



# mosaic-X5 Hardware Manual

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Version 1.1.0



mosaic-X5 Hardware Manual

Version 1.1.0

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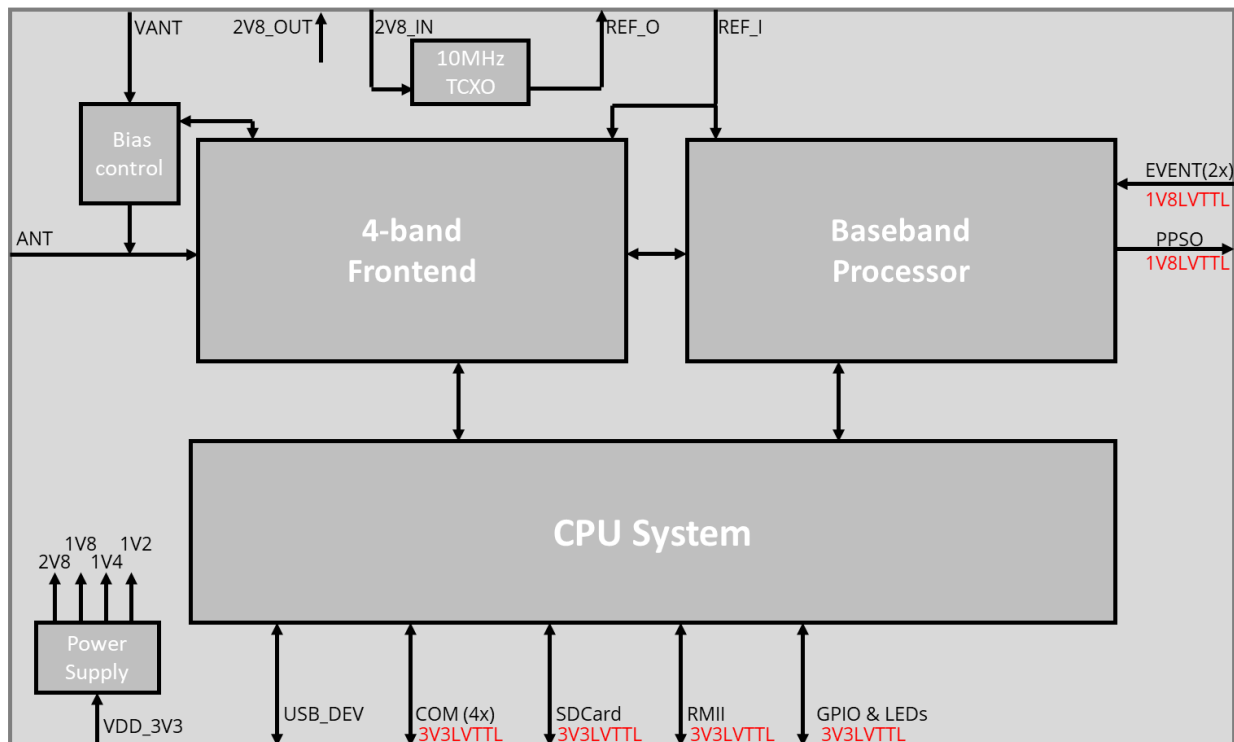
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## 2 mosaic-X5 GNSS Module

### 2.1 Overview

Septentrio mosaic-X5 is a low-power multi-band multi-constellation GNSS receiver packaged in a 31x31mm LGA module. The internal block diagram is shown below.



The module operates from a single 3V3 power supply (VDD\_3V3).

The antenna connects directly to the ANT pin without need for additional components. A 3V to 5.5V DC voltage can be applied to the antenna from the VANT pin. The bias control circuit detects overcurrent conditions (>150mA) and protects the module in case of short circuit. See section 3.2.

The module can use its internal TCXO as frequency reference, but also accepts an external frequency reference on the REF\_I pin. See section 3.7.

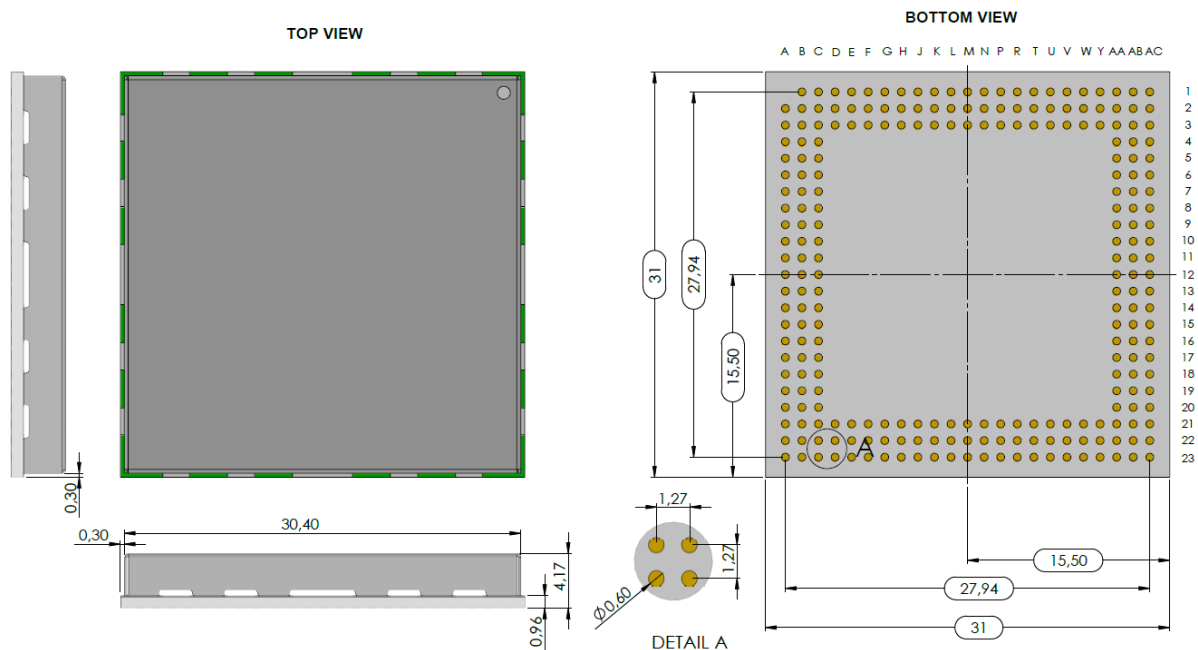
Two event timer pins and a PPS output are available (1.8V LVTTTL). See section 3.8.

The module features a rich set of communication interfaces:

- Four serial ports (3.3V LVTTTL), three of them with hardware flow control. See section 3.3.
- USB. See section 3.4.
- Ethernet (the PHY is external to the module). See section 3.5.

- SDCard interface for logging to an external SD-Card. See section 3.6.
- GPIO and LEDs output. See section 3.10.

## 2.2 Mechanical



All dimensions in millimeters.

Weight = 6.8g

| LGA Details         | Specification             |
|---------------------|---------------------------|
| Land pitch          | 1.27 mm                   |
| Land diameter       | 0.6 mm                    |
| Pin 1 mark          | The A1 pad is missing     |
| Land plating        | Nickle/Gold               |
| Array               | 23 x 23, three outer rows |
| Number of terminals | 239                       |

## 2.3 Absolute Maximum Ratings

The following conditions should never be exceeded, even momentarily, as it may cause permanent damage to the module.

| Parameter       | Comment  | Min  | Max | Units |
|-----------------|----------|------|-----|-------|
| VDD_3V3 voltage | See 3.1  | -0.3 | 3.6 | V     |
| VDD_BAT voltage | See 3.12 | -0.3 | 3.6 | V     |
| VANT voltage    | See 3.2  | -0.3 | 5.5 | V     |

|                             |         |      |             |      |
|-----------------------------|---------|------|-------------|------|
| 3V3_LVTTL input pin voltage |         | -0.3 | VDD_3V3+0.3 | V    |
| EVENT input voltage         | See 3.8 | -0.3 | 1V8_OUT+0.3 | V    |
| RF input power              | See 3.2 |      | 20          | dBm  |
| REF_I level                 | See 3.7 |      | 1.7         | Vp-p |
| Output pins drive current   |         |      | 10          | mA   |

## 2.4 Electrical Characteristics in Operational Conditions

### 2.4.1 Power Supply

| Parameter               | Comment  | Min   | Typ  | Max   | Units |
|-------------------------|----------|-------|------|-------|-------|
| VDD_3V3 voltage         | See 3.1  | 3.135 | 3.3  | 3.465 | V     |
| VDD_BAT voltage         | See 3.12 | 3.135 | 3.3  | 3.465 | V     |
| VANT voltage            | See 3.2  | 3.0   | 3.3  | 5.5   | V     |
| USB_VBUS1 voltage       | See 3.4  | 4.4   | 5.0  | 5.5   | V     |
| 1V8_OUT output voltage  |          | 1.764 | 1.8  | 1.836 | V     |
| 2V8_OUT output voltage  |          | 2.744 | 2.8  | 2.856 | V     |
| VDD_3V3 current         |          | 160   | 210  | 500   | mA    |
| VDD_BAT input current   |          |       | 0.03 | 1     | mA    |
| USB_VBUS1 input current | See 3.4  |       | 10   | 50    | mA    |
| 1V8_OUT output current  |          |       |      | 120   | mA    |
| 2V8_OUT output current  |          |       |      | 100   | mA    |
| VANT input current      |          |       |      | 150   | mA    |

### 2.4.2 I/O

| Parameter                        | Comment        | Min          | Typ | Max         | Units |
|----------------------------------|----------------|--------------|-----|-------------|-------|
| VIH, 1.8V inputs                 |                | 0.7*1V8_OUT  |     |             | V     |
| VIL, 1.8V inputs                 |                |              |     | 0.3*1V8_OUT | V     |
| Input capacitance<br>1.8V inputs |                |              | 2.0 |             | pF    |
| Pull-down, 1.8V inputs           |                | 80           | 210 | 515         | kOhm  |
| VOH, 1.8V outputs                | 7.2 mA         | 0.75*1V8_OUT |     |             | V     |
| VOL, 1.8V outputs                | 7.2 mA         |              |     | 0.4         | V     |
| VIH, 3.3V inputs                 |                | 0.7*VDD_3V3  |     | VDD_3V3     | V     |
| VIL, 3.3V inputs                 |                | 0            |     | 0.3*VDD_3V3 | V     |
| Pull-up, 3.3V inputs             | Except nRST_IN | 68           | 100 | 150         | kOhm  |
| Pull-up, nRST_IN                 |                | 9.6          | 9.8 | 10          | kOhm  |
| VOH, 3.3V outputs                | 1 mA           | VDD_3V3-0.15 |     |             | V     |
| VIL, 3.3V outputs                | 1 mA           |              |     | 0.15        | V     |
| REF_I input level                |                | 0.5          |     | 1.7         | Vp-p  |
| REF_I input capacitance          |                |              | 8   |             | pF    |
| REF_I input frequency            |                |              | 10  |             | MHz   |
| REF_O output level               | See 3.7.1      |              | 1.2 |             | Vp-p  |

## 2.5 Power Consumption

The module is powered through the VDD\_3V3 pins, see section 3.1.

The power consumption depends on the set of GNSS signals enabled and on the positioning mode. The following table lists the power consumption for some configurations, while tracking all satellites in view from an open sky, and with the module at room temperature. The current is applicable to a supply voltage of 3.3V.

| GNSS Signals                                                      | Positioning Mode  | Power (mW) | Current (mA) |
|-------------------------------------------------------------------|-------------------|------------|--------------|
| <b>GPS L1 C/A</b>                                                 | Stand-Alone (1Hz) | 550        | 167          |
| <b>GPS L1/L2</b>                                                  | RTK (1Hz)         | 670        | 203          |
| <b>GPS/GLONASS L1/L2</b>                                          | RTK (1Hz)         | 695        | 211          |
| <b>GPS/GLONASS L1/L2+GALILEO L1/E5a +BeiDou B1C/B2a (phase 3)</b> | RTK (1Hz)         | 850        | 258          |
| <b>GPS/GLONASS L1/L2+GALILEO L1/E5a +BeiDou B1C/B2a (phase 3)</b> | RTK (100 Hz)      | 930        | 282          |
| <b>GPS/GLONASS L1/L2 + L-band</b>                                 | PPP (1Hz)         | 760        | 230          |
| <b>All signals from all GNSS constellations</b>                   | Static (1Hz)      | 910        | 276          |
| <b>All signals from all GNSS constellations +L-band</b>           | Static(1Hz)       | 980        | 297          |
| <b>All signals from all GNSS constellations +L-band</b>           | Static (100Hz)    | 1080       | 327          |

Enabling wideband interference mitigation with the **setWBIMitigation** command adds 70 mW.

