nano avionics

UHF Radio

SAT2RF1-1B

Data Sheet

NA-UHF-G0-R9

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Contents

1 Feature Overview

- High-performance ARM 32-bit Cortex™-M4 CPU
- Clock Speed: 16-72 MHz (configurable)
- Up to 48 KB of Built-in SRAM
- 256 Kbytes of Built-in Program Memory
- 64 MB On-board NOR Flash Memory for User Data
- RF Architecture: Half Duplex
- Frequency Range: 430-440 MHz
- Bit Rate: 9600 bps
- RX Sensitivity at 9600 bps Bit Rate: -118 dBm
- RF Output Power: up to 2 W
- Modulation: 2-FSK (G3RUH compatible)
- Deviation: 3 kHz (G3RUH compatible)
- Bit Encoding: G3RUH
- Data Packet Format: AX25
- In-orbit Re-configuration Capability

2 Functional Description

2.1 Description

The system block diagram of the UHF radio is shown in Figure 1. The UHF radio utilizes a half-duplex architecture with high performance low power consumption transceiver which is controlled by a dedicated ARM Cortex-M4 MCU. The radio uses the ultra-high frequency band (UHF) that is programmable in 430 to 440 MHz range. The receiver has an excellent sensitivity of -118 dBm at 9600 bps bit rate and the transmitter operates in James Miller G3RUH (which has become the amateur radio standard) mode: 2-FSK modulation and AX25 data packet format. A bandpass filter can be selected depending on customer specific frequency (e.g. 435-438 MHz for the radio amateur satellite frequency band).

The power amplifier and system logic are supplied by separate 3.3 V power lines for electromagnetic compatibility reasons. The radio has 1 UART data interface for communication with external subsystems. 64 MB of NOR flash memory is connected via SPI data bus and can be used to store your mission data. The power amplifier (PA) is operating at constant gain with output power depending on the input signal level from the transceiver which is controlled in -16 dBm...+6 dBm interval. The temperature of the power amplifier is constantly monitored by MCU and in case an overtemperature event is detected the transmission is switched off automatically. After temperature dropped transmission is switched on automatically.

The radio has 4 input/output channels that can be configured for user specific needs (e.g. external WDT, boot control of external subsystems, etc.)

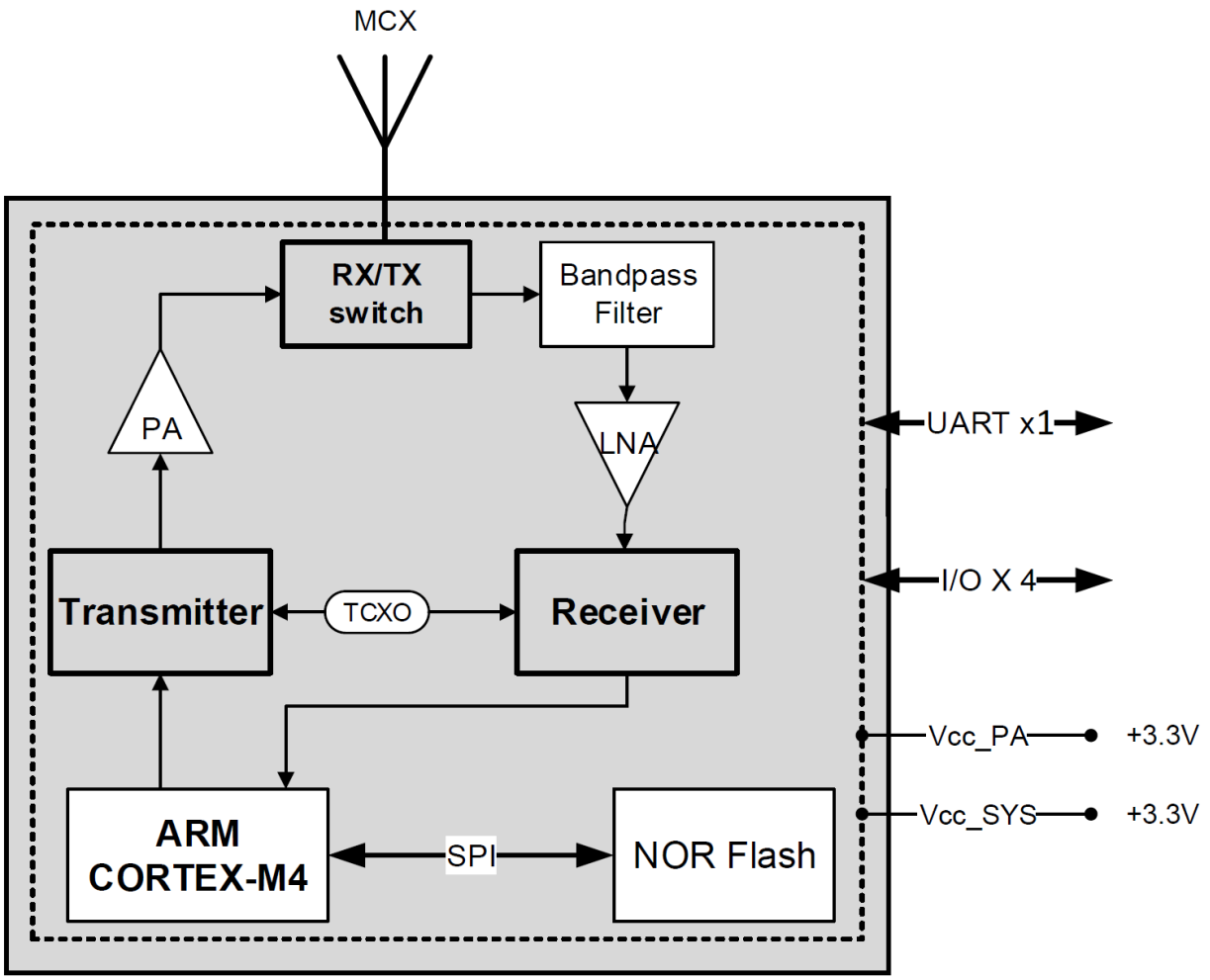


Figure 1 – System Block Diagram

2.2 Ordering Options

Table 1 – Available Ordering Options

Product ID	Description
NA-SCUHF-G0-R0	Stand-alone version, Figure 2
NA-SCUHF-G0-R1	Mounted on a PC/104 PCB, with a heat sink, Figure 3

