Myriota Module M2-24

Maker's Guide

MYRIOTA-TEC-179

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Revision History

Rev	Date	Description of Change
1.0	February 2021	Initial version
1.1	February 2021	Updated with celltech Suggestions

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Table of Contents

1 - System Overview

The Myriota M2-24 Module (“the Module”) employs smart power features and onboard edge computing, combined with the super low bandwidth Myriota Network, to provide an ideal IoT communications solution for remote devices.

1.1 - Features

Exceptional Battery Life

- The Module predicts the location of satellites in the Myriota constellation, waking to transmit and receive only when a satellite is overhead
- Intelligent scheduling and specially designed radio waveforms ensure reliable delivery at minimum power

ARM Cortex-M4 core

- Energy efficient ARM Cortex-M4 with 32-bit RISC processor capable of 1.25 Dhrystone MIPS/MHz

Inter-Integrated Circuit Interface (I^2C)

- The Module acts as a master, and supports standard-mode, fast-mode and fast-mode plus speeds

Universal Asynchronous Receiver/Transmitter (UART)

- The Universal Asynchronous serial Receiver and Transmitter (UART) supports full- and half-duplex asynchronous UART communication. One UART supports hardware flow control

Serial Peripheral Interface (SPI)

- The Serial Peripheral Interface (SPI) acts as a master, and supports clock data rates up to 24MHz

Low Energy Universal Asynchronous Receiver/Transmitter (LEUART)

- The Low Energy UART enables two-way communication on a strict power budget. Only a 32.768 kHz clock is needed to allow UART communication up to 9600 baud/s
- The LEUART makes asynchronous serial communication possible with minimal software and energy consumption. The LEUART can wake the Module from sleep mode

Pulse Counter (PCNT)

— The Pulse Counter (PCNT) can be used for counting pulses on an input while the Module is in sleep mode. It can also wake up the Module from sleep mode when a prespecified number of pulses have been counted

Analog to Digital Converter (ADC)

— 12-bit ADC supporting VIO_REF, 2.5V or 1.25V as reference voltages

Pre-Programmed UART Bootloader

— The pre-programmed bootloader can be used to program the flash, retrieve Module information and dump logs

1.2 - Safety and Compliance

1.2.1 - FCC Compliance

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference, and

2. This device must accept any interference received, including interference that may cause undesired operation.

- This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. End users must follow the specific operating instructions for satisfying RF exposure compliance. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

- Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

1.2.2 - Industry Canada Compliance

English

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

French

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil

1.2.3 – Host Integration Compliance

2.2 This device was evaluated to, and complies with, FCC 47 CFR Part 25 Subpart C and ISED RSS-170

2.3 This device shall only be used in the manner intended to be used and in accordance with FCC 47 CFR Part 25 Subpart C and ISED RSS-170.

2.4 This device is certified as an FCC Single Modular Approval and ISED Modular Approval (MA)

2.5 See Section 2.5 for trace design considerations

2.6(1) This device is approved for use with mobile and fixed applications. The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20cm from all persons.

2.6(2) The *Host* manufacturer is required to provide the above information to the end user in their end-product manuals, except in accordance with the FCC and ISED change procedures.

2.7. This device is approved for mono-pole, folded mono-pole, normal-mode helix, folded, normal-mode helix, and loaded monopole antennas with a gain of 6dBi or less and must not transmit simultaneously with any other antenna or transmitter, except in accordance with FCC and ISED multi-transmitter product procedures. Use of any other antenna type or antenna gain exceeding 6dBi violates the conditions for which it was approved.

2.8 The *Host* manufacturer is required to identify the FCC ID and IC ID of this module on their host device, either a physical label or e-label, for example:

“Contains FCC ID: 2ATKL-M2-24”

“Contains IC ID: 25148L-M224”

2.9 Contact Myriota for Test-mode software options.

2.10 Approval is limited to OEM installation only. This device shall only be used in the manner intended to be used and in accordance with FCC 47 CFR Part 25 Subpart C and ISED RSS-170. Compliance of this device in all final host configurations is the responsibility of the Host Grantee. The *Host* manufacturer is responsible for compliance to any other FCC and ISED rules that apply to the *Host* that are not covered by the modular transmitter grant of certification. Additional guidance for testing host products is given in KDB Publication 996369 D04 Module Integration Guide and RSS-Gen.

2 - Physical Specification

The Myriota M2-24 Module is designed to, and must be installed within an enclosed host system. With appropriate external connections, the host system and host system enclosure can be designed to meet full transceiver regulatory tests.

