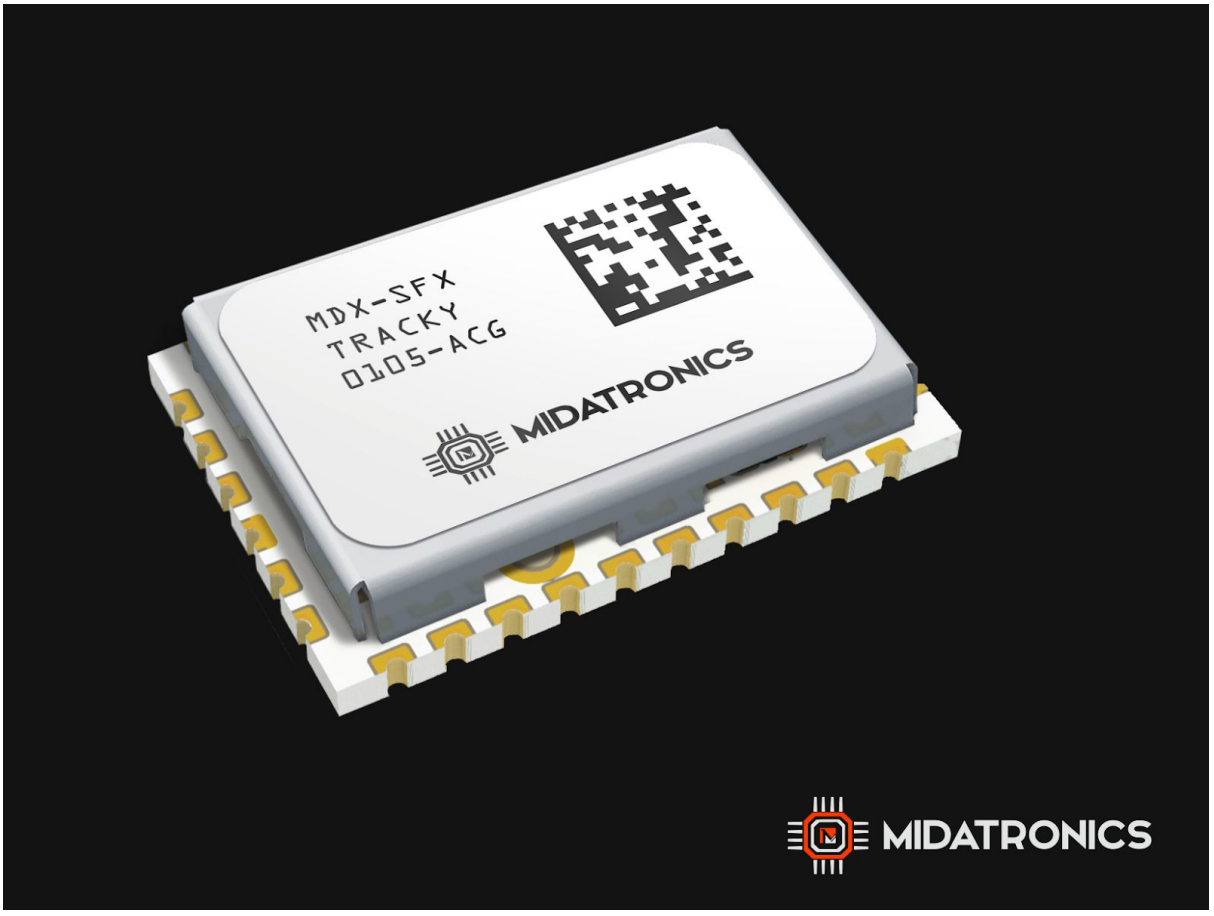

TRACKY MODEM

User's Guide

MDX-SFXMx-01 : Tracky

Outline

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Revisions

REVISION	DATE	DESCRIPTION	STATUS	AUTHOR	REVISER
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Disclaimer

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1 Introduction

1.1 Description

This document describes the Tracky Modem module.

The Tracky Modem is an IoT Sigfox Certified communication module based on ST Microelectronics STM32L0 MCU and S2-LP high performance ultra-low power RF transceiver, intended for RF wireless applications in the sub-1 GHz band. The module is designed to operate in both the license-free ISM and SRD frequency bands at 433, 512, 868 and 920 MHz.

The Sigfox protocol stacks is loaded on the STM32L0 low power MCU based on Cortex M0+ core.

Communication with external device through UART with or without RTS/CTS hardware handshaking.