3 Layout

3.1 Radio Module

Figure 2. Stand-alone Radio Module – General View

3.2 Mounted on PCB

Figure 3. Radio Module Mounted on CubeSat Standard Compatible PCB, Together with a Heatsink

4 Specifications

4.1 RF Characteristics

Table 2 – RF Characteristics, Based on CC1200 Chip in 430-440 MHz Band

Parameter	Min	Typ	Max
Frequency band (MHz)	430	-	440
Frequency resolution @430 ~ 440 MHz (Hz)	-	19.1	-
Bitrate (kbps)	-	9.6	-
Receiver sensitivity (G3RUH mode, 9.6 kbps, 2-FSK):		-118 dBm	
BandPass Filter Insertion loss 430 ~ 440 MHz IL (dB)	-	2.3	3.3
RF Switch Insertion loss (dB)	-	0.7	0.8
Power amplifier RF Output power @50Ω Load (dBm)	-	-	33 [1]

4.2 Absolute Maximum and Minimum Ratings

Table 3 - Absolute Minimum and Maximum Ratings

Parameter	Min/Idle	Typ	Max
Input Voltage on Vcc_SYS pin	2 V	3.3 V	3.6 V
Input Voltage on Vcc_PA pin	3 V	3.3 V	4 V
I/O voltage level	2 V	3.3 V	3.6 V
I/O current	-	-	25 mA
Operating temperature	-40 °C	-	+85 °C
Storage temperature	-40 °C	-	+125 °C
Power dissipation of power amplifier	-	3W	5 W
Current Consumption:			
on Vcc_SYS line @RX/TX mode	-	46 mA	70 mA
on Vcc_PA line @TX mode	-	1600 mA [2]	2000 mA
Leakage current on Vcc_PA line	5 µA	-	10 µA

WARNING: A heat sink must be used to transfer the dissipated heat from the power amplifier. The transceiver must not be operated in a higher than maximum operating temperature.

[1] At 3.3 V power amplifier supply voltage
[2] At 33 dBm RF output power

5 Electrical Interface

The UHF radio is designed as an SMD board to be mounted by soldering on a customer platform or can be delivered already soldered on a PC104 motherboard.

5.1 Service Connector and External Connectors Pinout

An 8-pin PicoBlade J301 service connector is provided for testing and debugging purposes. The pinout is shown in Table 4 and Table 5.

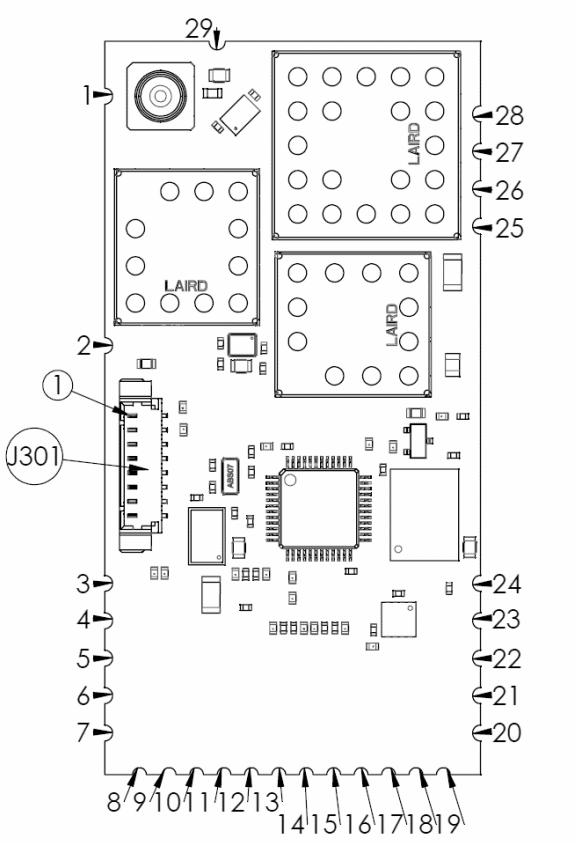


Figure 4. PCB Top View with Service Connector and External Side Connectors Pinout

Table 4 - Service Connector J301 Pinout

Pin No.	Name	Description
1	SWCLK	Serial wire clock
2	SWU	System boot configuration pin 0
3	SWDIO	Serial Wire Data Input/Output
4	UART1_RXD	Serial data receive (Input to the transceiver)
5	UART1_TXD	Serial data transmit (Output from the transceiver)
6	RST	Reset
7	GND	Ground
8	Vcc_SYS	Vcc_SYS logic power supply

Table 5 - External Side Connectors Pinout

Pin No.	Name	Description
1	GND	Ground
2	GND	Ground
3	-	N/C
4	-	N/C
5	-	N/C
6	GND	Ground
7	-	N/C
8	UART1_RXD	Serial data receive (Input to the transceiver)
9	UART1_TXD	Serial data transmit (Output from the transceiver)
10	IO1	GPIO 1
11	IO3	GPIO 3
12	IO4	GPIO 4
13	IO2	GPIO 2
14	-	N/C
15	-	N/C
16	-	N/C
17	-	N/C
18	-	N/C
19	IO5	GPIO 5
20	-	N/C
21	-	N/C
22	RST	Reset
23	GND	Ground
24	Vcc_SYS	Vcc_SYS logic power supply
25	GND	Ground
26	GND	Ground
27	3.3V_TX	3.3V PA power supply
28	3.3V_TX	3.3V PA power supply
29	GND	Ground

5.2 MCX RF Connector

MCX connector is used for RF cable connection. Either straight or right angle options can be ordered.