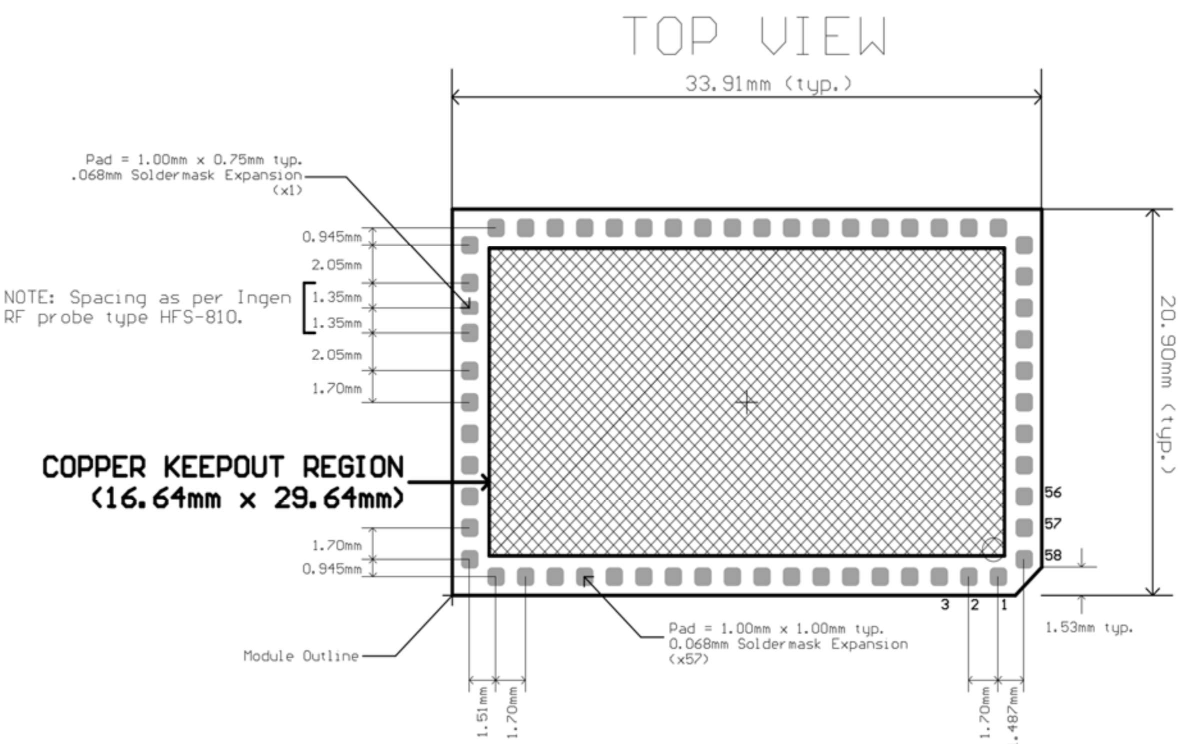
2.1 - Module Dimensions and Layout

The Myriota M2-24 Module dimensions and weight are outlined in Table 1, and in Figure 1 for illustrative purposes.

Table 1: M2-24 Module Dimensions and Approximate Weight

Length	33.91 mm
Width	20.90 mm
Depth	3.98 mm
Weight (appox.)	4 g

Figure 1: PCB Land Pattern



2.3 - Handling Information

Moisture Sensitivity Level (MSL): 3 per IPC/JEDEC standard J-STD-020.

Avoid washing as moisture can be trapped under the shield.

Electrostatic Discharge Caution: The module contains static-sensitive components and should be handled with care.

The following precautions are recommended to avoid static damage.

- Avoid touching pins. Always hold modules by its edges
- Handle modules in areas with adequate grounding
- Keep modules in trays/ESD bags until ready for assembly

2.4 - Soldering Information

The Myriota M2-24 is designed to be soldered in accordance with the latest IPC/JEDEC J-STD-020 recommendations for Pb-Free ánd Sn-Pb reflow soldering.

Follow the standard recommendations to avoid damage to the modules:

- Do not exceed peak temperature (Tp) of 250ºC
- Use solder paste with no clean flux
- Refer to solder paste datasheet for reflow profiles
- Avoid multiple reflows. For multiple reflow processes, solder module on the last reflow.