Main features:

- Sub-1 GHz transceiver supporting Sigfox protocol
- Ultra Low Power Platform
- Power Consumption in Low Power Mode: 1 µA
- Power Consumption in Run mode: 2 mA
- Sigfox ready compliant

Quick Specification:

- Excellent receiver selectivity (> 80 dB @ 2 MHz)
- Excellent performance of receiver sensitivity: down to -130 dBm
- Programmable RF output power up to +16 dBm
- Operating temperature range: -40 °C to +85 °C
- Dimensions: 17 x 11.5 mm
- Interface: UART optional RTS/CTS handshaking
- Supply Voltage: 1.8 to 3.6 Vcc
- Certification : CE, FCC,RoHS and Sigfox ready

2 System Overview

2.1 Sigfox LPWAN

From : https://ubidots.com/blog/explaining-sigfox/

Sigfox is a Low Power Wide Area Network (LPWAN) technology specially designed for the Internet of Things. Devices connected using SigFox consume **little power** and operate over **large distances** compared to WiFi and Bluetooth connection protocols which consume *more* power and work best in short range. The chronology of a SigFox application follows these three basic steps:

1. Numerous objects (devices) connected to the Internet send data through the SigFox network to a SigFox base station (gateway).
2. The base station then detects, demodulates, and reports the messages to the SigFox cloud across 3 channels, at least every 10 minutes.
3. The SigFox cloud then pushes these messages to many customer servers and IoT platforms based on the client's application.

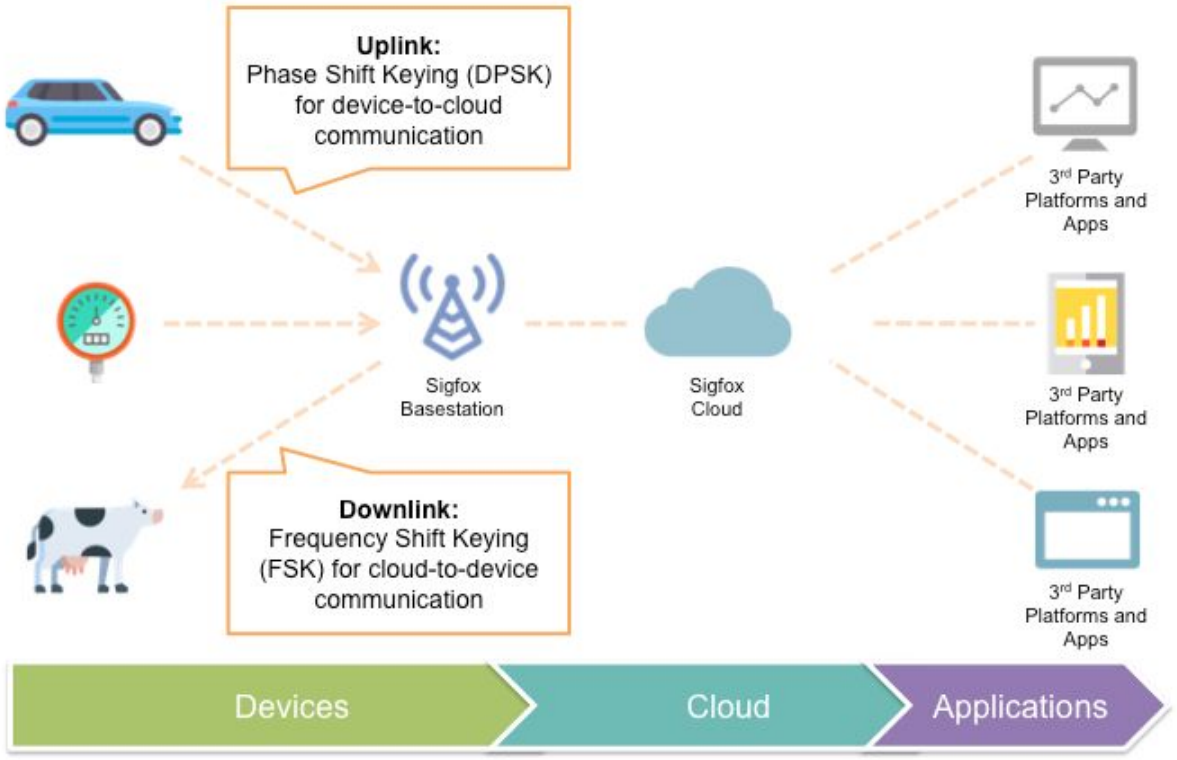
Technically, the SigFox network differs from other LPWAN networks in the methods it sends data and the electrical guidelines that govern the quantity, speed, and duration of the data being sent. SigFox is most used for **low-power** applications that only require sending **small amounts of data, infrequently, over large distances**. Perfect for Agro environments and asset management across vast distances.