Minimum power supply drive capability: 0.5A.

## 2.6 Environmental

Operational: -40 to +85 °C

Storage: -55 to +85 °C

## 3 Pinout and I/O Description

The module provides 239 LGA pads, configured as follows.

|    | 23           | 22          | 21          | 20      | 19      | 18      | 17    | 16          | 15          | 14          | 13          | 12          | 11          | 10          | 9           | 8           | 7            | 6           | 5           | 4       | 3           | 2           | 1           |
|----|--------------|-------------|-------------|---------|---------|---------|-------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------|-------------|-------------|---------|-------------|-------------|-------------|
| AC | GND          | GND         | GND         | ANT     | GND     | GND     | REF_I | REF_O       | GND         | VTUNE       | GND         | Reserved_NC | Reserved_NC | Reserved_NC | Reserved_NC | PPSO        | EVENTB       | EVENTA      | Reserved_NC | 1V8_OUT | SYNC        | Reserved_NC | Reserved_NC |
| AB | GND          | GND         | GND         | GND     | GND     | GND     | GND   | GND         | GND         | GND         | GND         | Reserved_NC | Reserved_NC | Reserved_NC | Reserved_NC | GND         | Reserved_GND | GND         | GND         | GND     | GND         | GND         | SD1_CMD     |
| AA | GND          | GND         | GND         | GND     | GND     | GND     | GND   | GND         | GND         | GND         | GND         | Reserved_NC | Reserved_NC | Reserved_NC | Reserved_NC | Reserved_NC | Reserved_NC  | Reserved_NC | Reserved_NC | GP1     | Reserved_NC | RMII_CLK    | SD1_CLK     |
| Y  | GND          | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | Reserved_NC | GND         | SD1_DATA0   |
| W  | GND          | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | Reserved_NC | MDIO        | Reserved_NC |
| V  | Reserved_GND | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | Reserved_NC | MDC         | Reserved_NC |
| U  | GND          | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | Reserved_NC | GND         | Reserved_NC |
| T  | GND          | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | Reserved_NC | RMII_RXD1   | Reserved_NC |
| R  | VANT         | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | GND         | RMII_RXD0   | Reserved_NC |
| P  | VANT         | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | GND         | GND         | GND         |
| N  | 2V8_OUT      | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | Reserved_NC | RMII_CRSDV  | CTS3        |
| M  | 2V8_IN       | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | Reserved_NC | RMII_RXER   | TXD3        |
| L  | GND          | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | GP2         | RMII_TXEN   | RTS3        |
| K  | GND          | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | LOG_BUTTON  | GND         | RXD3        |
| J  | GND          | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | Reserved_NC | RMII_TXD0   | CTS2        |
| H  | GND          | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | Reserved_NC | RMII_TXD1   | TXD2        |
| G  | GND          | Reserved_NC | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | Reserved_NC | GND         | RTS2        |
| F  | GND          | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | Reserved_NC | nRST_LAN    | RXD2        |
| E  | GND          | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | TXD4        | GND         | CTS1        |
| D  | GND          | GND         | GND         |         |         |         |       |             |             |             |             |             |             |             |             |             |              |             |             |         | RXD4        | GND         | TXD1        |
| C  | GND          | Reserved_NC | Reserved_NC | VDD_3V3 | VDD_3V3 | VDD_3V3 | GND   | GND         | GND         | Reserved_NC | Reserved_NC | Reserved_NC | Reserved_NC | Reserved_NC | Reserved_NC | Reserved_NC | GND          | Reserved_NC | Reserved_NC | GND     | Reserved_NC | Reserved_NC | RTS1        |
| B  | Reserved_NC  | Reserved_NC | GND         | VDD_3V3 | VDD_3V3 | VDD_3V3 | GND   | PMIC_ON_REQ | Reserved_NC | Reserved_NC | GND         | Reserved_NC | Reserved_NC | Reserved_NC | Reserved_NC | VDD_BAT     | GND          | GND         | GND         | GND     | Reserved_NC | LOGLED      | RXD1        |
| A  | GND          | GND         | GND         | VDD_3V3 | VDD_3V3 | VDD_3V3 | GND   | GND         | GND         | GPLED       | Reserved_NC | MODULE_RDY  | nRST_IN     | ONOFF       | Reserved_NC | USB_VBUS1   | GND          | USB_DEV_N   | USB_DEV_P   | GND     | RTC_XTALI   | RTC_XTALO   |             |
|    | 23           | 22          | 21          | 20      | 19      | 18      | 17    | 16          | 15          | 14          | 13          | 12          | 11          | 10          | 9           | 8           | 7            | 6           | 5           | 4       | 3           | 2           | 1           |

The following sections describe all the non-reserved pads. Pads are grouped by functions.

### Conventions:

- Pin Type: I=Input, O=Output, P=Power, Ctrl=Control, Clk=Reference clock
- PU: pulled up
- PD: pulled down
- K: keeper input type

## 3.1 Power Supply

The module is powered through the VDD\_3V3 pins.

| Pin Name   | Type    | Level      | Description                                                                                                     | Comment                                                                                 |
|------------|---------|------------|-----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| VDD_3V3    | P,I     | 3.3V +/-5% | Main power supply input                                                                                         | All VDD_3V3 pins must be tied together.                                                 |
| GND        | Gnd     | 0          | Ground                                                                                                          | All GND pins must be connected to ground.                                               |
| VDD_BAT    | P,I     | 3.3V +/-5% | "Always-on" supply.                                                                                             | Must be tied to VDD_3V3 unless an external power switch is available. See section 3.12. |
| nRST_IN    | Ctrl,PU | 3V3_LVTTL  | Reset input, active negative. Module is in reset when low. Short low pulses of less than 1 $\mu$ s are ignored. | Internally debounced, can be directly connected to a push-button.                       |
| MODULE_RDY | O       | 3V3_LVTTL  | Level is high when module is operating, and low when in standby or reset.                                       | Level becomes high about 300 milliseconds after powering / unresetting the module.      |
| 1V8_OUT    | P,O     | 1.8V       | 1.8V output, see below                                                                                          |                                                                                         |
| SYNC       | I       | 1V8_LVTTL  | Reserved. Must always be connected to 1V8_OUT.                                                                  |                                                                                         |

Note that the 2V8\_OUT and 2V8\_IN pins are exclusively reserved to power the internal TCXO. See section 3.7.

The 1V8\_OUT pin is a DC output (120mA max current) which can, for example, be used to power level-shifters for the 1V8\_LVTTL signals (EVENT and PPS), see for example section 3.8.

The module can also control an external power switch, to enable standby mode. See section 3.12 for details.

## 3.2 Antenna

The antenna can be directly connected to the ANT pad. The ANT-input is ESD-protected in the module and carries a DC-voltage to power the antenna, avoiding the need for an external bias-tee. This DC-voltage is imposed to the module via the VANT-pad.

In case of an overcurrent condition (e.g. short circuit in antenna cable), the module will first limit the current to about 150 mA and then switch off the antenna supply in about 3 ms. It will periodically retry to switch on the antenna supply until the overcurrent condition has disappeared.

Refer to 4.4.3 for RF-routing recommendations.

| Pin Name | Type | Level  | Description                                                                                                                                                                                                     | Comment |
|----------|------|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| ANT      | RF   |        | RF input                                                                                                                                                                                                        |         |
| VANT     | P,I  | 3–5.5V | DC supply to the antenna. Max current 150mA. DC supply to antenna is turned off if overcurrent is detected.<br><br>If this pin is not connected or if it is tied to GND, there is no DC voltage to the antenna. |         |



Never inject an external DC voltage into the ANT-pad as it may damage the module. For instance, when using a splitter to distribute the antenna signal to several GNSS receivers, make sure that no more than one output of the splitter passes DC. Use DC-blocks otherwise.

### 3.2.1 Electrical Specifications

|                                                              |                                                                                                                                                                       |
|--------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Equivalent DC series impedance at the ANT pin                | 2.5 Ohms typical, 3.0 Ohms max                                                                                                                                        |
| Antenna current limit                                        | 150 mA                                                                                                                                                                |
| Antenna net gain range <sup>1</sup>                          | 15-50 dB                                                                                                                                                              |
| Receiver noise figure <sup>2</sup><br>(NFRx, see Appendix B) | 8.5 dB with 15 dB net pre-amplification<br>18 dB with 25 dB net pre-amplification<br>26 dB with 35 dB net pre-amplification<br>35 dB with 45 dB net pre-amplification |
| RF nominal input impedance                                   | 50 Ohms                                                                                                                                                               |
| VSWR                                                         | < 2:1 in 1165-1255 MHz and 1525-1610 MHz range                                                                                                                        |

<sup>1</sup> The net gain is the total pre-amplification of the distribution network in front of the module. Typically, this equals antenna active LNA gain minus coax losses in the applicable GNSS bands.

<sup>2</sup> The listed noise figure is at room temperature. Add 1 dB for the noise figure at the worst temperature corner (85°C)

### 3.3 COM Ports

The module provides four serial COM ports. Three of them (COM1 to COM3) support RTS/CTS hardware flow control:

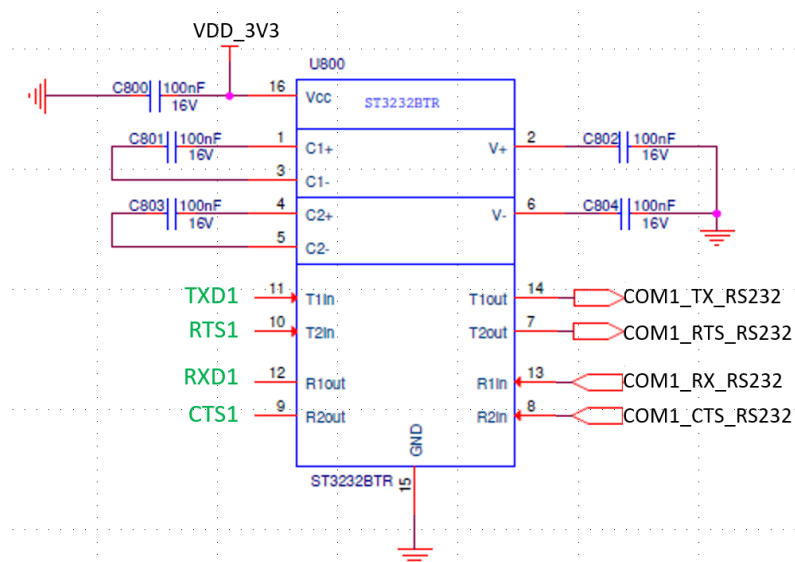
| Pin Name | Type  | Level     | Description                                        | Comment                                                        |
|----------|-------|-----------|----------------------------------------------------|----------------------------------------------------------------|
| TXD1     | O     | 3V3_LVTTL | Serial COM1 transmit line (inactive state is high) |                                                                |
| RXD1     | I, PU | 3V3_LVTTL | Serial COM1 receive line (inactive state is high)  |                                                                |
| RTS1     | O     | 3V3_LVTTL | Serial COM1 RTS line.                              | The module drives this pin low when ready to receive data      |
| CTS1     | I, PU | 3V3_LVTTL | Serial COM1 CTS line.                              | Must be driven low when ready to receive data from the module. |
| TXD2     | O     | 3V3_LVTTL | Serial COM2 transmit line (inactive state is high) |                                                                |
| RXD2     | I, PU | 3V3_LVTTL | Serial COM2 receive line (inactive state is high)  |                                                                |
| RTS2     | O     | 3V3_LVTTL | Serial COM2 RTS line.                              | The module drives this pin low when ready to receive data      |
| CTS2     | I, PU | 3V3_LVTTL | Serial COM3 CTS line.                              | Must be driven low when ready to receive data from the module. |
| TXD3     | O     | 3V3_LVTTL | Serial COM3 transmit line (inactive state is high) |                                                                |
| RXD3     | I, PU | 3V3_LVTTL | Serial COM3 receive line (inactive state is high)  |                                                                |
| RTS3     | O     | 3V3_LVTTL | Serial COM3 RTS line.                              | The module drives this pin low when ready to receive data      |
| CTS3     | I, PU | 3V3_LVTTL | Serial COM3 CTS line.                              | Must be driven low when ready to receive data from the module. |
| TXD4     | O     | 3V3_LVTTL | Serial COM4 transmit line (inactive state is high) |                                                                |
| RXD4     | I, PU | 3V3_LVTTL | Serial COM4 receive line (inactive state is high)  |                                                                |

Unused COM-port signals can be left floating. Flow control is disabled by default.