2.5 - PCB Layout Considerations

- The PCB trace connecting the Myriota Module's RF PORT to the antenna needs to be a controlled impedance, 50-ohm transmission line. Microstrip is recommended, but other types of transmission lines would be acceptable, depending on the trade-offs that are most important for a given application.
- The exact geometries of the 50-ohm microstrip depend on the characteristics of the PCB substrate that is being used in the application, i.e. laminate dielectric constant and thickness, copper weight/thickness, etc. Numerous online transmission line calculators are available that will be able to provide you with an estimate of the required microstrip geometries. The PCB fabrication house that you work with should be able to provide accurate microstrip geometries for your specific implementation.
- Use of multi-layer PCB is recommended for the application PCB. Multiple layers allow for a continuous RF reference (i.e. ground) plane to be provided underneath the Myriota Module, the RF interface between the Myriota Module's RF Port and the antenna.
- It is recommended that the PCB stack-up be arranged in a manner that places the RF reference ground plane on the internal copper layer adjacent to the layer in which the Myriota Module is mounted.
- It is desirable that the PCB stack-up be designed so that the laminate thickness between the internal RF reference plane and the microstrip traces on the outer layer realizes a microstrip trace width that is similar to the pad width of the size of the discrete components used. (i.e. 0402, 0603, etc.) Doing so will minimize the width transitions between the microstrip and component pads, thus keeping impedance anomalies to a minimum.
- For most applications, it should be possible to provide a functional PCB layout with a 4- or 6-layer PCB. For extremely cost-sensitive applications, it may be possible to use a 2-layer PCB, but it is not recommended.
- The RF port and antenna should be placed in a region of the PCB that is furthest away from possible noise sources on the application PCB. (i.e. clocks, digital buses, switching power supplies, etc.)
- Do not route any noise signal or power traces near the RF Port to Antenna interface region.
- The RF Port of the Myriota Module should be placed as close to the antenna as is practical to minimize RF signal losses.
- If using a multi-layer PCB, it is advisable to bury noisy signal or power traces on internal layers of the PCB and sandwich them between solid GND planes to provide shielding.

- Ground pads of the Myriota Module should be connected directly to the ground reference plane with the ground vias placed as close to the Myriota Module pads as is practical.
- Power supplied to the Myriota Module should be clean and isolated from potential noise sources originating from the application circuitry. This can be achieved through the use of filters or linear regulation in the power feed to the Myriota Module.
- The power source supplying the Myriota Module must have sufficient current sourcing capability to satisfy the Myriota Module's maximum specified current draw, as specified in the Myriota Module Data Sheet, plus some additional margin for good design practice.
- On the same layer that the Myriota Module is mounted, do not place any copper (i.e. traces, vias, pours) in the Copper Keepout Region. It is however recommended to place an RF ground reference plane underneath the Myriota Module on the next adjacent layer of the PCB.
- Make sure that the antenna that you have selected is nominally matched to 50-ohms at the frequency band that the Myriota Module is operating. If you are not certain how to do this, seek design assistance from an RF or antenna design engineer. A good antenna match is critical to the performance of the Myriota Module’s transceiver and should not be overlooked.
- If the radio contains multiple transceivers or receivers that could potentially be active at the same time, make sure to space their antennas as far apart as is practical in order to minimize the coupling between antenna elements. To further mitigate interference between these radio devices, RF filtering and shielding should be considered to mitigate unwanted signals in the frequency bands of interest.

2.6 - General Environmental Characteristics

Table 2: General Environmental Characteristics.

Parameter	Minimum	Typical	Maximum	Unit
Operating temperature	-30	-	70	ºC
Storage temperature	-55	-	150	ºC

3 - Electrical Information

Typical Values

The typical data are based on ambient temperature T_{AMB} = 25°C and power supply voltage VEXT = 3.6 V.

Absolute Maximum Ratings

The absolute maximum ratings are stress ratings, and functional operations under such conditions are not guaranteed. Stress beyond the limits specified in the table below may affect device reliability or cause permanent damage to the device.