2.1.1 How Sigfox works?

The SigFox network consists of these *elements*:

- Objects (devices)
- Base stations (gateways)
- Cloud (internet)

The diagram below illustrates the key *elements* of data transmission via SigFox:



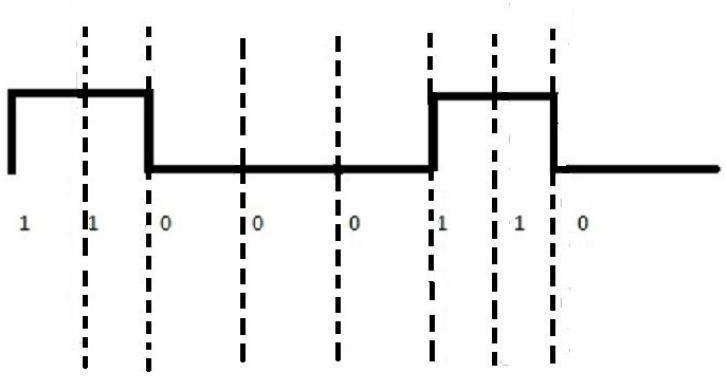
DPSK is a method used by base stations (gateways) to convert a signal, debug it, and forward to the cloud for processing.

SigFox data transmission can be better understood as follows: Objects (devices) are connected to the internet using the SigFox network. The object can be a temperature, humidly, and/or saturation (etc.) sensors located within 1,000 meters of a base station (gateway).Sigfox uses **Phase Shift Keying (DPSK)** for device-to-cloud communication, or "uplink", and **Frequency Shift Keying (FSK)** for cloud-to-device communication, or "downlink".

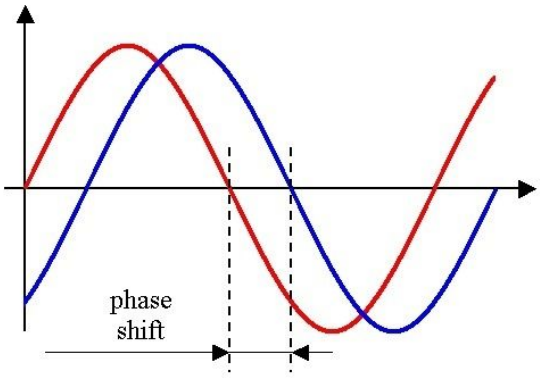
2.1.2 What is DPSK?

DPSK is a method used by base stations (gateways) to *convert* a signal, *debug* it, convert it back to be sent to the cloud. When a signal travels from a device to a base station, it inevitably encounters interference from the environment (think rain or dense forests). Interference is universal; any signal from any internet network will become impaired and look slightly different upon reaching its destination. SigFox alleviates this problem by utilizing DPSK. The role of DPSK is to make sure that the signal that leaves the base station is the same exact signal that left the device. The base station hardware accomplishes this by shifting the signal's phase to discover and eliminate impairments. SigFox hardware at the base stations accomplishes this by:

1. Object sends data to the base station in the form of digital bits. A "high" pulse occurs when there's a 1, and a "low" pulse occurs when there's a 0. Here is an input digital bit stream 1 1 0 0 0 1 1 0:



2. This bit stream is then converted into a *different* sequence of 1's and 0's as it passes through the demodulator circuit. The new sequence is not arbitrary, rather carefully calculated using sophisticated hardware. The purpose of this conversion is to prepare the signal for electrical analysis. Whenever the state of the input signal goes from high to low (1 to 0), the hardware shifts the phase of the signal. To phase shift, a signal simply means to impose a time gap between the signal's original and new paths. Once the phase is shifted, a signal will either lag/lead where the original path once was:



3. The more a signal at the base station becomes phase shifted, the more exposed its impairments become. Analogously, the more frequent an injured person visits the hospital, the more X-rays the doctors take to better understand and correct the injury. When a signal is "injured" from the environment, the injury is not noticeable until the signal is phase-shifted and run through the "X-ray" circuitry which analyzes these phase shifts, discovers where the impairments exist, and subsequently "cleans" the data for transmission. In summary, the base station hardware shifts the phase in order to take an "X-ray" of the data to diagnose what interference/impairments exist and how it is to be corrected.

4. Following the phase, the hardware circuitry converts the original signal back to its basis sequence, but without the impairments.

When the cloud receives an uplink signal from the base station, it will respond with a downlink signal to the device. Downlink signals use Frequency Shift Keying.