The COM port settings (baud rate, flow control, etc) are set with the **setCOMSettings** user command. The maximum baud rate is 4Mbits/s.

The LVTTL RXD and CTS inputs of the module shall not be driven while its VDD\_3V3 input supply is not present.

An example of a circuit to convert the COM1 signals to RS232 level is shown below. In green, the signals to be connected to the mosaic-X5 pins. The RTS1 and CTS1 signals can be left unconnected if hardware flow control is not required.



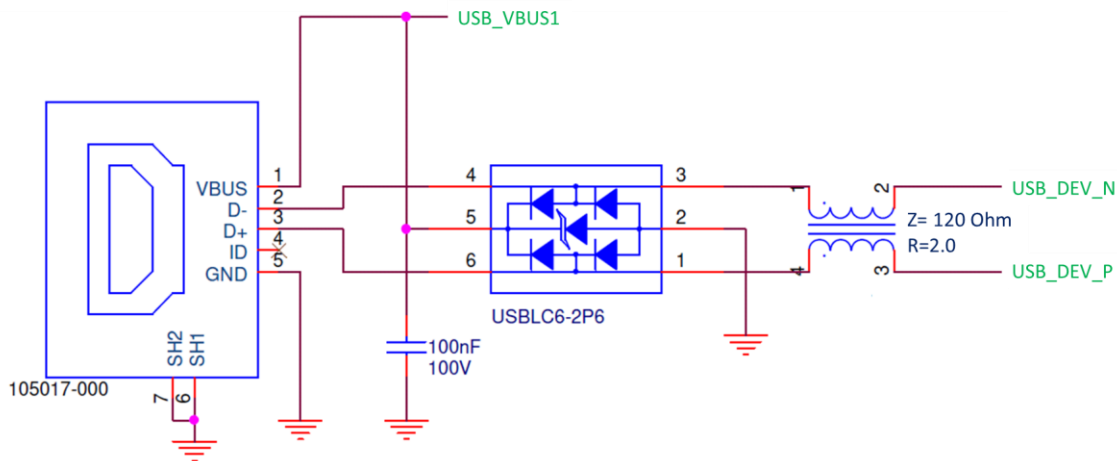
## 3.4 USB Device Interface

The following pins are used for accessing the module over USB in USB-device mode.

| Pin Name  | Type | Level         | Description                                                                                                                                                                                        | Comment |
|-----------|------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| USB_VBUS1 | P,I  | 4.40V to 5.5V | USB VBUS input.<br> This pin cannot be used to power the module.<br>Maximal current drawn by the module is 50 mA. |         |
| USB_DEV_N | I/O  | USB           | USB data signal, negative                                                                                                                                                                          |         |
| USB_DEV_P | I/O  | USB           | USB data signal, positive                                                                                                                                                                          |         |

USB is configured in USB 2.0 mode (high speed, 480Mbps max).

An example of an USB application circuit with ESD protection is shown below. The user shall make sure to use an ESD-protection and common mode choke compatible with high-speed USB if this is desired, for instance the USBLC6-2 from ST and DLP31SN121ML2L from Murata.



## 3.5 Ethernet

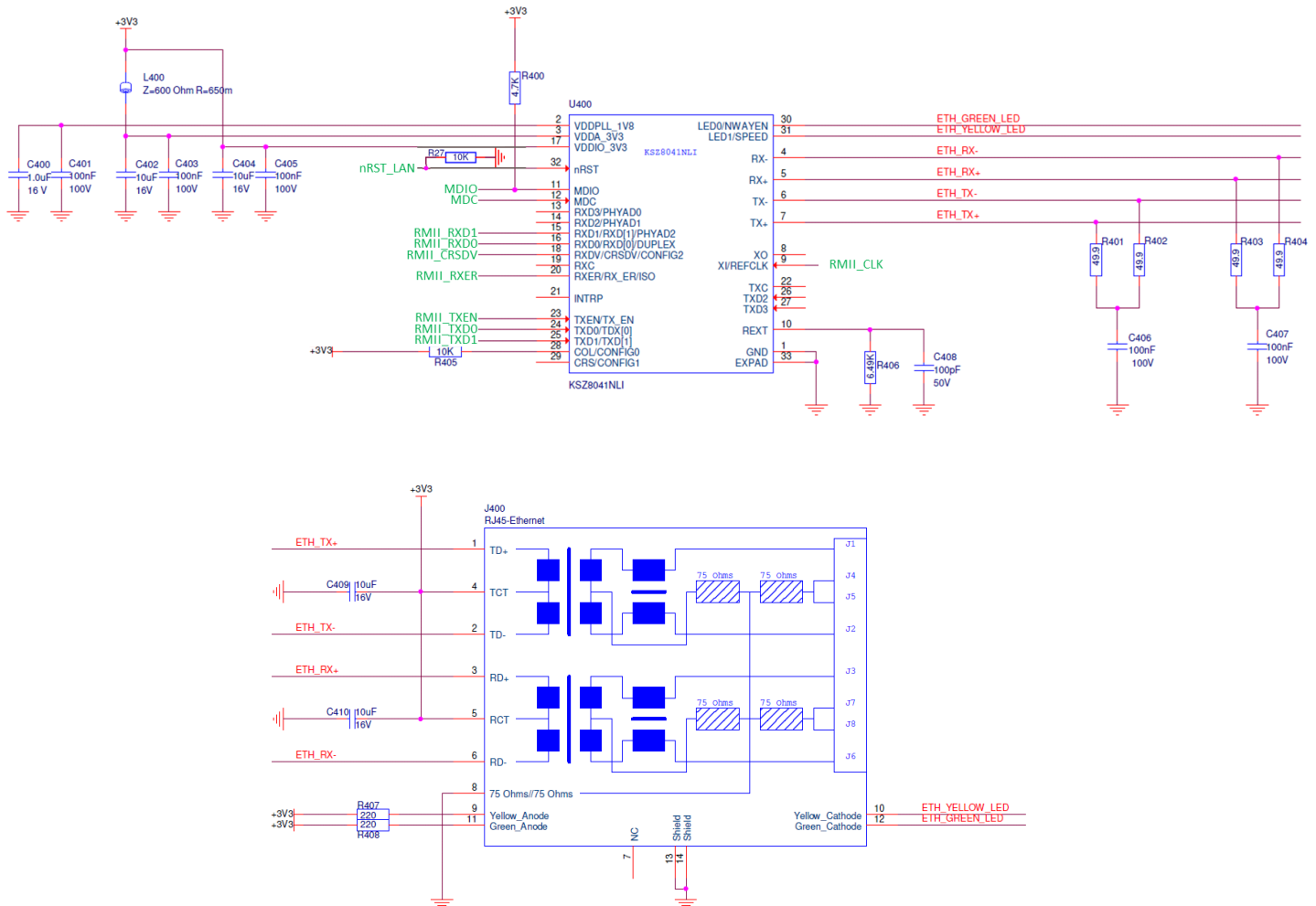
The module supports full duplex 10/100 Base-T Ethernet communication. The Ethernet PHY and magnetics are to be implemented on the host board. Connection with the PHY is through the RMII interface available on the following pins:

| Pin Name   | Type  | Level     | Description                      | Comment                                                                  |
|------------|-------|-----------|----------------------------------|--------------------------------------------------------------------------|
| RMII_CLK   | O     | 3V3_LVTTL | LAN PHY Clock                    |                                                                          |
| MDIO       | I/O   | 3V3_LVTTL | LAN PHY control data             |                                                                          |
| MDC        | O     | 3V3_LVTTL | LAN PHY control clock            |                                                                          |
| RMII_RXD1  | I, PU | 3V3_LVTTL | LAN PHY receive data 1           |                                                                          |
| RMII_RXD0  | I, PU | 3V3_LVTTL | LAN PHY receive data 0           |                                                                          |
| RMII_CRSDV | I, PU | 3V3_LVTTL | LAN PHY CRS                      |                                                                          |
| RMII_RXER  | I, PU | 3V3_LVTTL | LAN PHY RX error                 |                                                                          |
| RMII_TXEN  | O     | 3V3_LVTTL | LAN PHY transmit enable          |                                                                          |
| RMII_TXD0  | O     | 3V3_LVTTL | LAN PHY transmit data 0          |                                                                          |
| RMII_TXD1  | O     | 3V3_LVTTL | LAN PHY transmit data 1          |                                                                          |
| nRST_LAN   | O     | 3V3_LVTTL | LAN reset (low to reset the PHY) | When connecting this pin to enable an Ethernet PHY, add a 10k pull-down. |

If Ethernet is not used, all these pins should be left unconnected.

The PHY compatible with the module is the KSZ8041NLI PHY from Microchip.

An application circuit using this PHY and a Würth 74990111217 RJ45 connector with integrated magnetics is given below. In green, the signals to be connected to the mosaic-X5 pins.

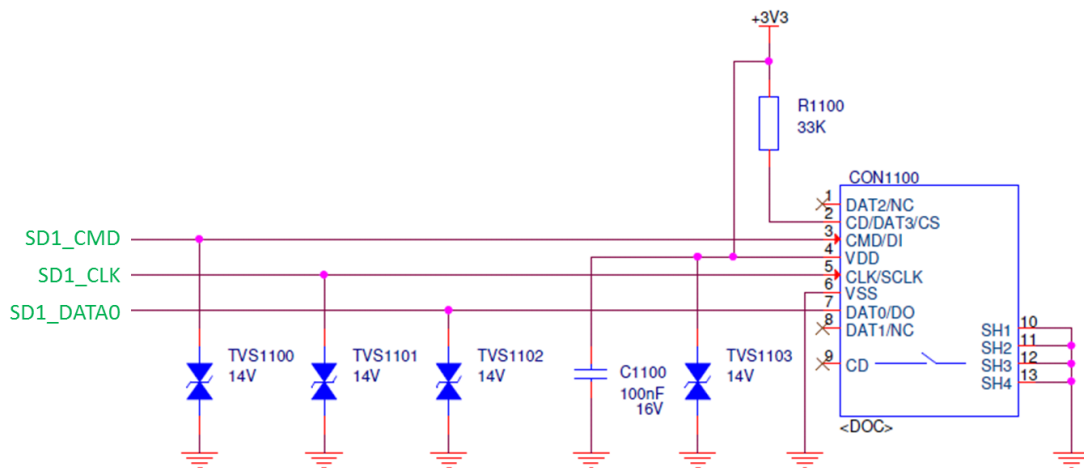


### 3.6 SD Memory Card

The module can interface to an external SD memory card through the pins listed in the table below.

| Pin Name  | Type  | Level     | Description                                                | Comment |
|-----------|-------|-----------|------------------------------------------------------------|---------|
| SD_CLK    | O     | 3V3_LVTTL | SD card CLK line                                           |         |
| SD_CMD    | O     | 3V3_LVTTL | SD card CMD line                                           |         |
| SD_DAT0   | I/O   | 3V3_LVTTL | SD card DAT0 line                                          |         |
| LOGBUTTON | I, PU | 3V3_LVTTL | Toggle logging on/off or mount/unmount the disk. See below |         |

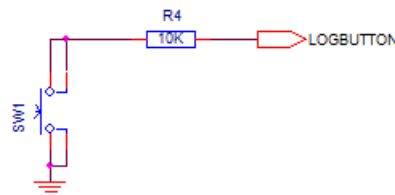
The module supports the 1-bit SD transfer mode with 3V3 signaling. An example circuit to a 9-pin SD memory card socket is shown below. The maximum clock frequency (SD CLK) is 33.000 MHz.



Driving the LOGBUTTON pin low for 100 ms to 5 seconds toggles logging on and off.

Driving the LOGBUTTON pin low for more than 5 seconds and then releasing it unmounts the SD card if it was mounted, or mounts it if it was unmounted. The SD card mount status can be checked with the LOGLED pin (see Appendix A).

The module debounces the signal in software, so no external debouncing circuit is required. It is however recommended to add a 1-10 kOhm series resistor with the switch, to protect the module from voltage spikes.



See instructions in the Reference Guide for details on how to configure SD card logging. The module is compatible with SD cards of up to 32GB. The file system is FAT32.

When powering off the module while logging, the last seconds of data may be lost. To avoid data losses, it is advised to first unmount the SD card. This can be done in two ways:

1. By entering the command **"exeManageDisk, DSK1, Unmount"** before turning off the module (see the Reference Guide for a description of all the user commands).
2. By driving the LOGBUTTON pin low for at least 5 seconds before turning off the module.