3.1 - Block Diagram

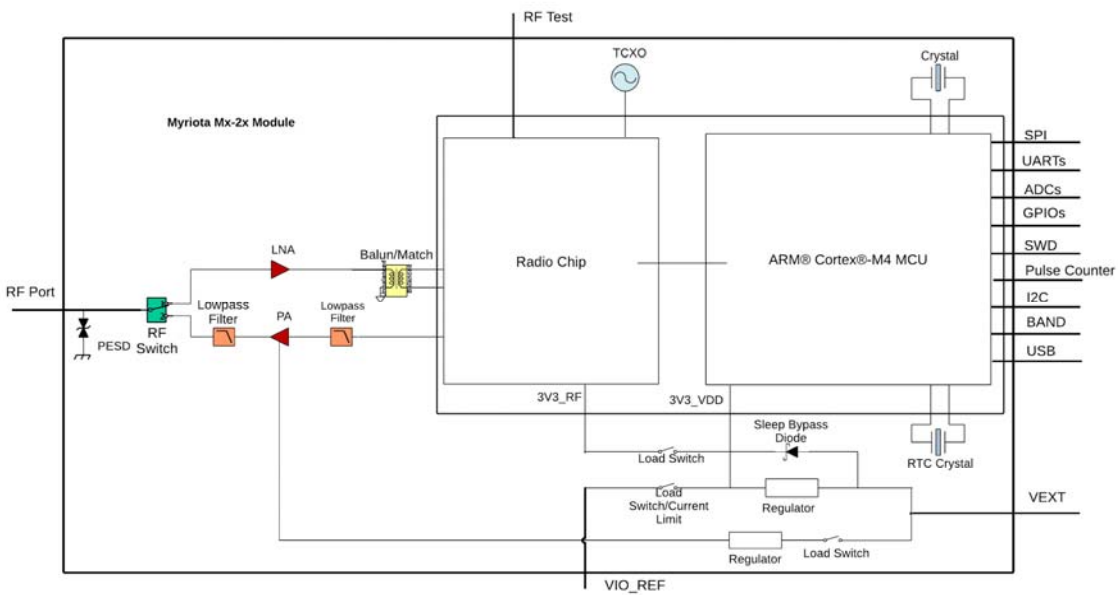


Figure 2: A simplified block diagram of the Myriota Mx-2x series.

3.2 - Module Pin Assignment

The Myriota M2-24 Module features 58 pins, as depicted in Figure XX, and Table XX.