2.1.3 What is Frequency Shift Keying?

Frequency Shift Keying (FSK) is similar to Differential Phase Shift Keying (DPSK) in the sense that both processes convert the input signal, analyze/discover impairments, eliminate them, and convert the data back to the original signal. However, instead of shifting and analyzing the phase, FSK shifts and analyzes the frequency. Just like phase shifts in DPSK, the frequency shifts in FSK expose the signal's impairments where sophisticated circuitry can debug them. The outstanding question now becomes, why does SigFox use DPSK for uplink transmission and FSK for downlink?

1. DPSK is more bandwidth efficient than FSK so it has fewer frequencies and channels available to transmit the signal.
2. Less "space" to transmit the signal = lower data rate and throughput
3. Lower data rate = more sensitive receiver (like a base station) of the signal
4. Higher sensitivity = more achievable range. ie. data from sensor devices can be detected from farther away.
5. Uplink signals typically encounter more interference than downlink signals, so having a narrow bandwidth in DPSK = power is more concentrated = more robustness to interference
6. Since interference is not as big as a concern for downlink, downlink signals are more focused on reaching as many applications as efficiently as possible. In FSK, more bandwidth = more space to send a signal = more reachable applications

2.1.4 Conclusion

The technology used by SIGFOX contributes a long-range, low-power, low throughput communications network with excellent protection from environmental interference allowing data to reach many applications effectively. SIGFOX is still in the "early adopter stage" for connectivity solutions; however, there are already many millions of connected devices around the world with Sigfox technology proving it has the potential to provide a cost-effective solution in a variety of markets and industries.

2.2 S2-LP ULP Transceiver

STMicroelectronics S2-LP Ultra-Low Power, High Performance, Sub-1GHz Transceivers are designed for RF wireless applications. The S2-LP Transceivers operate in the license-free ISM and SRD frequency bands at 433MHz, 512MHz, 868MHz, and 920MHz. The Transceivers can also be programmed to operate at other additional frequencies in the 413MHz to 479MHz, 452MHz to 527MHz, 826MHz to 958MHz, and 904MHz to 1055 MHz bands.

The S2-LP supports the 2(G)FSK, 4(G)FSK, OOK, and ASK modulation schemes. The air data rate is programmable from 0.1kbps to 500kbps. The S2-LP Transceiver can be used in systems with channel spacing down to 1kHz enabling the narrow band operations.

The S2-LP shows an RF link budget higher than 140dB for long communication ranges and meets the regulatory requirements applicable in territories worldwide, including Europe, Japan, China, and the USA.

For more informations on S2-LP visit the following site:

https://www.st.com/b/en/wireless-transceivers-mcus-and-modules/s2-lp.html

2.3 Block Diagram

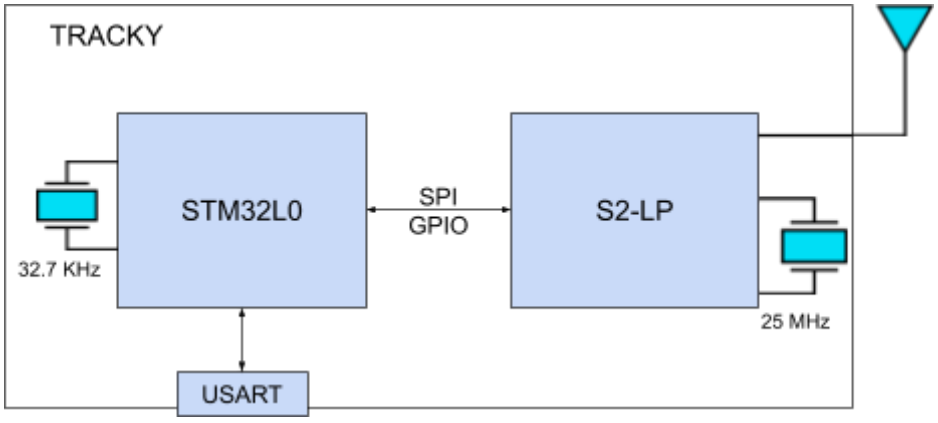


Figure 2. Tracky Module Block Diagram

The Tracky module is composed by:

- STM32L0 low power MCU
- S2-LP Transceiver
- 32.768 KHz Quartz
- 25 MHz Quartz

The STM32L0 MCU controls the S2-LP module using an SPI serial communication channel and a set of 4 GPIOs .

The Tracky module communicates with external microcontroller/microprocessors using an USART with optional RTS/CTS hardware handshaking.

