX0 port at the CubeSat board connector.

9 Operational usage

9.1 System integration

9.1.1 Mating with other boards

To integrate the device into a satellite it can be stacked onto other electronic boards that comply with the CubeSat connector layout. Use M3x15 mm spacers between the boards. (If such a stacked configuration is not feasible or desired, another option would be to route the electrical signals from the CubeSat connector via harness to the other subsystems.)

Make sure that all devices are powered off during mating.

Before mating the device with other boards make sure that the electrical connections are compatible with each other and remain within their specified levels at all times.

9.1.2 Antenna attachment

Connect a 50 ohm antenna for UHF band to the SMA terminal of the device via a 50 ohm coaxial cable. If the antenna or cable is not properly matched to 50 ohm, attenuation will be introduced. In case of excessive mismatch this may result in damage to the transmitter.

Always make sure that a 50 Ohm antenna (or dummy load) is properly connected to the device before operation.

9.1.3 Antenna deployment mechanism attachment

An antenna deployment circuitry is implemented on the device that essentially consists of an active low switch, controlled via the device's register. When the switch is activated, the antenna deployment positive terminal will be connected to VBAT, which may be used to active an external antenna deployment mechanisms (such as melting a wire or releasing a hook).

9.2 Operations procedures

9.2.1 Control and monitoring

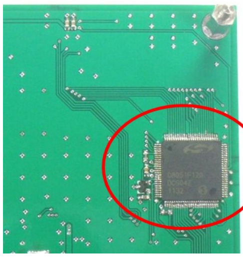
For control and monitoring of the device, the device’s registers are used as described in section 5.3. To achieve this, an external controller (on board computer) must operate on the I2C bus to read and write the registers of the device.

9.2.2 Housekeeping

The device periodically captures housekeeping data and updates the corresponding registers at periods defined in the *hkperiod* register. This function can be disabled. A manual triggering of housekeeping capture can be triggered via command. The housekeeping data consists of analog measurements and status bits as described in the next section. The *measure* register defines which measurements to update.

9.2.3 Measurements

The device provides two types of measurements. Temperature measurements from MCU and HPA are available. The locations are shown in Illustration 11. The RSSI measurement provides an indication on the strength of a received signal.



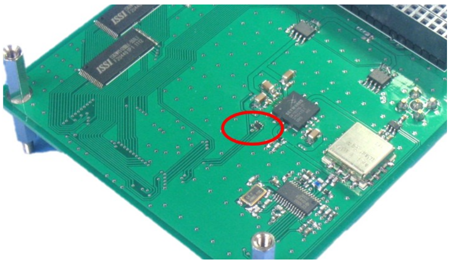


Illustration 11: Location of temperature measurements

9.2.4 Sending telemetry

Same as Section 8.2.3.

9.2.5 Receiving telecommands

Same as Section 8.2.4.

9.2.6 Antenna deployment

Send the relevant command to the device via the I2C bus.