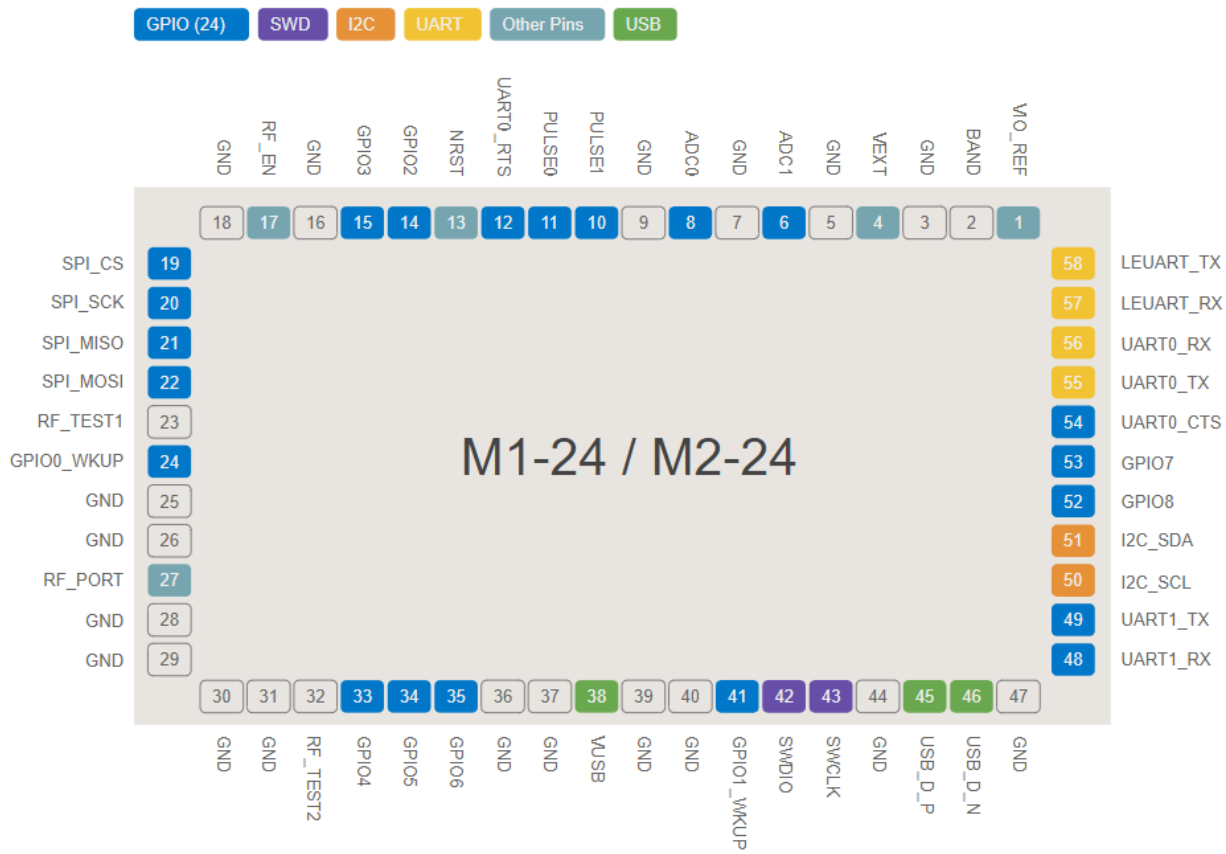


Figure 3: M2-24 Module Pin Assignment

Table 3: Pin Descriptions

Number	Name	Description / Alternative Functionality
1	VIO_REF	Voltage reference output for all external devices
2	BAND	Read-only, do not connect. High on M1 variant and low on M2 variant
3	GND	Ground
4	VEXT	Power supply
5	GND	Ground
6	ADC1	ADC port 1. GPIO
7	GND	Ground
8	ADC0	ADC port 0. GPIO
9	GND	Ground
10	PULSE1	Pulse counter. GPIO
11	PULSE0	Pulse counter. GPIO
12	UART0_RTS	UART0 RTS. GPIO
13	NRST	Reset input, active low. Drive NRST low to reset. An internal pull-up ensures that NRST is released
14	GPIO2	GPIO
15	GPIO3	GPIO
16	GND	Ground
17	RF_EN	Output only. High when radio is enabled and low when radio is disabled
18	GND	Ground
19	SPI_CS	SPI chip select. GPIO
20	SPI_SCK	SPI SCLK. GPIO
21	SPI_MISO	SPI MISO. GPIO
22	SPI_MOSI	SPI MOSI. GPIO
23	RF_TEST1	Reserved, do not connect
24	GPIO0_WKUP	GPIO. Can wake the Module from sleep mode
25	GND	Ground

26	GND	Ground
27	RF_PORT	RF port for both input and output
28	GND	Ground
29	GND	Ground
30	GND	Ground
31	GND	Ground
32	RF_TEST2	Reserved, do not connect
33	GPIO4	GPIO
34	GPIO5	GPIO
35	GPIO6	GPIO
36	GND	Ground
37	GND	Ground
38	VUSB	USB 5.0 V VBUS input. Reserved, do not connect
39	GND	Ground
40	GND	Ground
41	GPIO1_WKUP	GPIO. Can wake up the Module from sleep mode
42	SWDIO	Debug-interface Serial Wire data input / output with built-in pull up
43	SWCLK	Debug-interface Serial Wire clock input with built-in pull down
44	GND	Ground
45	USB_D_P	USB D+ pin. Reserved, do not connect
46	USB_D_N	USB D- pin. Reserved, do not connect
47	GND	Ground
48	UART1_RX	UART1 RX, input. GPIO
49	UART1_TX	UART1 TX, output. GPIO
50	I2C_SCL	I^2C SCL with built-in 2.2kOhm pull up. External pull up is not recommended
51	I2C_SDA	I^2C SDA with built-in 2.2kOhm pull up. External pull up is not recommended
52	GPIO8	GPIO

53	GPIO7	GPIO
54	UART0_CTS	UART0 CTS. GPIO
55	UART0_TX	UART0 TX, output. Bootloader TX
56	UART0_RX	UART0 RX, input. Bootloader RX
57	LEUART_RX	LEUART RX, input
58	LEUART_TX	LEUART TX, output

3.3 - Power Consumption

The Module is designed with a very low power consumption profile, and is designed to attain multi-year battery life with two “AA" battery cells. Table XX lays out the power consumption for the Module.

Table 4: Specific average power consumption measured at 25ºC

Mode	3V	3.3V	3.6V	Unit
Sleep	1.4	1.5	1.6	uA
Sleep with Pulse Counter enabled	1.9	2.0	2.1	uA
Sleep with LEUART enabled	2.0	2.1	2.2	uA
MCU Processing	22	19	17	mA
Receive	37	35	32	mA
Transmit	640	570	510	mA

3.4 - Electrical Specifications

The electrical parameters for the Module are detailed in the tables below.

Table 5: General Operating Conditions

Parameter	Minimum	Typical	Maximum	Unit
Operating temperature	-30	-	70	ºC
Clock frequency	-	-	48	MHz
VEXT	3.0		3.6	V
VIO_REF (non sleep mode)	-	3.3	-	V
VIO_REF (sleep mode)	-	VEXT-0.2	-	V
VIO_REF output current			100	mA

Table 6: General Purpose Input Output

Parameter	Minimum	Typical	Maximum	Unit
Input low voltage	-	-	0.30 VIO_REF	V
Input high voltage	0.7 VIO_REF	-	-	V
Output high voltage	0.8 VIO_REF	-	-	V
Output low voltage	-	-	0.25 VIO_REF	V
Input leakage current	-	±0.1	±100	nA
I/O pin pull-up resistor	-	40	-	kOhm
I/O pin pull-down resistor	-	40	-	kOhm

Table 7: Analog Digital Converter (ADC)

Parameter	Minimum	Typical	Maximum	Unit

Input voltage range	0	-	Reference voltage	V
Resolution	-	12	-	bit
Input capacitance	-	2	-	pF
Input ON resistance	1	-	-	MOhm
Input RC filter resistance	-	10	-	kOhm
Input RC filter/decoupling capacitance	-	250	-	fF
ADC Clock Frequency	-	13	3	MHz
Conversion and acquisition time	87	-	-	ADCCLK Cycles
non-linearity (INL)	-	±1.2	±3	LSB
Offset voltage	-3.5	0.3	3	mV