## 3.7 Clock Frequency Reference

The module can use its internal TCXO frequency reference, or can accept an external frequency reference, bypassing the internal TCXO.

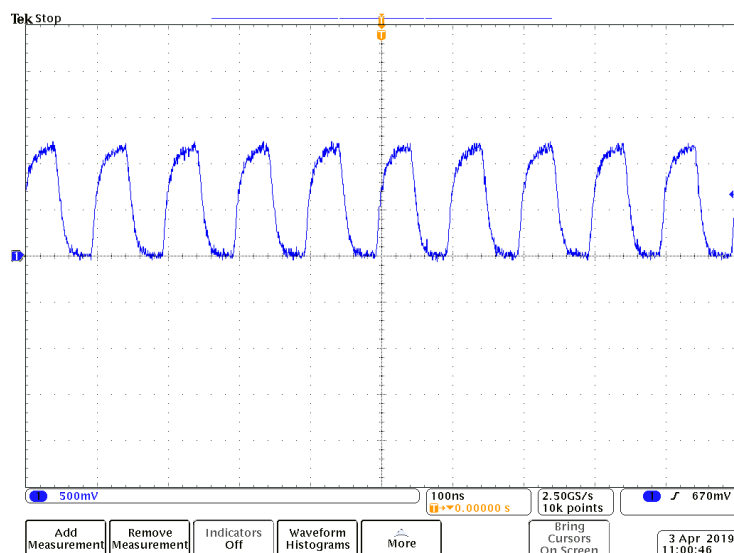
| Pin Name | Type | Level       | Description                                                              | Comment                                                                                   |
|----------|------|-------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| REF_I    | Clk  | 0.5-1.7Vp-p | Main frequency reference input, DC-decoupled, input capacitance is 8 pF  | See section 3.7.2.                                                                        |
| REF_O    | Clk  | 1.2Vp-p     | Frequency reference output from the internal TCXO                        | See section 3.7.1.                                                                        |
| 2V8_OUT  | P,O  | 2.8V        | 2.8V supply output for the internal TCXO.                                | Do not power any external device from this pin. It is only intended to connect to 2V8_IN. |
| 2V8_IN   | P,I  | 2.8V        | 2.8V supply input for the internal TCXO. Typically connected to 2V8_OUT. |                                                                                           |
| VTUNE    | I    |             | Reserved                                                                 | Leave unconnected.                                                                        |

### 3.7.1 Using the internal TCXO

To have the module run on its own TCXO:

- REF\_I must be connected to REF\_O (those pins are next to each other);
- 2V8\_IN must be connected to 2V8\_OUT (those pins are next to each other). Do not use another 2.8V supply than the one from the 2V8\_OUT pin.

The 10-MHz signal from the internal TCXO is available at the REF\_O pin, with peak-to-peak amplitude of 1.2V. The waveform is illustrated in the oscilloscope screen capture below.

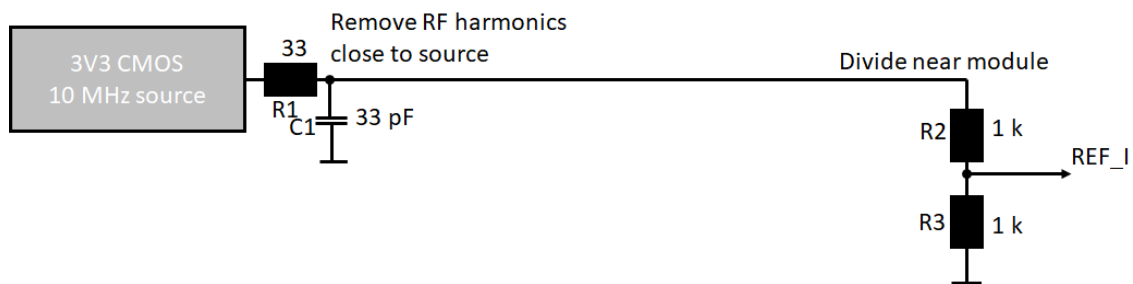


### 3.7.2 Using an external frequency reference

To use an external frequency reference:

- 2V8\_IN must be tied to ground
- REF\_O and 2V8\_OUT are not used and should be left unconnected
- The 10-MHz reference must be fed into the REF\_I pin. It is preferably a sine wave or a band-limited square wave. If CMOS or LVTTTL signals are used, it is recommended to filter them at the source with an RC filter with a pole near 100 MHz. The level at the REF\_I input has to be between 0.5 and 1.7 Vp-p. If a higher signalling voltage is divided with a resistive divider, the impedance level shall be sufficiently low to avoid excessive level drop because of the filtering of the divider

with the input capacitance of the REF\_I input (8 pF). Below an example circuit. The module has a build-in DC-decoupling capacitor.



Note that support for an external frequency reference is under permission. Make sure that the FreqSync permission is enabled to use this feature. Using an external reference without corresponding permission will cause the module to block most SBF output.

## 3.8 Event/TimeSync inputs

The module features two event inputs, which can be used to time tag external events with a time resolution of 20ns.

| Pin Name | Type  | Level     | Description                                                 | Comment                       |
|----------|-------|-----------|-------------------------------------------------------------|-------------------------------|
| EVENTA   | I, PD | 1V8_LVTTL | Event A or TimeSync input. The pull-down is about 200 kOhm. | Leave unconnected if not used |
| EVENTB   | I, PD | 1V8_LVTTL | Event B or TimeSync input. The pull-down is about 200 kOhm. | Leave unconnected if not used |

Use the **setEventParameters** user command to configure the EVENT pins (e.g. to set the polarity). Note that this feature requires the TimedEvent permission to be enabled in the module. For correct detection, the minimum time between two events on the same EVENTx pin must be at least 5ms, and there must be no more than 20 events in any interval of 100ms, all EVENTx pins considered.

If the TimeSync permission is enabled, the event inputs can also be configured as TimeSync source using the **setTimeSyncSource** command. When an event pin is configured as TimeSync source, the mosaic-X5 expects to see a one-pulse-per-second (1PPS) signal on that pin. It will then synchronize its internal time base (i.e. the time at which GNSS measurements are sampled) to that 1PPS signal. TimeSync is typically used in conjunction with ExtFreq (see section 3.7.2) to fully synchronize the module internal time base with the time of an external clock.

Note that there is a delay of 15 to 50 ns between the PPS pulse at the EVENT pin and the module internal time base. That delay is dependent on the phase difference between the 10 MHz frequency at the REF\_I pin and the PPS pulse at the EVENT pin. It is possible to measure this delay by synchronizing the PPS OUT pulse with the internal time base, with the **setPPSPParameters,,,,RxClock** command.

Note the timing signals use 1.8V logic. If 3.3V logic would be required, the EVENT-signals can be generated via a resistive divider, considering the integrated pull-down (see 2.4.2).

They could as well be created via a level shifter, using the 1V8\_OUT output from the module to supply the module side.

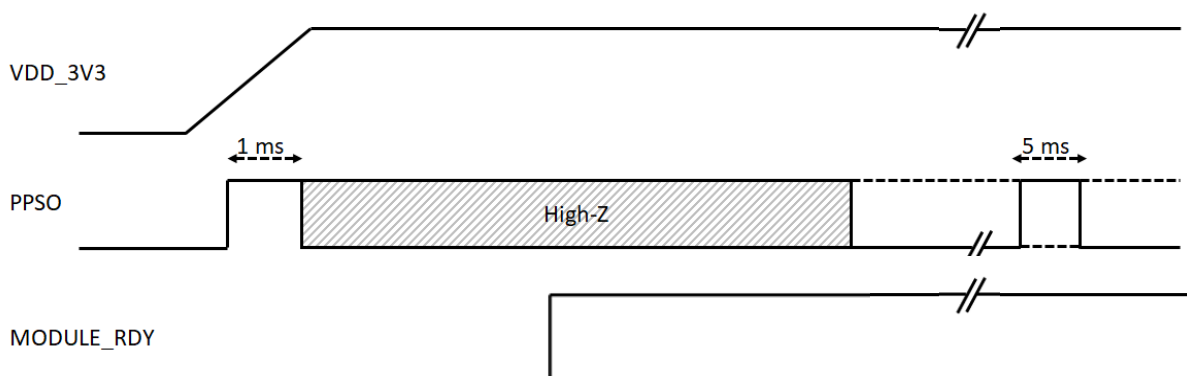
### 3.9 PPS output

| Pin Name | Type | Level     | Description                                                                                                                                                                                         | Comment |
|----------|------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| PPSO     | O    | 1V8_LVTTL | PPS output. Max output current: 10 mA. Polarity and rate user selectable. During start up, this pin is in high-Z mode. See Reference Guide for operating instructions. Default pulse duration: 5ms. |         |

The polarity, frequency and pulse width can be set with the **setPPSPParameters** command.

The PPSO signal uses 1.8V logic. It can be level-shifted if 3.3V logic is required (e.g. with SN74AVC4T245RSV).

The PPSO signal is briefly driven high during startup of the module (for about 1 ms), then gets high-impedant while the module is starting up. It finally gets driven to the intended level (low or high depending on the user-selected PPS polarity) after a few seconds. If this start-up behavior is undesirable, it can be shielded by a buffer (or level shifter) with an output enable. The output enable can be controlled with the MODULE\_RDY pin of the module. The MODULE\_RDY signal gets high about 300ms after applying power to VDD\_3V3. The input and output of the buffer should be pulled-up or pulled-down depending on the desired inactive state of the PPSO signal.



### 3.10 General Purpose Output (GPx)

The GP1 and GP2 pins are general purpose digital outputs, of which the level can be programmed with the **setGPIOFunctionality** command.

| Pin Name | Type | Level     | Description                                                         | Comment |
|----------|------|-----------|---------------------------------------------------------------------|---------|
| GP1      | O    | 3V3_LVTTL | General purpose output. GP1 in <b>setGPIOFunctionality</b> command. |         |
| GP2      | O    | 3V3_LVTTL | General purpose output. GP2 in <b>setGPIOFunctionality</b> command. |         |

During the first seconds after powering up the module, these pins are in tristate. Use an external pull-down or pull-up resistor to have the desired level during boot.

The GPx pins can drive a maximum current of 10mA.

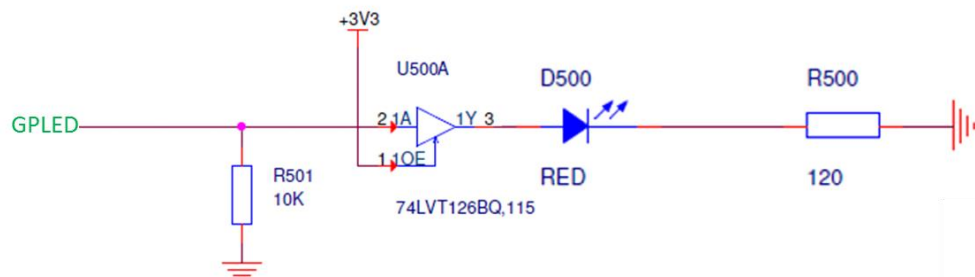
### 3.11 LEDs

The LED pins can be used to monitor the module status. They can be used to drive external LEDs. It is assumed that the LED lights up when the electrical level of the corresponding pin is high. See also Appendix A.

| Pin Name | Type | Level     | Description                                                                                | Comment |
|----------|------|-----------|--------------------------------------------------------------------------------------------|---------|
| GPLED    | O    | 3V3_LVTTL | General purpose LED.<br>Max output current: 10 mA; output impedance: 20 Ohms               |         |
| LOGLED   | O    | 3V3_LVTTL | Internal logging status indicator.<br>Max output current: 10 mA; output impedance: 20 Ohms |         |

During boot, i.e. during the first seconds after powering the module, the state of the LEDs is not defined. Use a pull-down or pull-up resistor to force a desired state.

An example of a circuit with a 10k pull-down and a driver is shown below.



### 3.12 Standby

The module can control an external power switch, allowing for example to toggle between standby and active modes upon pressing an “on/off” push-button.