Figure 5 - MCX RF Connector

6 Command and Data Interface

UHF radio uses modified KISS protocol for communication. KISS (Keep It Simple, Stupid) is used for transmission of AX.25 packet radio frames and radio commands over an asynchronous serial link. The data is sent in binary format MSB first. The bit rate should be set to 115200 bps. The packet format is shown in Table 6. Packet begin and end are specified by FEND character. The data frame size has to be less than 256 bytes in length (standard AX.25 packet size) otherwise the data will be truncated to 256 bytes. There is no support for flow control or error handling.

Table 6 - UHF Radio KISS Packet Format

Begin	Command	Data0..DataN	End
FEND	Command code	Data	FEND

6.1 Special Characters

If the FEND or FESC codes appear in the data to be transferred, they need to be escaped. The FEND code is then sent as FESC, TFEND:

C0 -> DB DC

And the FESC is then sent as FESC, TFESC:

DB -> DB DD

Table 7 - Special Characters

Hex Value	Abbreviation	Description
0xC0	FEND	Frame End
0xDB	FESC	Frame Escape
0xDC	TFEND	Transposed Frame End
0xDD	TFESC	Transposed Frame Escape

6.2 Command Codes

All command codes are fixed to 1 byte in length, but command can have up to 4 bytes of arguments. The command codes and arguments are listed and explained in Table 8.

Table 8 - KISS Command Codes and Arguments

Hex Value	Name	Argument Size	Description
0x00	Data Frame	Varies	This frame contains data that should be sent out of the UHF radio or data packet received by radio. The maximum number of bytes in the data frame should be less than 256. No reply to this command
0x01-0x06, 0xFF	KISS Special Commands	–	Not used
0x20	Set Frequency	UINT32	Set the radio frequency in Hz Response (UINT8): 0 – OK, ≠0 – error code
0x21	Get Frequency	–	Read the radio frequency in Hz. The error of set and read frequencies should not exceed 80 Hz Response (UINT32): frequency, Hz
0x22	Set Power	INT8	Set the RF output power in dBm (-16dBm...+6dBm) Response (UINT8): 0 – OK, ≠0 – error code
0x23	Get Power	–	Read the RF output power in dBm Response (INT8): RF output power level, dBm
0x24	Get RSSI	–	Read the RSSI level of the last received packet Response (INT8): RSSI, dBm
0x25	Ping/Command	UINT32	Command to the radio: 0x00000000 – PING; 0x00000001 – restart; 0x00000002 – enable debug information 0x00000003 – disable debug information Response (UINT32): 0x00000000 – answer to PING 0x00000001 – program start 0x00000002 – enabled debug information 0x00000003 – disabled debug information
0x26	Debug	varies	Radio Debug information in ASCII format
0x27	Set Correlation Coef.	UINT8	Set correlation coefficient (0..31) for sync word search. AX25 reception starts when sync word is found. As a rule of thumb values 0..10 should be considered as higher reception threshold, and 14..31 – lower threshold and higher susceptibility to noise; Response(UINT8): 0 – OK, ≠0 – error code
0x28	Get Correlation Coef.	–	Get correlation coefficient Response(UINT8): correlation coefficient
0x29	Set Mode	UINT8	Set radio mode: 0x00 - Packet receive mode (default receive mode) 0x01 - Transparent receive mode 0x02 - Continuous transmit mode Response (UINT8): 0 – OK, ≠0 – error code
0x30	Get Mode	-	Get radio mode Response (UINT8): 0x00 - Packet receive mode 0x01 - Transparent receive mode 0x02 - Continuous transmit mode 0x03 – AX25 packet transmit in progress (packet transmission can last up to 300ms)

For example, to ping the radio you would send:

C0 25 00 00 00 00 C0

The radio then replies:

C0 25 00 00 00 00 C0

To send the characters „Hello“ over the radio you would send:

C0 00 48 65 6C 6C 6F C0

To set the frequency of the radio to 435 MHz you would send:

C0 20 19 ED 92 DB DC C0

The radio then replies with command code 0x20, argument 0x00 means that frequency was set successfully: C0 20 00 C0. Note here that in the frequency set command „C0” in the frequency value 19ED92C0 (435 000 000 Hz) is replaced with special character „DB DC“.

6.3 Radio Modes

6.3.1 Receiver Operational Modes

There are 2 modes supported for the receiver part: transparent mode and packet mode. In transparent mode, digital packet detection and decoding is performed by the microcontroller software. The packet is detected when the specific carrier signal to noise ratio is exceeded (15 dB above noise in case of AX.25 packets). In packet mode, packet detection and de-coding is accomplished automatically by hardware. The packet mode is more sensitive compared to the transparent mode, however it is more susceptible to the interference cause by the noisy signals.

6.3.2 Transmitter Operational Modes

The transmitter supports normal and continuous transmit modes. A normal mode is the default mode which is used whenever transmitting data packets. Users can use the transmitter in continuous transmit mode for testing and development purposes. In this mode, only the carrier wave is transmitted at user specified frequency and signal strength until mode is changed back to packet or transparent mode.