Table 8: I²C

Parameter	Minimum	Typical	Maximum	Unit
SCL clock frequency	0	-	100	kHz
SCL clock low time	4.7	-	-	us
SCL clock high time	4.0	-	-	us
SDA set-up time	250	-	-	ns
SDA hold time	8	-	3450	ns
Repeated START condition set-up time	4.7	-	-	us
(Repeated) START condition hold time	4.0	-	-	us
STOP condition set-up time	4.0	-	-	us
Bus free time between a STOP and a START condition	4.7	-	-	us

Table 9: Temperature Sensor

Parameter	Minimum	Typical	Maximum	Unit
Measurement range	-30	-	+70	ºC
Accuracy	± 2	-	-	ºC

Table 10: Test Conditions

Parameter	Minimum	Typical	Maximum	Unit
Storage temperature	-55	-	150	ºC
External supply voltage (VEXT)	0	-	3.6	V
Voltage on any I/O pin	-0.3	-	VIO_REF+0.3	V

4 - Radio Elements

4.1 Operational Frequencies

The Myriota M2-24 variant module transmits and receives on UHF. A single antenna can be used to provide both channels.

Table 11: Operational Frequencies.

	Frequency
UHF Transmission	399.9 - 400.05 MHz
UHF Receive	400.15 - 401 MHz

4.2 - Antenna Connection

This Module has no integrated connector. All RF activity is operated over Pin 27. Methods by which a temporary may be used for testing are detailed in Section 4.2, but by no means should be integrated with a final product.

4.3 - Antenna Integration

General considerations

When integrating your antenna, the following guidelines should be followed to ensure the design achieves the highest possible system performance.

- The sum of all losses from transmission lines or components in the signal path between the module and an antenna must be less than 1 dB
- Keep transmission lines and cables as short as possible. The number of RF connectors in the signal path should also be minimised.
- Minimise the length of micro-striplines on multi-layered or thin FR4 substrates. The commonly used 3 mm wide track on a 1.6 mm FR4 substrate has 1.5 dB/m loss. In comparison, a thinner 0.7 mm track, 0.36 mm substrate layer arrangement can have 2.5 dB/m. Avoid using PCB vias in the signal path.
- If a matching network is required for the antenna use low-loss inductors or, if possible, avoid inductors altogether. Inductors with high quality factor (Q), and low DC resistance

(DCR) from Taiyo Yuden are a good choice. The inductor’s self resonant frequency (SRF) should be higher than the operating frequency. An example of a 120 nH inductor is HK1005R12J-T. Its specifications are: DCR=1.6 Ohm; Q=8 @ 100 MHz; SRF=600 MHz. Q scales approximately by $\sqrt{f}$, so in this example the inductor would have a Q of about 16 at 400 MHz.

- Often an RF connector is added to assist testing or developing a PCB. In cases where the RF connector is permanent, use of an inline-type connector eliminates the need for a 0R resistor to switch the signal path. If a 0R resistor is used to switch the signal path to a test RF connector, arrange the circuit such that the switch resistor is normally not loaded in order to connect the module to an embedded antenna.
- Figure XX below shows an example use of a temporary RF connector which can be loaded on the PCB as required. The component footprint could be one component of the matching network of an embedded antenna, removed as required to isolate the embedded antenna. In this way a series 0R resistor is eliminated in the signal path.