Details of the communication protocol in "Serial Protocol Communication Manual".

The external antenna must be connected following instructions in "Board Layout - Mounting Suggestions" paragraph.

3 Connectors

The following picture shows the connectors of the Tracky Module.

3.1 Tracky Module

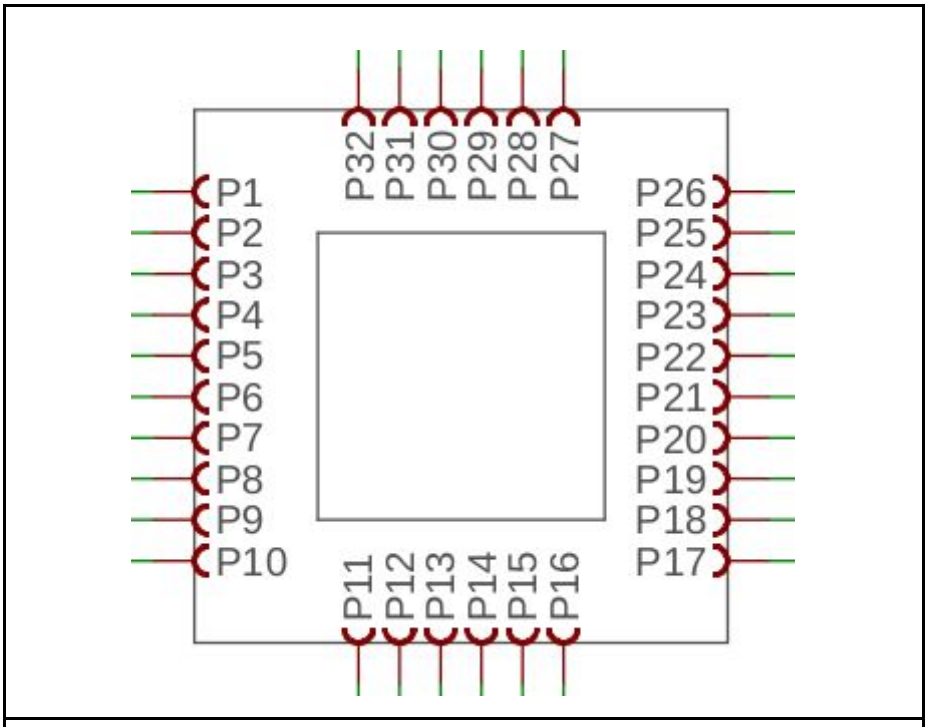


Figure 3. Tracky Module Pinout

3.2 Tracky Pinout

Tracky Pin	MCU pin	MCU Pin		STM32L07xxx I/O
P1		GND	S	
P2		GND	S	
P3			O	ANTENNA CONNECTION
P4		GND	S	
P5		GND	S	
P6	19	PA9	O	**USART1_TX, connect to external MCU serial RX**
P7	20	PA10	I	**USART1_RX, connect to external MCU serial TX**
P8	21	PA11	I	**USART1_CTS, connect to external MCU RTS, if not used connect to gnd**
P9	22	PA12	O	**USART1_RTS, connect to external MCU CTS, if not used connect leave unconnected**
P10	23	PA13	I/O	SWDIO, if not used leave unconnected
P11	25	PA14	I/O	SWCLK, if not used leave unconnected
P12	28	PB6	I/O	RESERVED, leave unconnected
P13	29	PB7	I/O	RESERVED, leave unconnected
P14	30	BOOT0	I/O	BOOT0, internally pulled down, if not used connect leave unconnected
P15		VDD_MCU	s	**VDD, VDDIO2**
P16		GND	S	
P17	27	PB5	I/O	RESERVED, leave unconnected
P18	26	PB4	I/O	RESERVED, leave unconnected
P19	3	NRST	I/O	Negative Reset, internally pulled up, if not used connect leave unconnected
P20		AGND	S	AGND
P21		VDDA	S	VDDA
P22	1	VDD	S	S2-LP VDD_SMPS, VDD_ANA, VDD_TX, VDD_DIG

P23	6	PA0	I	**SYS_WKUP1, wakeup on rising edge, if not used connect to gnd**
P24	7	PA1	O	**ACTIVITY LED, if not used leave unconnected**
P25		GND	S	
P26		GND	S	

Table 1. Tracky Pinout

Legend:

I/O Input/Output pin

S Supply Pin

4 Usage

This chapter describes how to connect, configure and interact with the Tracky module.