6.4 Radio Setup

For testing and debug purposes you can control the radio via the J301 service connector. To set up the radio, perform following procedure:

1. Connect 50 ohm and at least 2 W RF load or antenna to the radio MCX connector.
2. Connect USB-to-UART converter TX to J301 UART1_RXD pin (4) and RX to J301 UART1_TXD pin (5).
3. Connect USB-to-UART converter +3.3 V pin to J301 Vcc_SYS pin (8).
4. Connect USB-to-UART converter ground pin to J301 ground pin (7).
5. Connect USB-to-UART converter to your PC.
6. Open any terminal software that can send binary HEX data via COM port. Below is the example how to connect to radio using Hercules SETUP utility.
7. Set Bit to 115200, Data size - 8, parity - none, no flow control.
8. Open connection using the COM port where the radio is connected. You should see a green text message on the Received/Sent Data screen: “Serial port COMxx opened” (where xx is the COM port number where the radio is connected).

9. Press the right mouse button on the Received/Sent Data screen and ensure that “Hex Enable” and “Special Chars -> Hexadecimal” are turned on (refer to Figure 6)
10. Enter any command in HEX format in any of the three Send fields and press send (don’t forget to turn on the “HEX” tick mark). You should see sent values as well as radio response in the Received/Sent Data screen (refer to Figure 7)