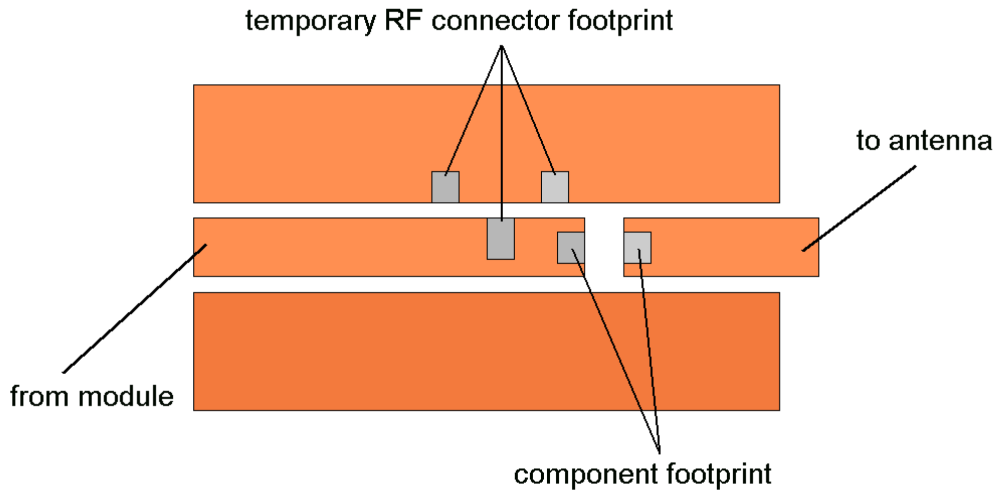


Figure 4: Example use of a temporary RF connector

4.4 - Antenna Requirements

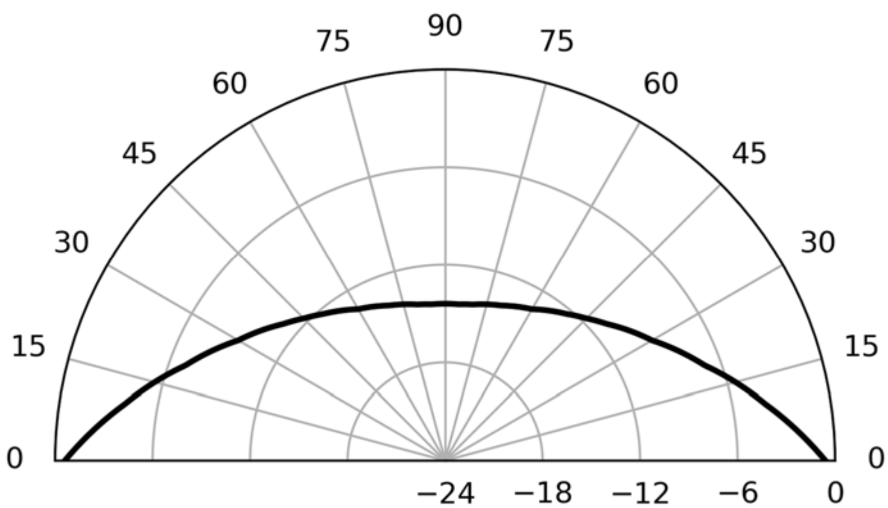
The following sections define the network requirements on both the transmit and receive antennas for the M2-24 Myriota Module. The requirements are defined in terms of recommended antenna gains, assuming the device has clear sky view in all directions.

An antenna that exceeds the recommended gain requirement will result in increased performance of your device. Likewise, an antenna that has less gain will result in reduced device performance.

UHF Transmit & Receive

Requirement

A UHF antenna with a gain versus elevation pattern as shown below will result in the recommended minimum signal strength at the ground receiver.



Elevation (deg.)	0	5	10	20	30	40	45	50	60	70	80	85	90
Required Gain (dBi)	-1	-2	-4	-7	-9	-11	-12	-12	-13	-14	-14	-14	-14

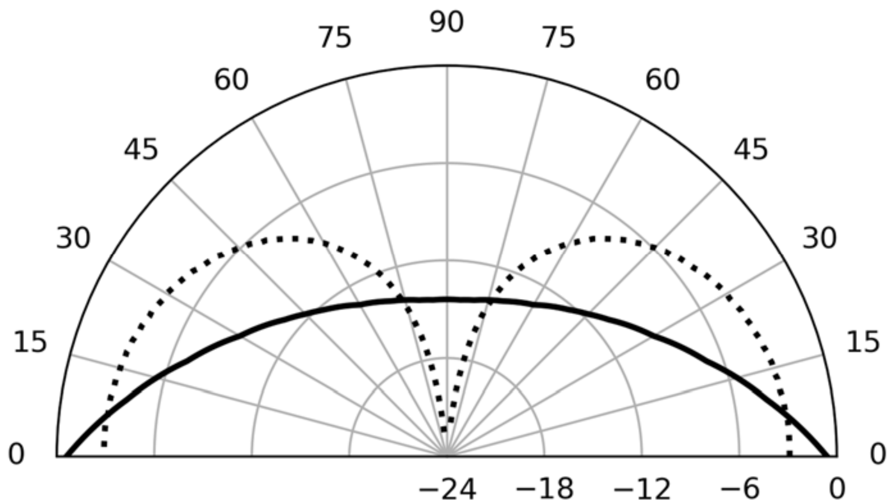
Figure 5 & Table 12: Required UHF Antenna Gain (dBi) vs Satellite Elevation (deg.)

Example Use Case

A second example shown in the graph below provides an analysis of the suitability of a UHF antenna for both transmit and receive use on the Myriota Network. The gain of the example antenna (dashed line) is plotted alongside the UHF antenna requirement (solid line).

Comparing the gain of the antenna to the recommended minimum, you can see that it either meets or exceeds the requirement at mid elevations, with diminished performance at high and very low elevations. Again this is representative of the characteristics expected from an electrically small monopole with vertical polarisation.

Depending on system requirements, the reduced performance at high and very low elevations can be considered acceptable.