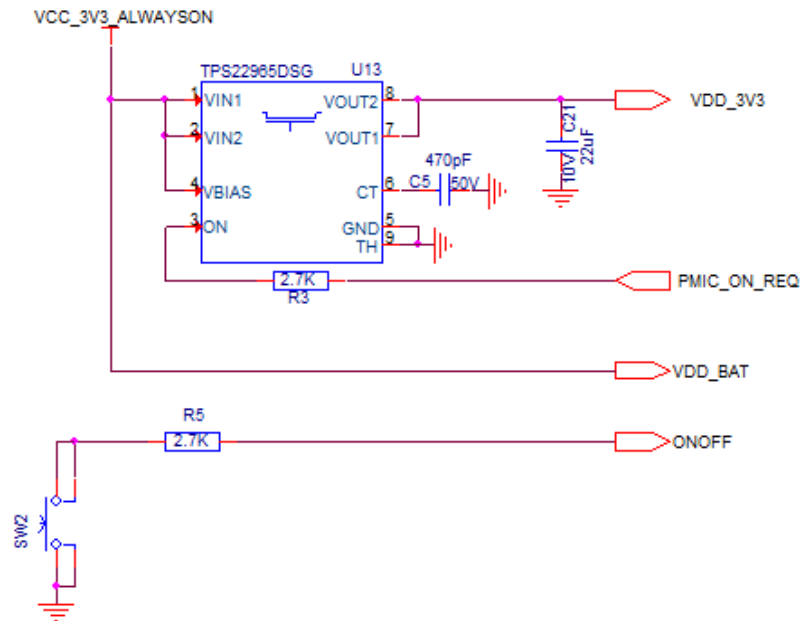
This functionality involves the following pins:

| Pin Name    | Type  | Level      | Description                                                                                                                                                                         | Comment                                 |
|-------------|-------|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|
| VDD_3V3     | P,I   | 3.3V +/-5% | Main power supply input, controlled by the external power switch                                                                                                                    | All VDD_3V3 pins must be tied together. |
| VDD_BAT     | P,I   | 3.3V +/-5% | Always-on power supply, which must remain available when VDD_3V3 is turned off by the external power switch                                                                         |                                         |
| ONOFF       | I, PU | 3V3_LVTTL  | Typically connected to a push-button to toggle between active and standby mode. Toggling occurs when the ONOFF pin is driven low for at least 50ms.                                 | Internally debounced                    |
| PMIC_ON_REQ | O     | 3V3_LVTTL  | Typically connected to the control pin of an external power switch. The power switch is expected to enable VDD_3V3 when PMIC_ON_REQ is high, and to disable VDD_3V3 when it is low. |                                         |



The external power switch is optional. When not using an external power switch, always connect VDD\_BAT together with VDD\_3V3.

An example circuit with an external power switch and an on/off push-button is shown below.



The module can be put in standby by either:

- Entering the **exePowerMode, standby** user command;
- Driving the ONOFF pin low for at least 50ms (i.e. pressing the button for at least 50ms).

After standby is requested, the module terminates all running processes, unmounts the disk, and drives the PMIC\_ON\_REQ pin low to turn off the main power supply (VDD\_3V3). The module power consumption in standby is <5mW.

When in standby, driving the ONOFF pin low for at least 50ms wakes up the module. The module restarts in the configuration stored in the boot configuration file.

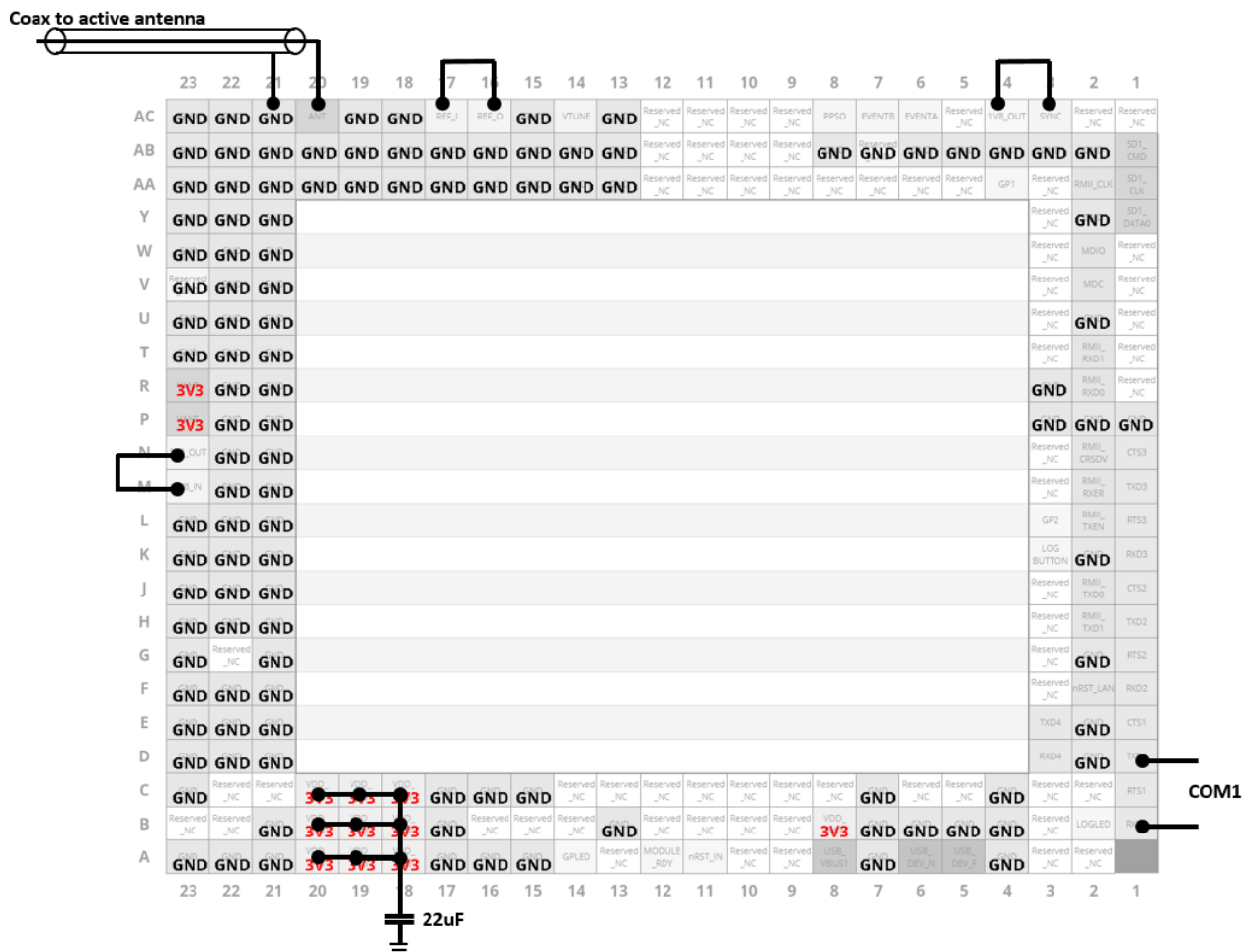
The ONOFF pin is internally pulled up and has a built-in debouncing circuit. It can be connected to a push-button (level low when button pressed).

## 4 mosaic-X5 Integration

### 4.1 Minimal Design

A minimal design, exposing only a single serial port (COM1-TTL) is shown below. In this example:

- All ground pins and the pins marked “Reserved\_GND” are connected to ground (GND).
- A 3.3VDC supply is provided to the VDD\_3V3 pins and to the VDD\_BAT pin. A 22μF decoupling capacitor is recommended.
- To provide power to the antenna, the VANT pins are also connected to the 3.3V supply.
- The antenna is directly fed into the ANT pin.
- The 2V8\_IN and 2V8\_OUT pins are connected, as no external frequency reference is used (see section 3.7).
- The REF\_I and REF\_O pins are connected for the same reason.
- 1V8\_OUT is connected to SYNC (this must always be the case).
- All other pins are left unconnected.



For easier debugging during host design development, it is recommended to always route at least one of the COM ports to test pads or a test header.

## 4.2 Electrical Recommendations

- All ground pins must be connected.
- Do not drive a non-zero voltage into input pins (pins type “I” in the tables in chapter 3) when the module is not powered (i.e. when there is no supply on the VDD\_3V3 pins).
- When pull-up/down resistors are needed, use 10 kΩ.
- Unused pins (e.g. pins of an unused interface) must be left unconnected unless explicitly mentioned otherwise.
- Many pins are reserved, which means that their functionality is proprietary or is not supported yet by the firmware. Reserved pins are marked “Reserved\_NC” and “Reserved\_GND”. The Reserved\_NC pins must be left unconnected. The Reserved\_GND pins (i.e. only V23 and AB7) must be tied to ground.

## 4.3 Decoupling

The VDD\_3V3 supply shall be decoupled with at least a 22 µF capacitor with proper voltage rating. The other supply terminals don't need external decoupling.

## 4.4 Layout Recommendations

### 4.4.1 Coplanarity

It is important to avoid warpage of the motherboard on which the module will be soldered. More in particular:

- Use a symmetrical layer stack
- Make sure layers opposite from the center of the board have a similar amount of copper (copper-balancing).
- Avoid iron-based soldered shielding cans in the proximity of mosaic-x5
- If the motherboard thickness is 1.2 mm or less, it needs to be supported during reflow.

### 4.4.2 Power

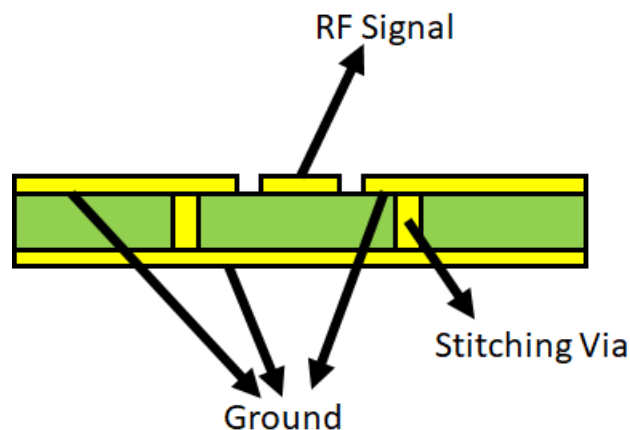
The power trace to the VDD\_3V3 terminals should be sufficiently wide to avoid excessive voltage drop. Online trace resistance calculators are available for this, e.g. at <https://www.eeweb.com/tools/trace-resistance>. The resistance of the trace to the power supply shall be less than  $(\text{minimum supply voltage} - 3.135\text{V})/0.5\text{A}$ .

Use a ground plane.

### 4.4.3 Antenna Input

The antenna input trace shall be routed as a 50-ohm coplanar waveguide with ground, as in the picture below. It is best to use stitching vias every few mm for good ground coherence. The width of the trace to set the impedance to 50 ohm can be calculated with online tools (e.g. <https://chemandy.com/calculators/coplanar-waveguide-with-ground-calculator.htm>). Usually it is best to use the top-layer for the coplanar waveguide and the second layer for ground.

The antenna trace can be directly routed to the desired type of coax connector, as all protection circuitry is integrated in mosaic-x5.



### 4.4.4 Avoiding Self-Interference

The antenna input connection is sensitive to interference from higher harmonics of other signals on the board. Even clock signals of just a few MHz can produce harmful harmonics at GNSS frequencies (1155-1300 MHz and 1540-1610 MHz).

It is best to keep the antenna input connection short, to reduce the area in which signals can be picked up. Stitching vias at the input trace could be arranged as a via fence to shield it from interference.

Furthermore, it is important to avoid digital signals in the MHz-range (SDIO, RMII, MDIO,...) from running close to the antenna input.

If an external frequency reference is used, it will get close to the antenna input because of the proximity of the REF\_I and ANT pad. This is not a problem if it doesn't have many harmonics. It can however cause issues if the reference signal is originating from a high-speed buffer or comparator. This can be avoided at circuit level, by filtering the signal with an RC-filter near the source (see section 3.7.2).

Most self-interference issues relate to radiated interference into a collocated GNSS-antenna. The following applies when the GNSS antenna is closer than 1 meter from electronics which are not in a shielded box:

- The SDIO, RMI and MDIO signals of mosaic-x5 can cause harmful radiated interference if not properly routed. In designs with a collocated antenna, these signals shall preferably be routed in an inner layer of the board, shielded by ground planes or a ground copper pour at top and bottom layers, connected with stitching vias. This approach puts them in a Faraday cage.
- The same holds for other high-speed digital signals in other electronics on the motherboard, like memory busses and clock signals. They should also be routed in an inner layer, flanked with copper pours connected to ground.
- Large processor and memory chips sometimes already radiate via the bondwires inside their package. Connectors like SD-card sockets and radio-module sockets also tend to radiate. It's best to put these components at the side of the board facing away from the collocated antenna. In this way the ground-layer will shield them. Alternatively, they could be placed underneath an EMI shielding can. There is less of a concern if the associated clock frequencies have no harmonics in the GNSS bands.

See also Appendix C.