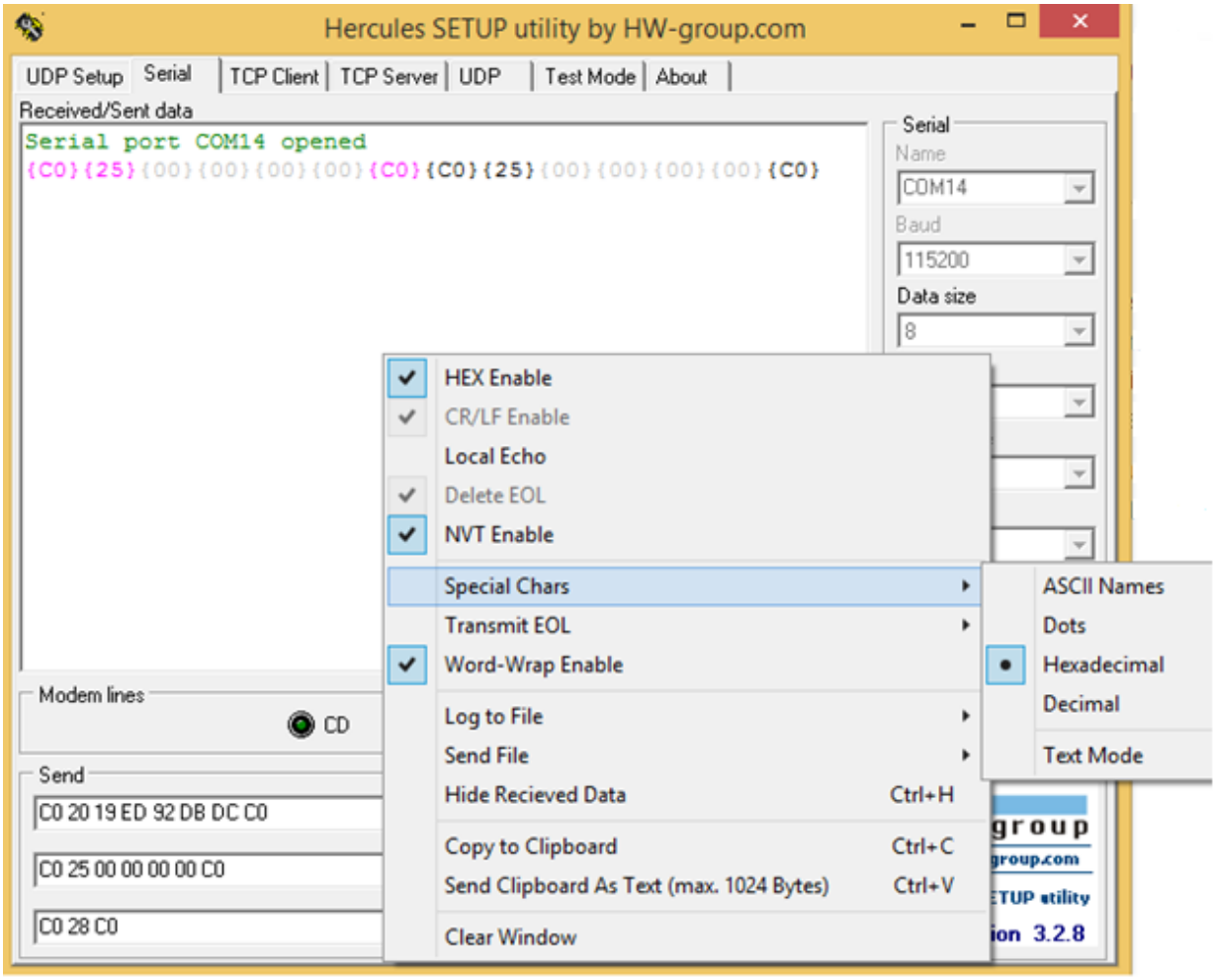


Figure 6 – Hercules SETUP Utility Settings

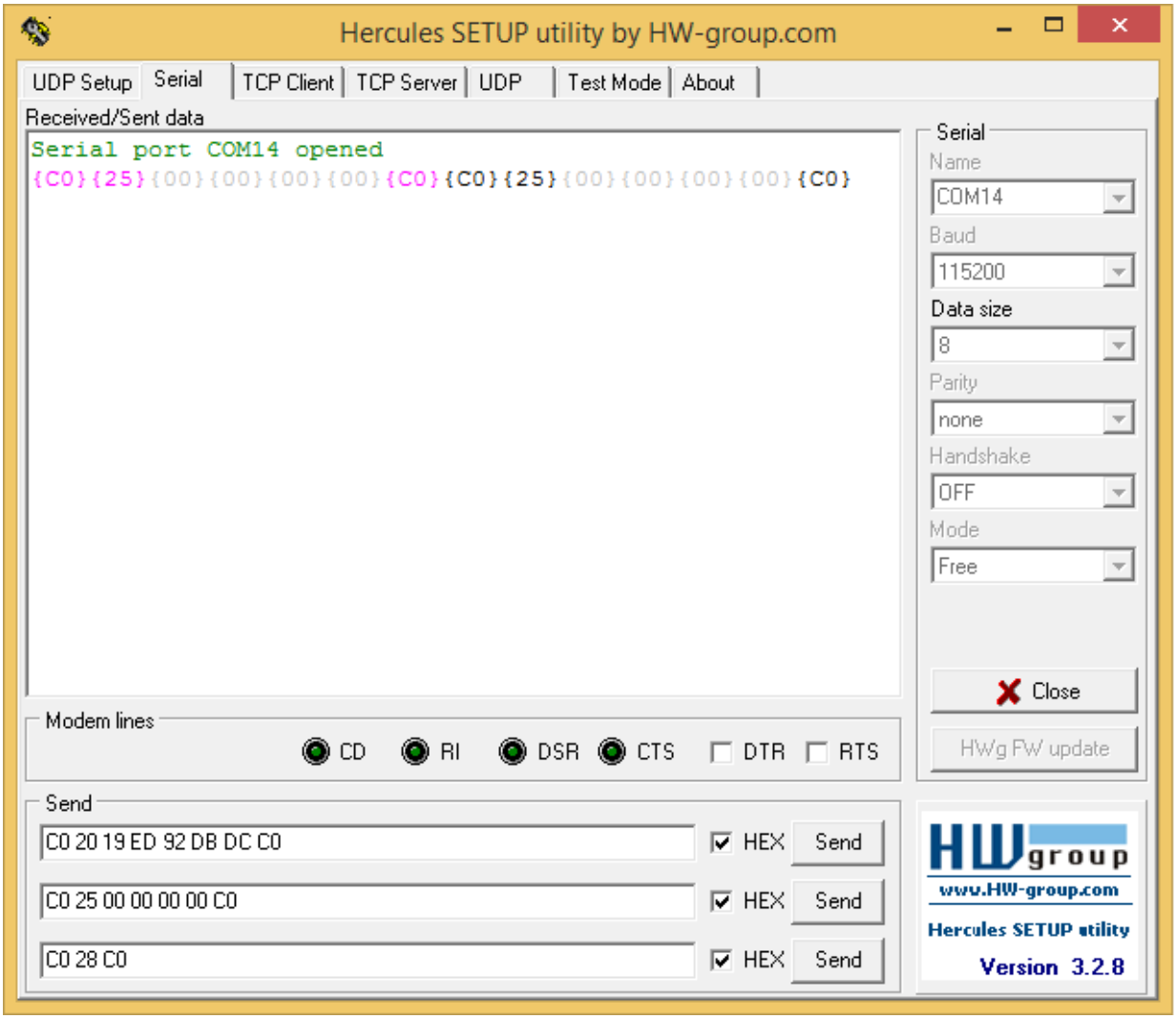
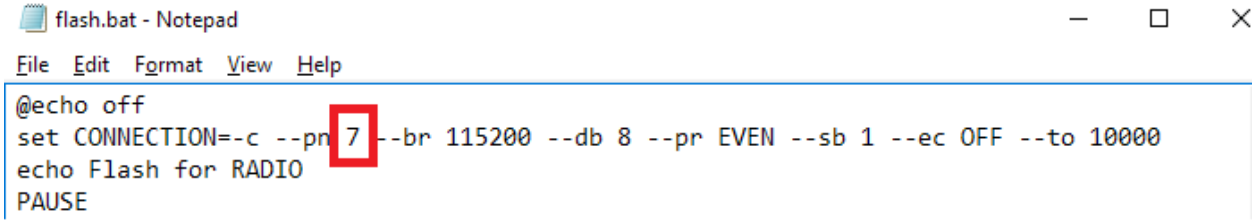


Figure 7 - Example of Ping Command and Response in the Hercules SETUP Utility

6.5 Firmware Upload

In order to flash firmware, take these step-by-step instructions:

1. Connect USB-to-UART converter TX to J301 UART1_RXD pin (4) and RX to J301 UART1_TXD pin (5).
2. Connect J301 header pin SWU pin (2), to Vcc_SYS pin (8), to enter Boot Mode.
3. Reset device by connecting for a few seconds J301 header RST pin (6), to GND pin (7).
4. Open device manager and find USB-to-UART converter COM port number.
5. Open firmware update package.
6. Set com port number by opening flash.bat file in text editor (Notepad).



7. Double click flash.bat, if everything ok, firmware will be flashed to device.
8. After successful flashing disconnect J301 header pin SWU pin (2) from Vcc_SYS.
9. Reset device by connecting for a few seconds J301 header RST pin (6), to GND pin (7).

Now new firmware should be running.

TROUBLESHOOTING:

If flashing application cannot connect:

1. Check if COM port number is set correctly in flash.bat.
2. Exchange RX and TX connections, because some USB-to-UART converters can have different marking.

7 Mechanical Interface

7.1 Physical Dimensions

All dimensions are given in mm.