4.1 Power Supply

Tracky module is powered by:

- VDD_MCU pin, power for STM32L0 MCU from 1.65 V to 3.6 V
- VDD pin, power for S2-LP module, from 1.8 to 3.6 V
- VDDA pin, analog power supply and positive reference voltage for the ADC, $V_{DDA} \geq V_{DD}$.

  VDDA is the external analog power supply for A/D converters, D/A converters, voltage reference buffer, operational amplifiers and comparators. The VDDA voltage level is independent from the VDD voltage and should preferably be connected to VDD when these peripherals are not used.

- AGND ground for analog power supply

4.2 Suggested Application Diagram

Figure 4. Tracky suggested application diagram

4.5 Serial Communication

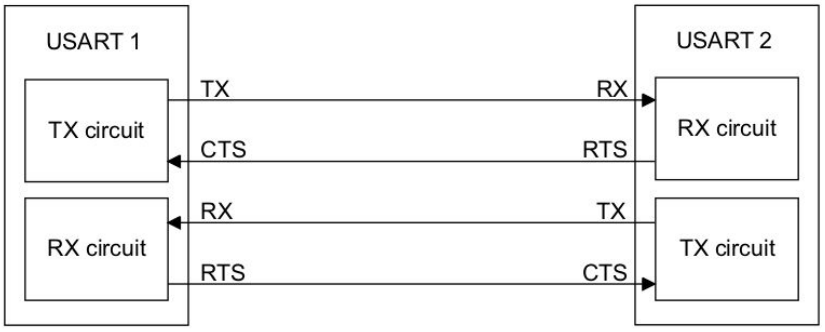


Figure 5. Hardware flow control between 2 USARTs

RS232 RTS flow control

If the RTS flow control is enabled, then RTS is asserted (tied low) as long as the USART receiver is ready to receive a new data. When the receive register is full, RTS is de-asserted, indicating that the transmission is expected to stop at the end of the current frame. Figure 6 shows an example of communication with RTS flow control enabled.

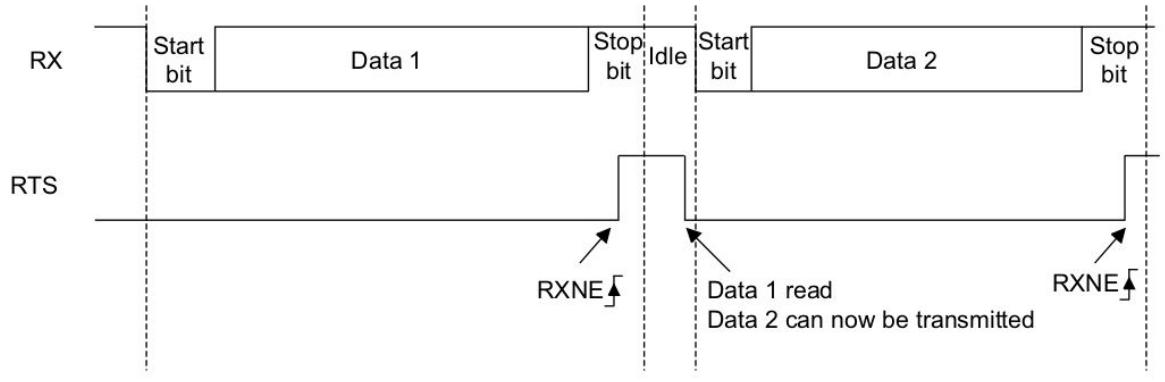


Figure 6. RS232 RTS flow control

RS232 CTS flow control

If the CTS flow control is enabled, then the transmitter checks the CTS input before transmitting the next frame. If CTS is asserted (tied low), then the next data is transmitted (assuming that data is to be transmitted), else the transmission does not occur. when CTS is de-asserted during a transmission, the current transmission is completed before the transmitter stops.

Figure 7 shows an example of communication with CTS flow control enabled.