Elevation (deg.)	0	5	10	20	30	40	45	50	60	70	80	85	90
Example Gain (dBi)	-3	-3	-3	-3	-4	-5	-6	-7	-9	-12	-18	-24	-38
Required Gain (dBi)	-1	-2	-4	-7	-9	-11	-12	-12	-13	-14	-14	-14	-14
Margin (dB)	-2	-1	1	4	5	6	6	5	4	2	-4	-10	-24

Figure 6 & Table 13: Antenna Gain (dotted) vs UHF Antenna Requirement (solid)

4.4 - RF Characteristics

Table 14 lays out the RF characteristics of the Module.

Table 14: Radio Characteristics.

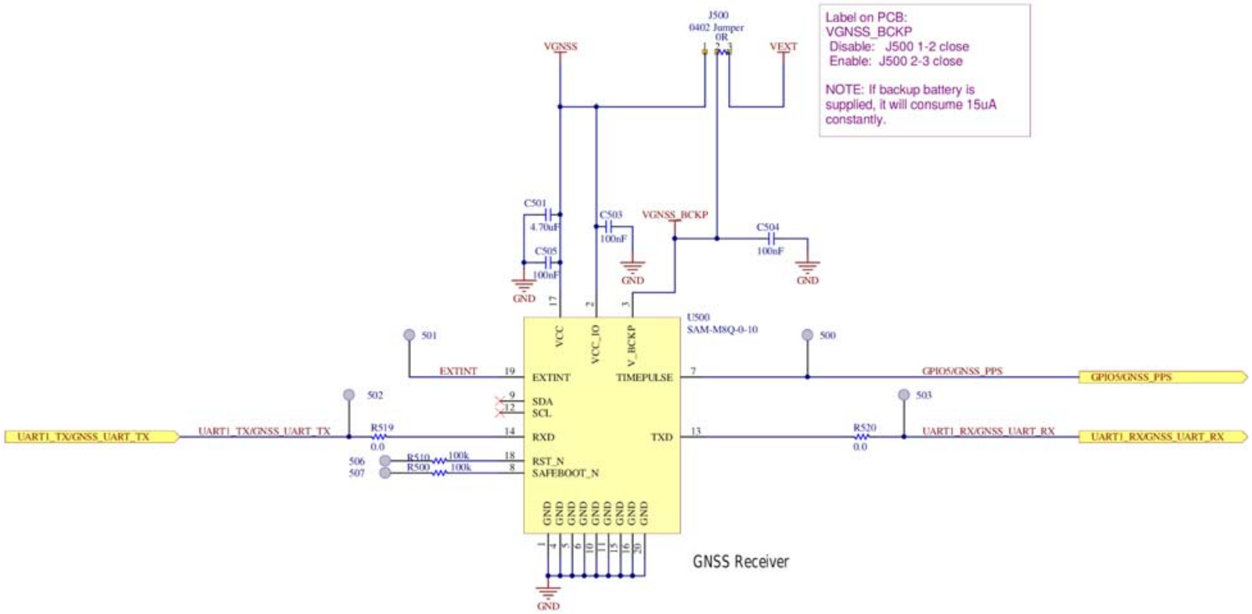
Parameter	Minimum	Typical	Maximum	Unit
Transmission duration		260		ms
Transmission interval	5			s
UHF TX frequency	399.9	-	400.05	MHz
UHF RX frequency	400.15	-	401	MHz
LPD frequency	433	-	435	MHz
UHF output power	-	-	28	dBm
LPD output power	-	-	14	dBm

4.5 - GNSS (Global Navigation Satellite System)

The Myriota Module requires an external GNSS device for normal operations. Currently, all uBlox™ M8 chips are supported via UART1. The following figure shows an example of using the SAM-M8Q-0-10 GNSS module[1].

[1] Datasheet Available here:
https://www.u-blox.com/sites/default/files/SAM-M8Q_DataSheet_%28UBX-16012619%29.pdf

Figure 15: The SAM-M8Q-0-10 GNSS module



The SAM-M8Q-0-10 module has a backup voltage supply (V_BCKP). When the power supply to the module is off, V_BCKP supplies the real-time clock (RTC) and battery-backed RAM (BBR).

Use of valid time and the GNSS orbit data at start-up will improve the GNSS performance, i.e. hot starts and warm starts.

If no backup battery is connected, the module performs a cold start at power-up. It is important to note that connecting the V_BCKP pin to a permanent supply will consume an extra 15uA of sleep current.

For a detailed description of integrating the GNSS module please refer to the SAM-M8Q Hardware Integration Manual[2].

[2] Available Here: https://www.u-blox.com/sites/default/files/SAM-M8Q_HardwareIntegrationManual_%28UBX-16018358%29.pdf

5 - Getting Started

Visit the Myriota Developer Site

Once you are ready to begin developing the software for the Module, head over to the Myriot Developer Site at: https://developer.myriota.com/

Figure XX: The Myriota Developer Site