## 5 Product Handling

### 5.1 ESD Precautions

Electrostatic discharge is a sudden flow of current from one object to another either object or to ground. Electrostatic charges can accumulate on common items such as polystyrene drinking cups, cellophane tape, synthetic clothing, untreated foam packaging material, and untreated plastic bags and work folders, to name but a few.



Electronic components and assemblies can be permanently damaged or destroyed when near or in contact with electro-statically charged objects. When you handle components or assemblies that are not in protective bags and you are not sure whether they are static-sensitive, assume that they are static-sensitive and handle them accordingly.

#### General rules

Always test your ground strap, bench mat, conductive work surface, and ground cord before either removing components and assemblies from their protective bags or before beginning any disassembly or assembly procedures. Perform all service procedures in a static-protected environment. Always use techniques and equipment designed to protect personnel and equipment from electrostatic discharge.

#### Handling

- Remove static-sensitive components and assemblies from their static-shielding bags only at static-safe workstations - a properly grounded table and grounded floor mat - and only when you are wearing a grounded wrist strap (with a resistor of at least 1 mega-ohm in series) or other grounding device. Avoid having non-ESD safe material on the workbench. Clear the work station of static generators like e.g. polyethylene, vinyl's, foam, notebooks, document holders, etc.
- Use only grounded tools when manipulating static-sensitive components and assemblies.
- Place and seal static-sensitive components and assemblies in their original static-shielding bags before removal from static-protected areas.
- Stacking of board assemblies should be avoided to prevent physical damage to devices.

#### Transport & Storage

- Limit as much as possible the manipulation of ESD-sensitive devices and components.
- Handle ESD-sensitive parts as far as possible in their (original) protective packaging.
- Protect ESD-sensitive components against dust as this is a possible carrier of static loads. Assembled printed circuit boards (PCB's) must always be placed in an anti-static shielding bag, box or PCB containers during transport between workplaces or to a warehouse.

## ROHS/WEEE NOTICE

Septentrio receivers and modules are compliant with the latest WEEE, RoHS and REACH directives. For more info see [www.septentrio.com/en/environmental-compliance](http://www.septentrio.com/en/environmental-compliance).



## 5.2 Packaging

The mosaic-X5 modules are delivered on JEDEC CO-029AN 9x3 matrix trays, with 27 modules per tray.

## 5.3 Part Number

Mosaic-X5 ordering code: **410322**

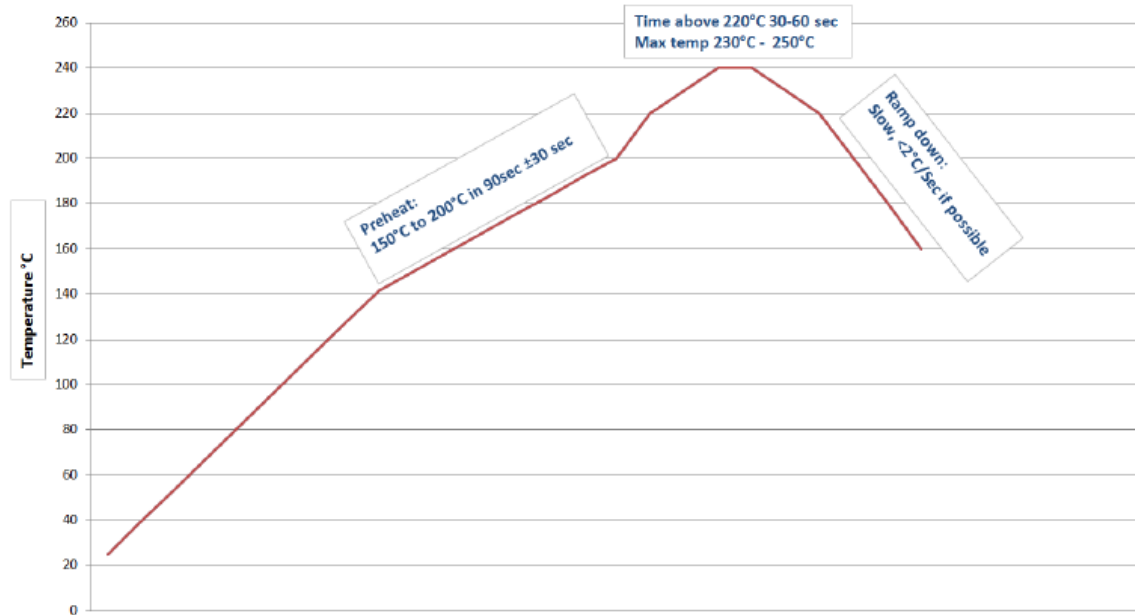
## 5.4 Moisture Sensitivity

The moisture sensitivity level (MSL) is 3.

## 5.5 Soldering

Reflow soldering is the soldering method recommended to assemble mosaic-X5 modules.

The recommended temperature profile is specified with the graphic below. Refer also to "IPC-7530A: Guidelines for Temperature Profiling for Mass Soldering Processes (Reflow and Wave)".



When implemented on a double-sided PCB, it should be made sure that the board side on which mosaic-X5 is assembled is reflowed last.

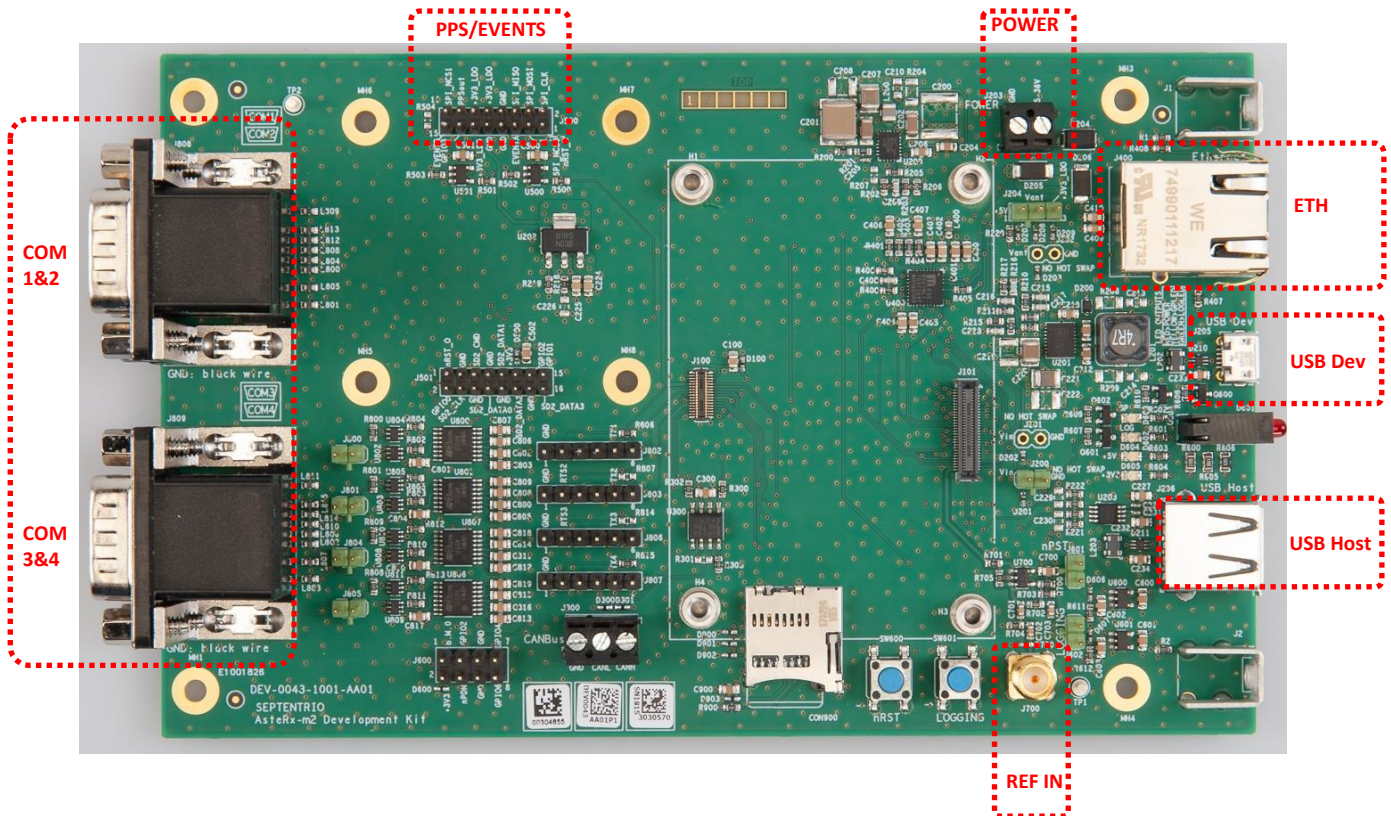
Don't use glue to attach the component, as this might lift the component and jeopardize bonding.

A stencil thickness of 0.1 mm / 4 mil is recommended.

Mount the part with the largest available placement nozzle, attached to the center of the shield. Use the slowest possible speed of the pick and place machine. Preferably place mosaic-X5 as the last component on the board.

If the motherboard thickness is 1.2 mm or less, it is recommended to support the assembly during the reflow process to minimize bow of the motherboard.

## 6 Development Kit



The mosaic-X5 Development Kit is composed of the mosaic-X5 module soldered on an interface PCB (GTB-0051), itself plugged on the DevKit board (DEV-0043). The above picture shows the DevKit board without the mosaic-X5.

DevKit Part Number: **410331P3161** (including antenna and accessories).

### 6.1 Powering the DevKit

There are two ways to power the DevKit:

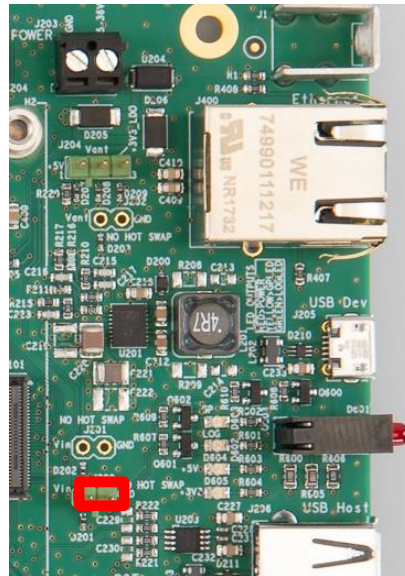
1. From the USB Dev connector (J205). This allows powering the board from a PC or from a standard phone-charger adapter. The supported USB voltage range is 4.5V-5.5V.
2. Using the POWER connector (J203). The supported voltage range is 5-36V.



When powering from the USB Dev connector, it is recommended to use the USB cable provided with the DevKit. Low-quality USB cables often suffer from excessive voltage drop, preventing correct operation.

It is safe to provide power to both connectors in parallel. The DevKit will use the source with the highest voltage.

Make sure that a jumper is placed on header J200, as shown below. Otherwise the DevKit will be powered, but not the mosaic-X5 module.



To measure the power consumption of the mosaic-X5 module (excluding the contribution from the DevKit and the antenna, but including a small contribution from the interface board, remove the jumper on J200 and connect the two pins to the probes of a multimeter in current-sensing mode. Measure the current flowing between the two pins and multiply it by 3.3V to obtain the power consumption. It is recommended to set the multimeter in high ampere setting to keep the voltage drop as low as possible.

## 6.2 Antenna Connectors

There is no antenna connector on the DevKit. The antenna must be connected directly to the u.FL or MMCX antenna connector on the mosaic-X5 interface board.

The DC voltage (5V or 3.3V) at the antenna connectors is determined by the position of the jumper on header J204, as shown below.

Vant = 5V

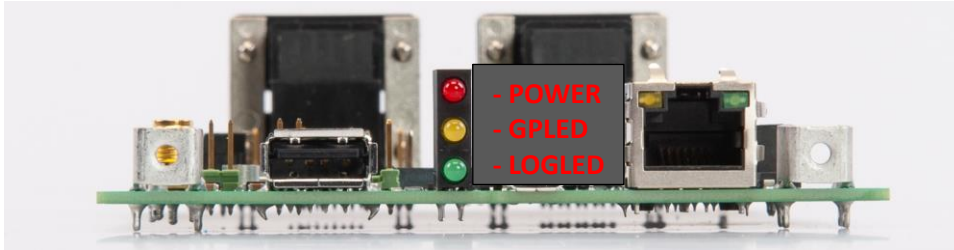


Vant = 3.3V



The jumper can be removed if the antenna does not need to be powered by the module. In that case, there is no DC voltage at the antenna connector.