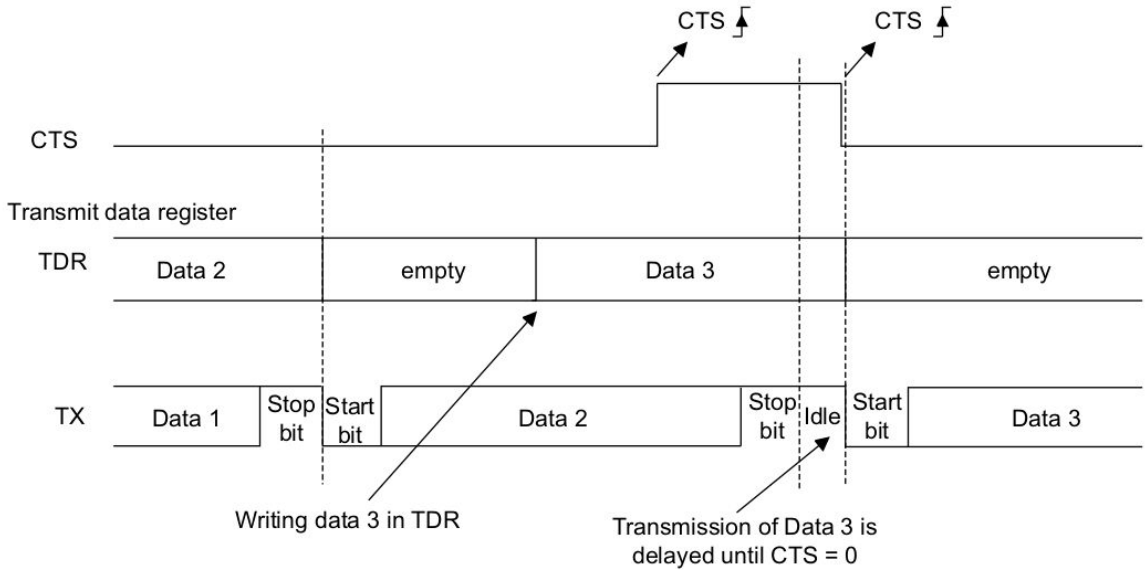


Figure 7. RS232 CTS flow control

5 Board Layout

The following pictures show the dimensions of the Tracky Module.

5.1 Tracky Module

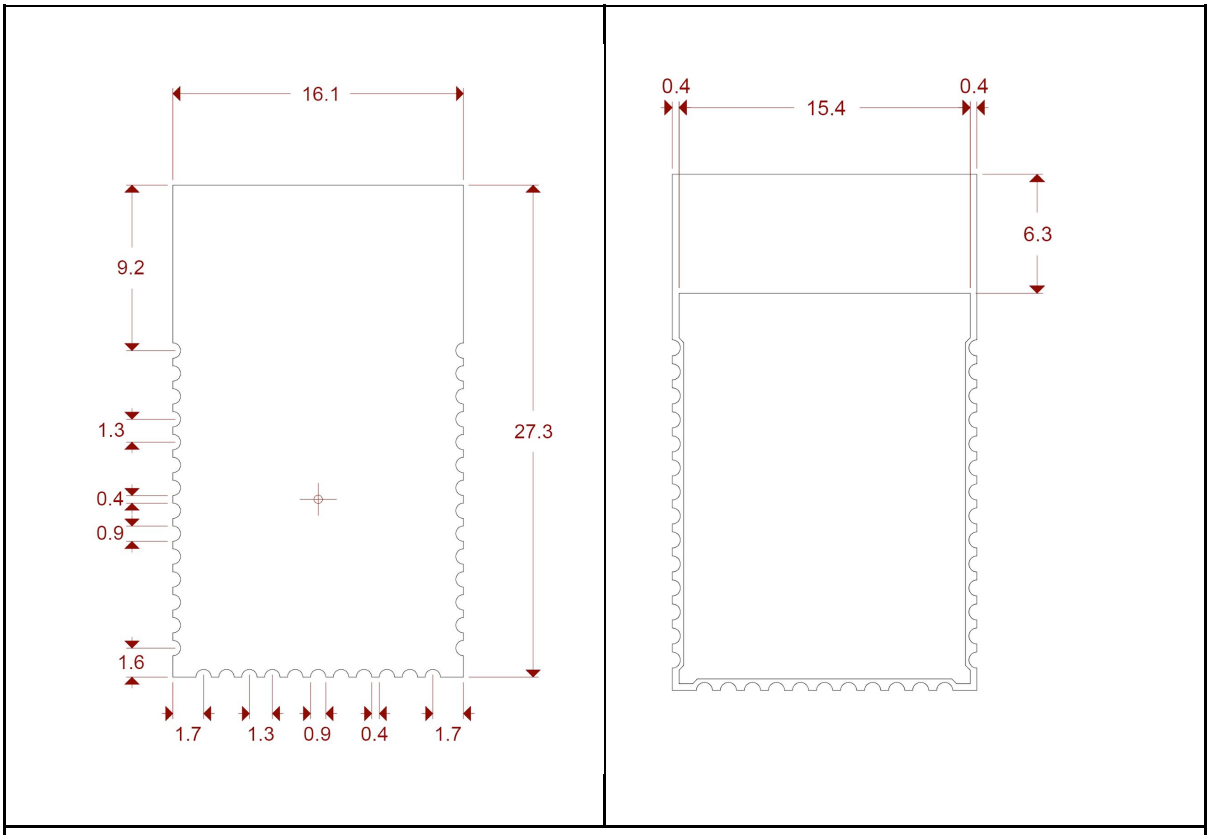
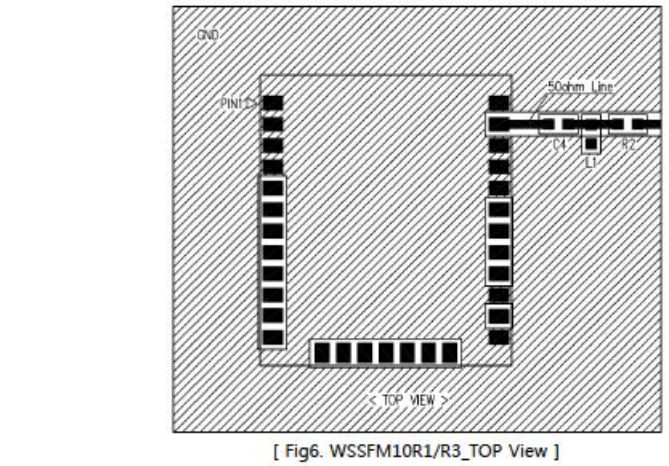