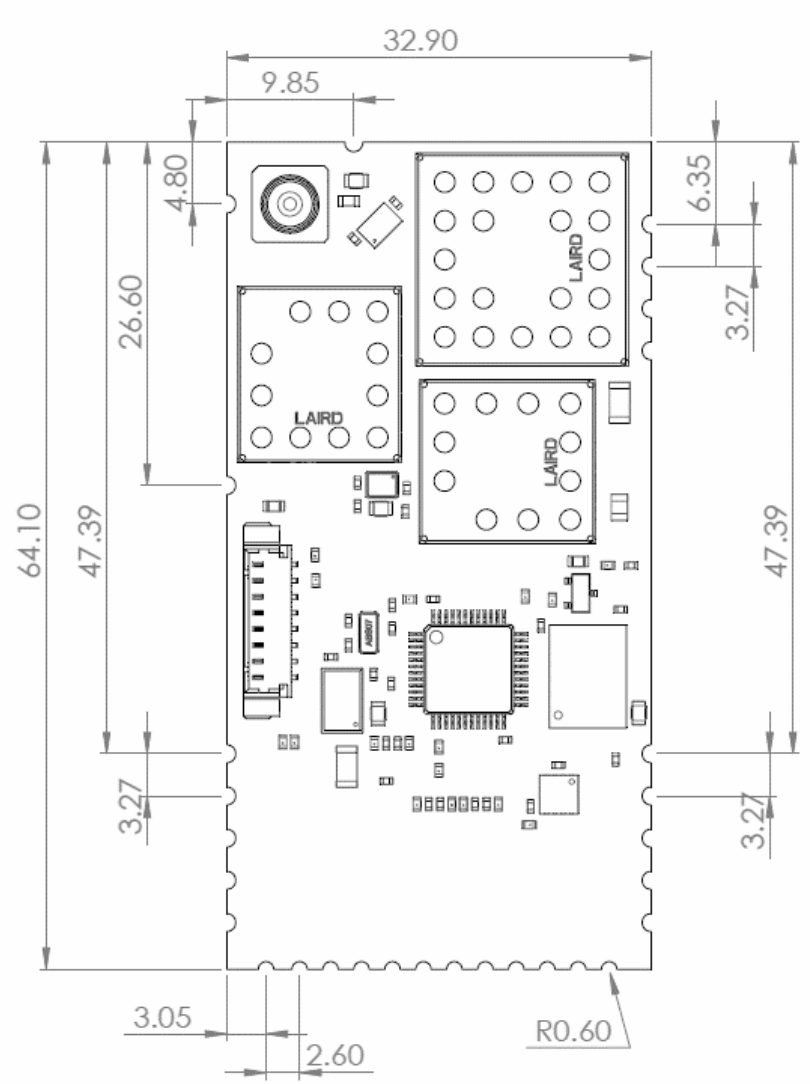


Figure 8. UHF Radio Dimensions

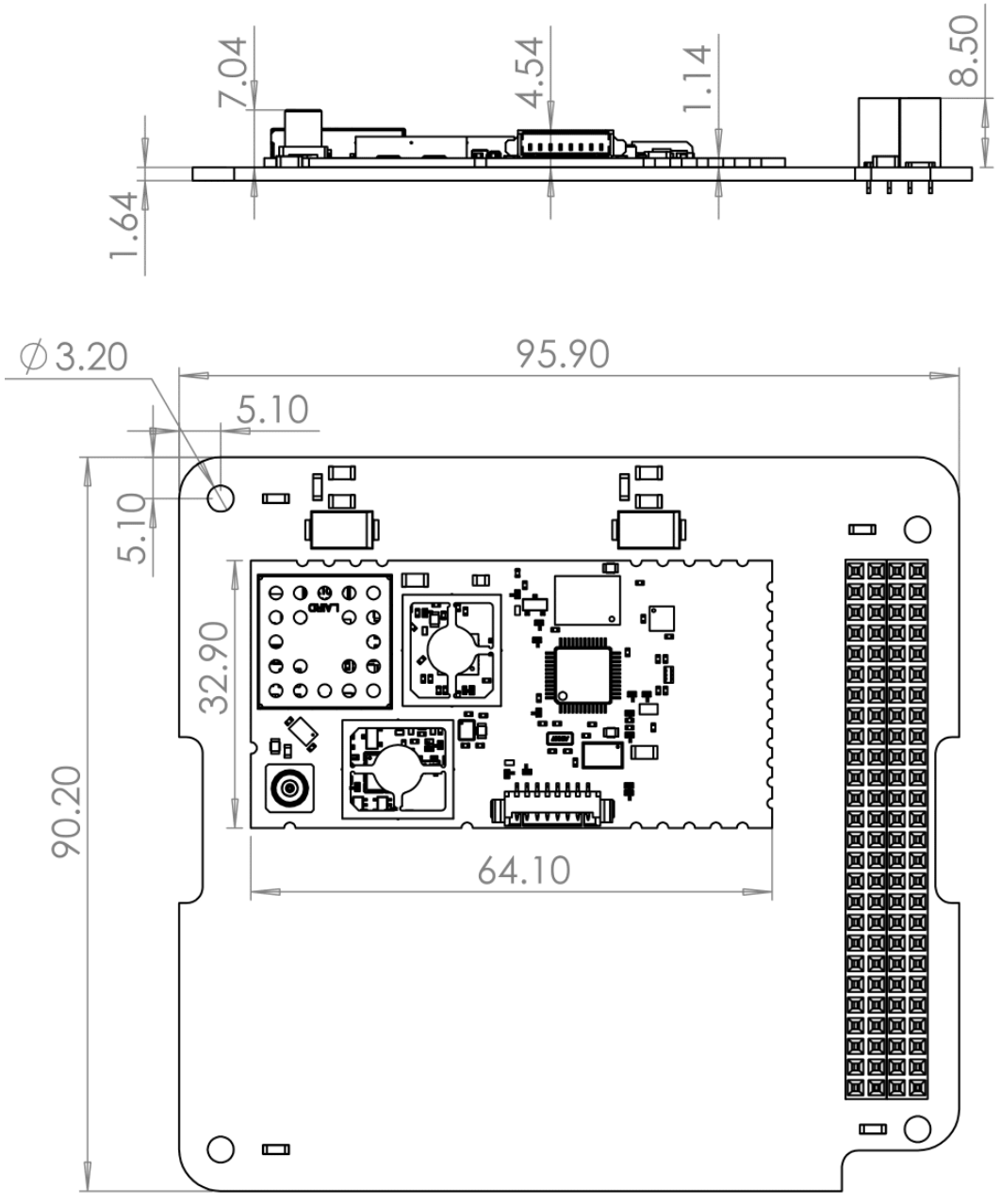


Figure 9. UHF Radio Dimensions, Mounted on a PC/104 Standard Complying PCB Board

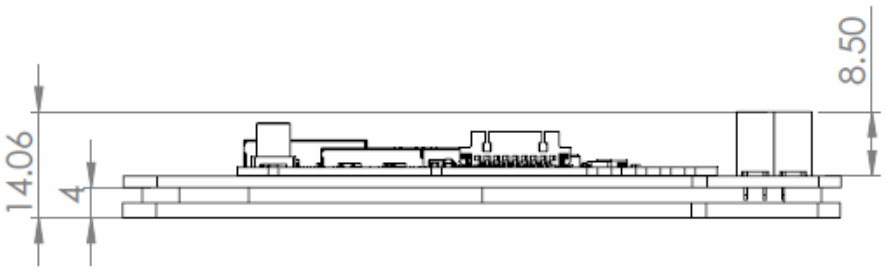


Figure 10. Physical Dimensions of the PCB with Heat Sink

7.2 Mechanical Specifications

Table 9 - Mechanical Specifications

Parameter	Value
Mass, UHF Stand-alone Radio	8 g
Mass, Radio Module Mounted on a PC/104 Board with a Heat Sink	60 g
PCB Material	FR-4 (E-glass/epoxy)
Heat Sink Material	Hard anodized aluminium
Assembly Level	IPC-A-610 Class 2