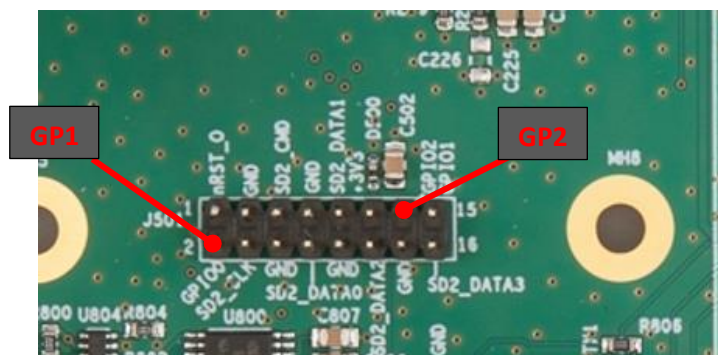
## 6.3 LEDs and General Purpose Output Pins



The POWER LED lights when the DevKit is powered.

The GPLED and LOGLED are connected to the homonymous pins of the mosaic-X5 module. See section 3.11 for the pinout, and Appendix A for a description of the LED behavior.

The 3.3V GP1 and GP2 outputs are available on the J501 header.

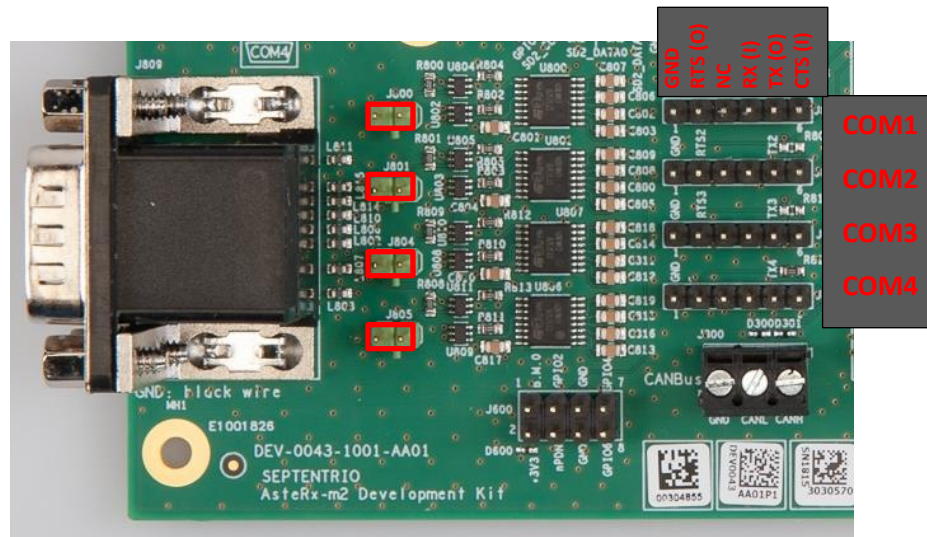


## 6.4 COM Ports

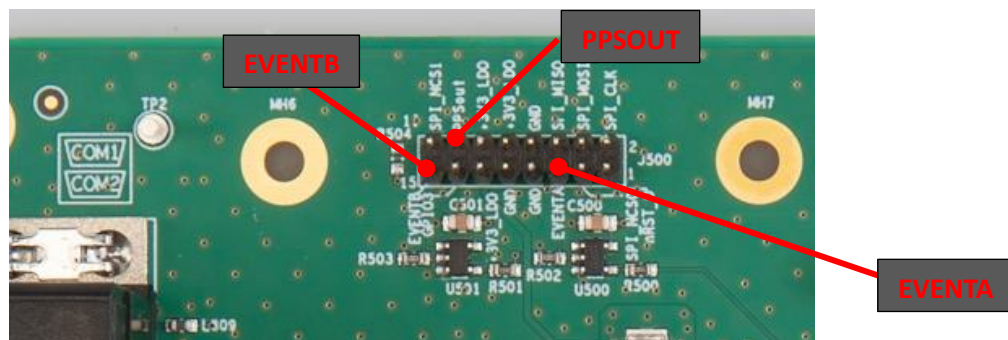


By default, the four COM ports of the mosaic-X5 module are routed to the four DB9 connectors of the DevKit. Electrical levels on the DB9 conform to the RS232 standard. RTS/CTS lines are supported only on COM2 and COM3 (the mosaic-X5 has RTS/CTS lines on COM1 as well, but they are not routed to the DevKit). Connection to a PC is done through a null-modem cable.

Alternatively, 3.3V TTL signals are available through four 6-pin headers, as shown below. The pinout is compatible with standard FTDI 6-pin SIL connectors. To route a COM port to the 6-pin header instead of the DB9 connector, a jumper must be placed on J800 (COM1), J801 (COM2), J804 (COM3) and/or J805 (COM4). Only those COM ports for which the jumper is placed are routed to the 6-pin header. The other COM ports are still routed to the DB9 connectors, using the RS232 levels.



## 6.5 PPS Out and Event Inputs



The PPSout pin of header J500 is connected to the PPSOUT pin of the mosaic-X5 module through a 1.8V to 3.3V level shifter. The PPS level at the header is 3.3V.

The EVENTA and EVENTB pins of J500 are connected to the EventA and EventB pins of the mosaic-X5 through a level shifter to 1.8V. The voltage level at the header pins must be between -0.5V and +6V. These pins are pulled-down by a 100kOhm resistor.

## 6.6 Ethernet

The DevKit supports 10/100 Base-T Ethernet. It is not possible to power the DevKit through the Ethernet connector.

## 6.7 USB Dev

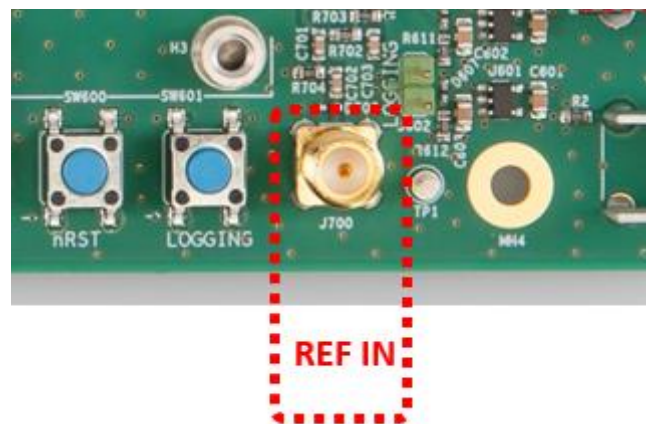
That connector can be attached to a PC to power the DevKit and to communicate with the module over its USB port.

## 6.8 USB Host

Reserved.

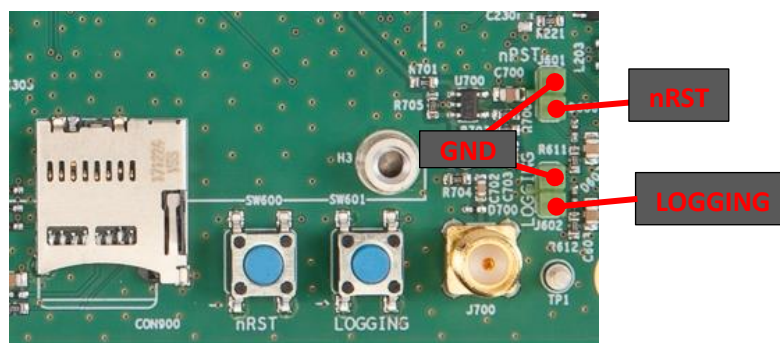
## 6.9 REF IN

The REF IN SMA connector can be used to feed the module with an external 10-MHz sinusoidal frequency reference.



Input impedance: 50  $\Omega$ .  
Input level: between -10dBm and +14dBm (0.2Vp-p to 3.2Vp-p).

## 6.10 Buttons



Pressing the nRST button drives the nRST pin of the mosaic-X5 low, which resets the module.

Pressing the LOGGING button drives the LOGBUTTON pin of the mosaic-X5 low. This can be used to enable and disable logging, as described in section 3.6.

The buttons are also connected to J601 and J602 2-pin headers (see above picture). Connecting the nRST or LOGGING pins of these headers to ground is the same as pressing the respective button.

## 6.11 SD Card Socket

The module can log files on the micro SD Card in this socket. See section 3.6 for a description of the SD Card logging on the mosaic-X5 module.

## Appendix A LED Status Indicators

The LED pins can be used to monitor the module status. They can be used to drive external LEDs. It is assumed that the LED lights when the electrical level of the corresponding pin is high.

The general-purpose LED (GPLED pin) is configured with the **setLEDMode** command. The following modes are supported. The default mode is "PVTLED".

| GPLED mode                                         | LED Behaviour                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|---------------------------------------|----------------------------------------------------|---------------------------------------------|----------------------------------------------------|------|---------------------------|------|-----------------------------|------|-----------------------------|------|-----------------------------|-----------|-----------------------------|-----------|
| PVTLED                                             | LED lights when a PVT solution is available.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| DIFFCORLED                                         | <p>Differential correction indicator. In rover PVT mode, this LED reports the number of satellites for which differential corrections have been provided in the last received differential correction message (RTCM or CMR).</p> <table> <tr> <th>LED behaviour</th><th>Number of satellites with corrections</th></tr> <tr> <td>LED is off</td><td>No differential correction message received</td></tr> <tr> <td>blinks fast and continuously (10 times per second)</td><td>0</td></tr> <tr> <td>blinks once, then pauses</td><td>1, 2</td></tr> <tr> <td>blinks twice, then pauses</td><td>3, 4</td></tr> <tr> <td>blinks 3 times, then pauses</td><td>5, 6</td></tr> <tr> <td>blinks 4 times, then pauses</td><td>7, 8</td></tr> <tr> <td>blinks 5 times, then pauses</td><td>9 or more</td></tr> </table> <p>The LED is solid 'ON' when the module is outputting differential corrections as a static base station.</p> | LED behaviour | Number of satellites with corrections | LED is off                                         | No differential correction message received | blinks fast and continuously (10 times per second) | 0    | blinks once, then pauses  | 1, 2 | blinks twice, then pauses   | 3, 4 | blinks 3 times, then pauses | 5, 6 | blinks 4 times, then pauses | 7, 8      | blinks 5 times, then pauses | 9 or more |
| LED behaviour                                      | Number of satellites with corrections                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| LED is off                                         | No differential correction message received                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks fast and continuously (10 times per second) | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks once, then pauses                           | 1, 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks twice, then pauses                          | 3, 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks 3 times, then pauses                        | 5, 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks 4 times, then pauses                        | 7, 8                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks 5 times, then pauses                        | 9 or more                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| TRACKLED                                           | <table> <tr> <th>LED behaviour</th><th>Number of satellites in tracking</th></tr> <tr> <td>blinks fast and continuously (10 times per second)</td><td>0</td></tr> <tr> <td>blinks once, then pauses</td><td>1, 2</td></tr> <tr> <td>blinks twice, then pauses</td><td>3, 4</td></tr> <tr> <td>blinks 3 times, then pauses</td><td>5, 6</td></tr> <tr> <td>blinks 4 times, then pauses</td><td>7, 8</td></tr> <tr> <td>blinks 5 times, then pauses</td><td>9 or more</td></tr> </table>                                                                                                                                                                                                                                                                                                                                                                                                                                       | LED behaviour | Number of satellites in tracking      | blinks fast and continuously (10 times per second) | 0                                           | blinks once, then pauses                           | 1, 2 | blinks twice, then pauses | 3, 4 | blinks 3 times, then pauses | 5, 6 | blinks 4 times, then pauses | 7, 8 | blinks 5 times, then pauses | 9 or more |                             |           |
| LED behaviour                                      | Number of satellites in tracking                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks fast and continuously (10 times per second) | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks once, then pauses                           | 1, 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks twice, then pauses                          | 3, 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks 3 times, then pauses                        | 5, 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks 4 times, then pauses                        | 7, 8                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |
| blinks 5 times, then pauses                        | 9 or more                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |               |                                       |                                                    |                                             |                                                    |      |                           |      |                             |      |                             |      |                             |           |                             |           |

The LOGLED reports the SD card mount status and logging activity.

| LED    | LED Behaviour                                                                                                                                            |
|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| LOGLED | LED is off when the SD card is not present or not mounted.<br>LED is on when the SD card is present and mounted. Short blinks indicate logging activity. |

## Appendix B System Noise Figure and C/N0

The system noise figure, in dB, can be calculated as:

$$NF_{sys} = 10 \cdot \log_{10}(10^{NF_{ant}/10} + (10^{NF_{rx}/10} - 1)/10^{G_{preamp}/10})$$

where

- $NF_{ant}$  is the antenna LNA noise figure, in dB;
- $NF_{rx}$  is the module noise figure, in dB, as in section 3.2;
- $G_{preamp}$  is the net pre-amplification in front of the module, in dB.