Figure 8. Tracky Module dimensions

5.2 Mounting Suggestions



[Fig6. WSSFM10R1/R3_TOP View]

Figure 9. Tracky Module Mounting for ext Antenna

5.3 Tracky Breakout

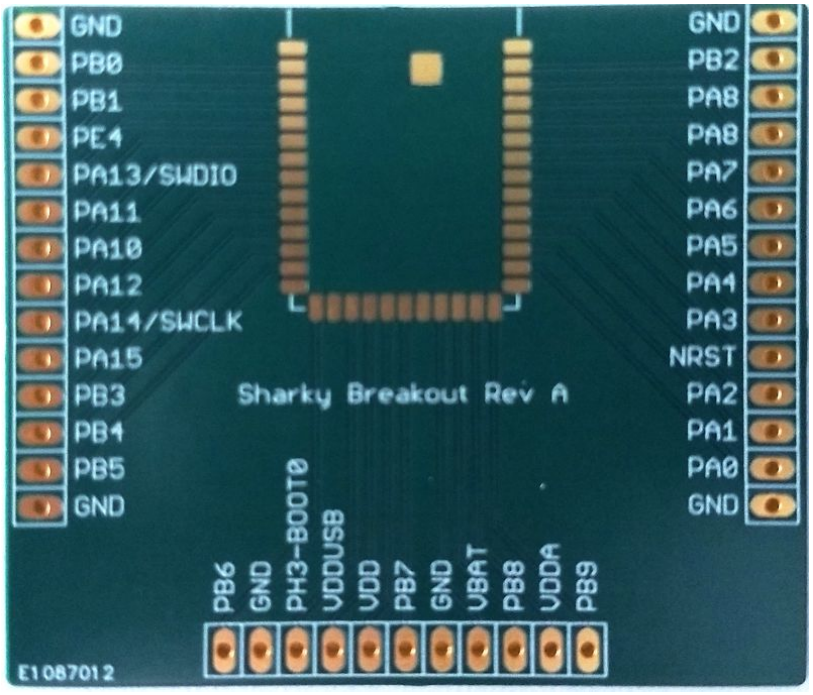


Figure 10. Tracky Module Breakout

6 Radiation pattern plots of the Tracky PCB-Ant module

7 Firmware Upload

The STM32L0 SoC inside the Tracky module has a single Cortex M0+ core for the Sigfox Stack

The module is delivered with Sigfox communication stack firmware installed.

The GUI application for flashing firmware is STM32CubeProgrammer, available for Windows, Linux and MacOS operating systems. It can be downloaded from ST at:

https://www.st.com/en/development-tools/stm32cubeprog.html

The firmware for the M0+ CPU can be uploaded:

- Using an STLink V2 or V3 device connected to the SWD interface
- Using the embedded ROM Bootloader that is selected by rising the BOOT0 pin. In this case the firmware can be uploaded via UART

8 References and Useful Links

8.1 Data Sheets and documents

- https://www.st.com/b/en/wireless-transceivers-mcus-and-modules/s2-lp.html
- https://www.st.com/resource/en/datasheet/s2-lp.pdf

8.2 WebSites

- http://www.midatronics.com
- https://www.st.com