7.3 UHF Radio Footprints

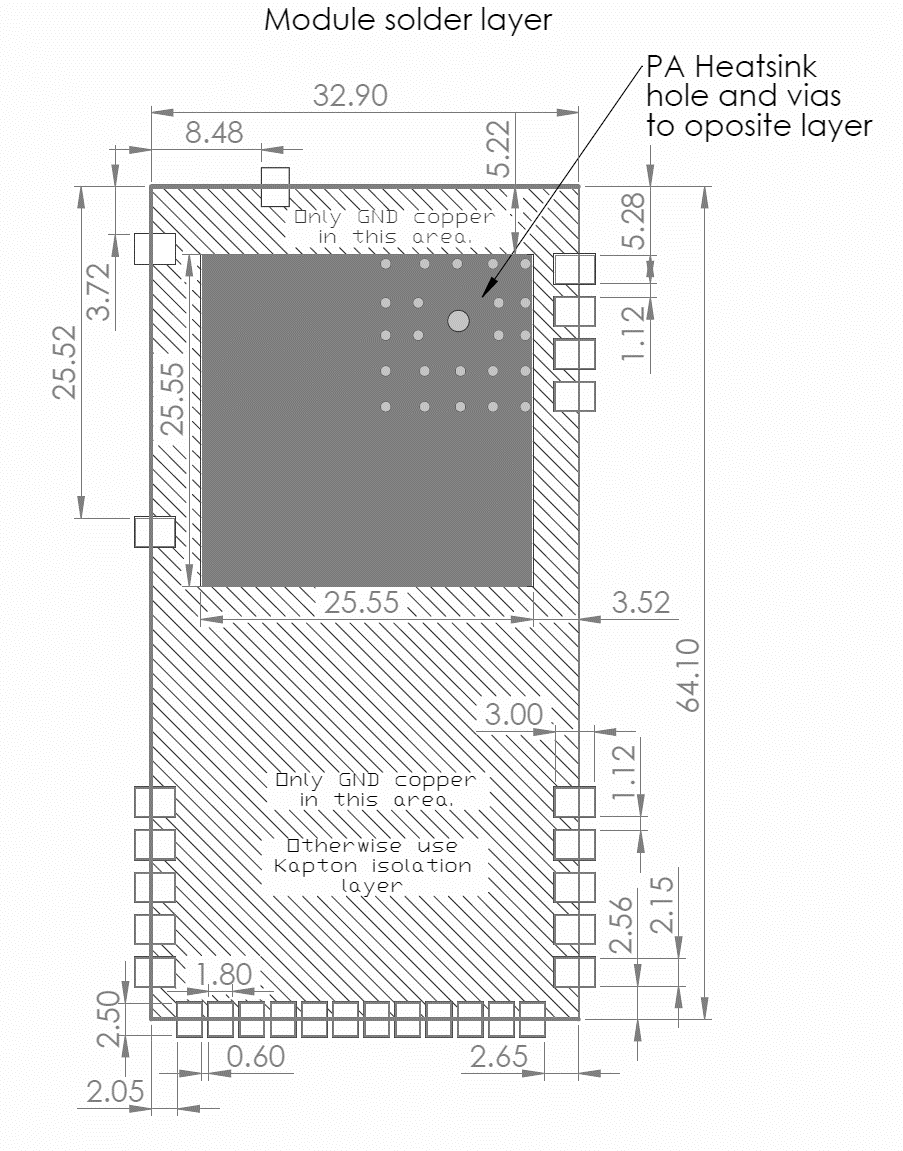


Figure 11. Module Solder Layer Footprint

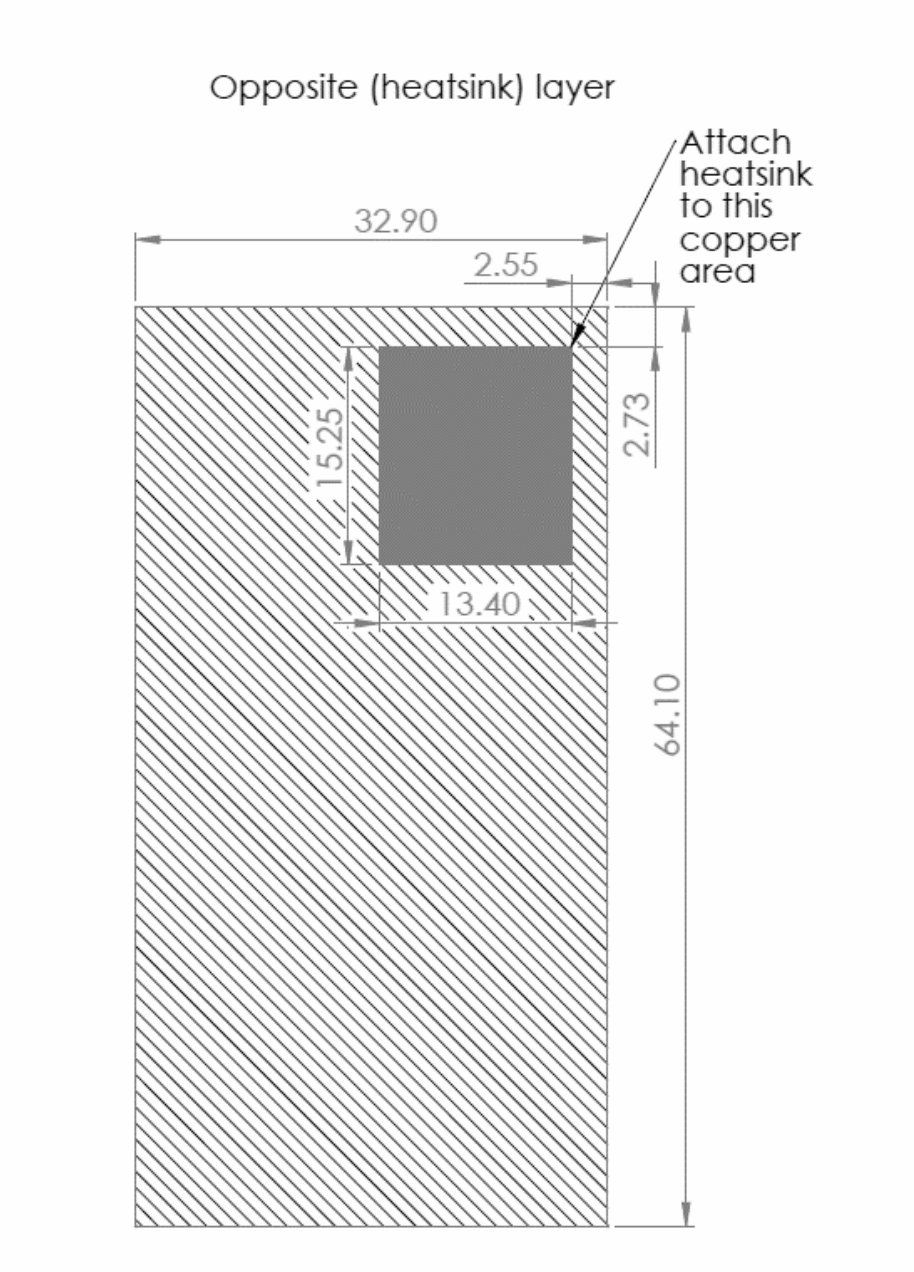


Figure 12. Opposite (heatsink) Layer Footprint

8 Handling Conditions

8.1 Protection for Electrostatic Discharge Sensitive (ESDS) devices

1. Work area:

- It is essential to handle ESDS devices at static-safe workstations. This will prevent yield loss (through catastrophic damage) or worse, potential reliability failures in the field (through latent damage).
- Where it is impractical or impossible to use antistatic wrist-straps or remove items that are composed of insulative materials at a static-safe workstation, use an air ionizer designed to neutralize electrostatic charges or apply topical antistats to control generation and accumulation of static charges.
- When an air ionizer is utilized, it is vital that maintenance procedures and schedules are adhered to in order to ensure that ions generated by the ionizer are sufficiently balanced.
- Avoid bringing sources of static electricity within 1 meter of a static-safe work bench.
- Where it is necessary to use air-guns, use special models that do not generate static charges in the air stream.

2. Personnel:

- Any accumulated charge on the body of the human operator should be discharged first before opening the protective container with ESDS devices inside. The discharge can be accomplished by putting a hand on a grounded surface or, ideally, by wearing a grounded antistatic wrist-strap.
- The use of an antistatic smock for each worker is highly recommended.

WARNING: Do not operate radio transmitter without antenna connected to the radio TX output port

Note: The impedance of the antenna must be 50 Ohms.

WARNING: Make sure the transceiver is cooled properly.

8.2 General Handling

Gloves (ESD compliant) should be worn when handling all flight hardware.

The COMM is robust and designed to withstand flight conditions. However, care must be taken when handling the device. Do not drop the device.

8.3 Shipping and Storage

The devices are shipped in anti-static packaging, enclosed in a Peli case. This case should be used for storage. All hardware should be stored in anti-static containers at temperatures between 20°C and 40°C and in a humidity-controlled environment of 40-60%rh.

9 Disclaimer

The information in this document is subject to change without notice and should not be construed as a commitment by NanoAvionics, LLC. NanoAvionics assumes no responsibility for any errors that may appear in this document.