For example, with a 2.5-dB antenna LNA noise figure, 30-dB antenna LNA gain and 15-dB cable loss,  $G_{preamp} = 30\text{dB} - 15\text{dB} = 15\text{dB}$  and  $NR_{rx}$  is 8.5dB (see table in section 3.2). In this case, the system noise figure is:

$$NF_{sys} = 10 \cdot \log_{10}(10^{2.5/10} + (10^{8.5/10} - 1)/10^{15/10}) = 2.95 \text{ dB}.$$

The C/N0, in dB-Hz, of a GNSS signal received at a power P can be computed by:

$$C/N0 = P - 10 \cdot \log_{10}(T_{ant} + 290 \cdot (10^{NF_{sys}/10} - 1)) + 228.6 \text{ dB}$$

where

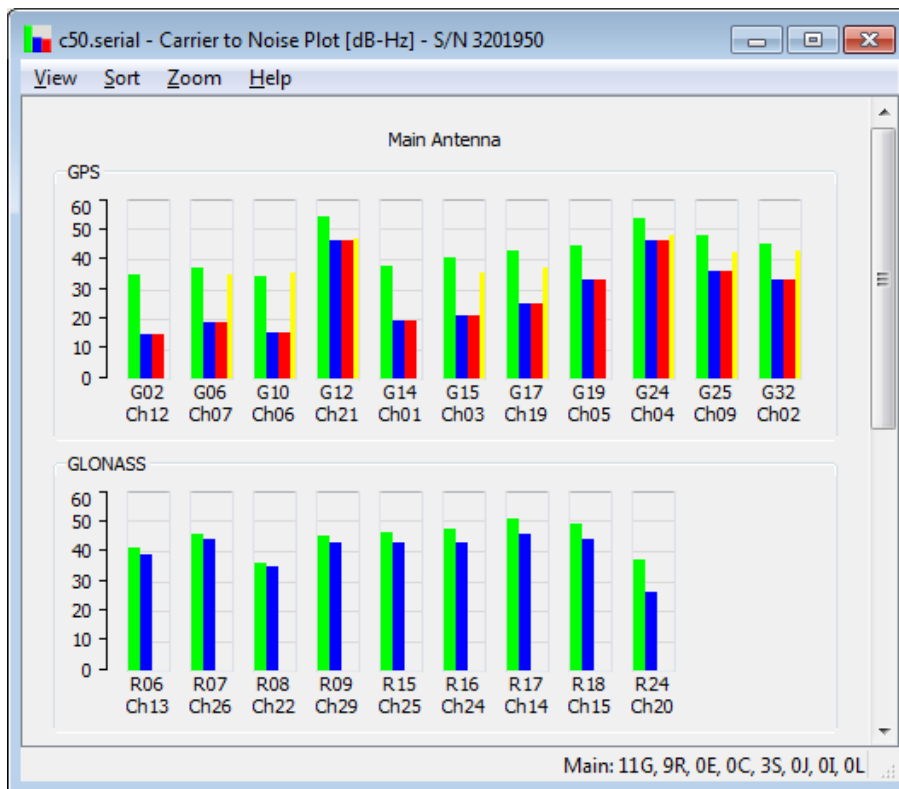
- P is the received GNSS signal power including the gain of the antenna passive radiating element, in dBW (e.g. -155dBW)
- $T_{ant}$  is the antenna noise temperature, in Kelvin. Typically  $T_{ant} = 130\text{K}$  for an open-sky antenna.
- 228.6 is  $-10 \cdot \log_{10}(k_B)$  with  $k_B = 1.38 \cdot 10^{-23} \text{ J/K}$  the Boltzmann constant.

Note that, when connecting the module directly to a GNSS simulator, the applicable value for  $NF_{sys}$  is 8.5 dB and  $T_{ant} = 290\text{K}$ .

## Appendix C EMC Considerations

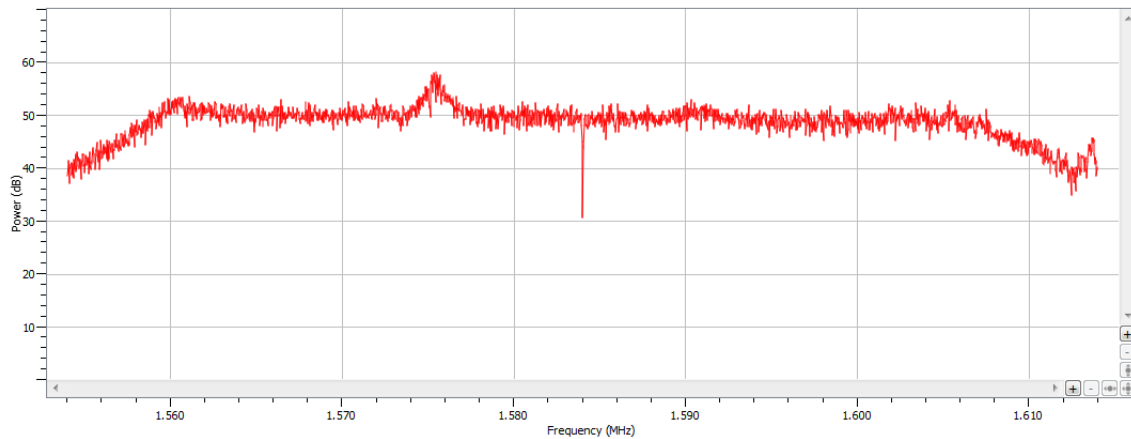
In applications in which the electronics are collocated with the GNSS antenna, cross-talk could be a major concern. GNSS signals are very weak and easily interfered by radiated harmonics of digital signals.

The most useful indicator of the signal reception quality is the C/N0 of the satellites in view. The C/N0 can be viewed in the RxControl graphical interface by clicking *View / Carrier to Noise Plot*. In open-sky conditions, the C/N0 values should reach up to 50 dB-Hz for the strong signals on L1 and L5, and up to 45 dB-Hz on L2, as illustrated below.

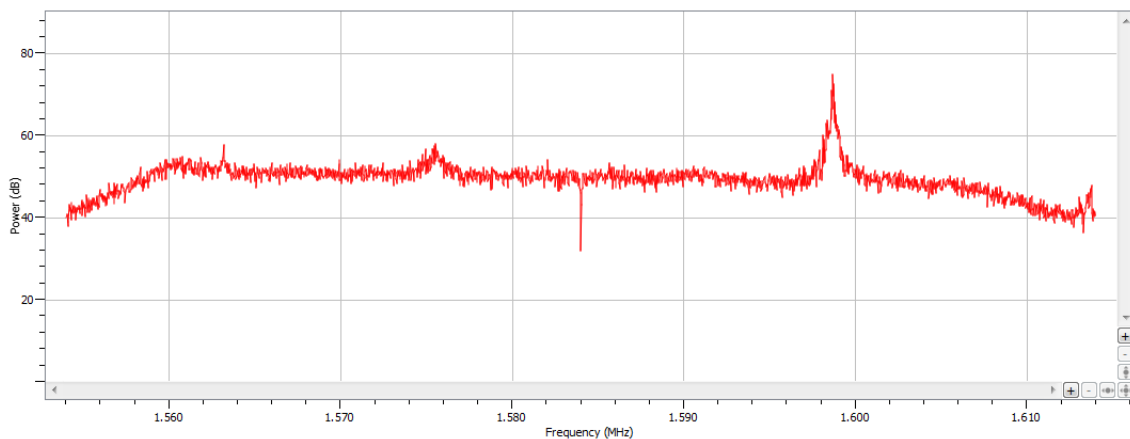


If the maximum C/N0 is lower than expected, interference and cross-talk from nearby electronics is likely, and the source of the problem needs to be identified. This is where the RF spectrum monitor built in the GNSS receiver comes in handy. The spectrum monitor can be accessed in RxControl under the *View / Spectrum View* menu. The spectrum can also be monitored offline if the `BBSamples` SBF blocks are logged.

The figure below shows a clean open-sky L1-band spectrum. The bump at 1575MHz corresponds to the GNSS signals at the L1/E1 frequency, and is normal.

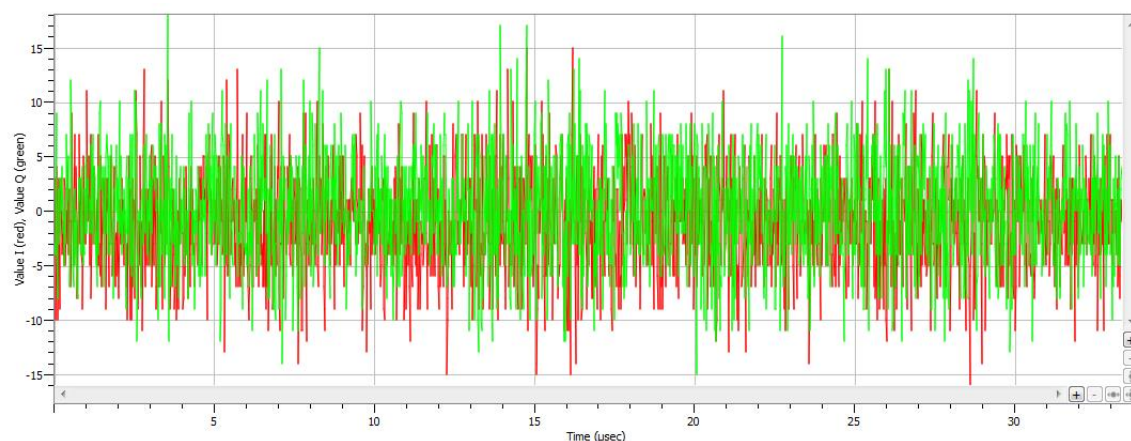


An example of interference is shown below. This particular interference at about 1598 MHz falls in the GLONASS L1 band and slightly degrades the L1 C/N0 of some GLONASS satellites.

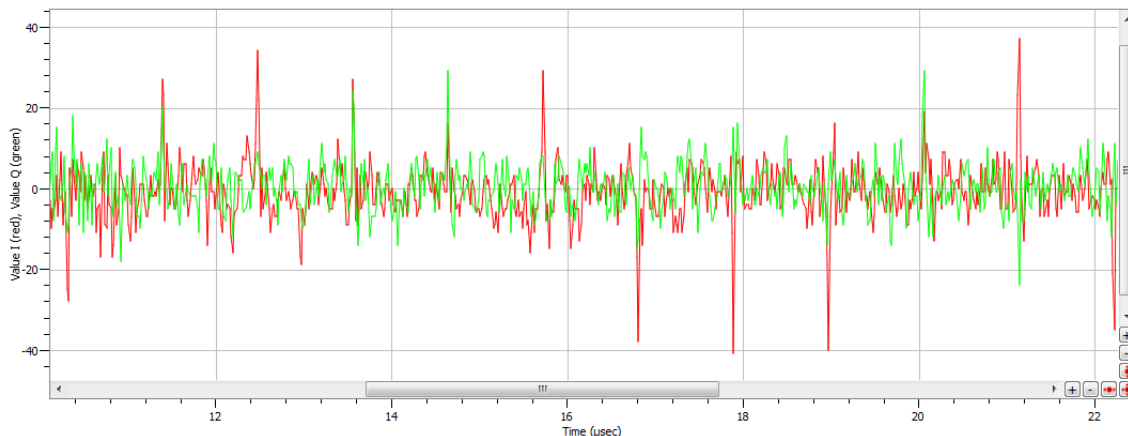


Try to keep personal computers and other equipment more than 2 meters away from the antenna while assessing electromagnetic compatibility of the integration.

RxControl also allows to observe the time domain signal. This should look like white Gaussian noise as illustrated below.



Intermittent interference ( $\mu\text{s}$ -scale) has little impact if its duty cycle is below 10%. For example, these short pulses from a digital circuit close to the antenna are essentially harmless.



If interference is detected, look for the root cause by switching off devices. Typical sources of interference are:

- Unshielded flat cables carrying digital signals or power signals towards digital circuits. Particularly, cable joints tend to radiate.
- High-speed digital devices, such as application processors, modems and cameras.
- Digital signals on the application board (e.g. clock signals, SDIO signals).

If spectral peaks are observed in the spectrum, this usually relates to radiated harmonics. The source can be identified by looking for an integer relation between the observed spectral peaks and the system frequencies. For example, peaks at 1200 and 1248 MHz are an indication of an interfering source at 48 MHz as this maps to the 25<sup>th</sup> and 26<sup>th</sup> harmonic of a 48 MHz signal. This may correspond to the frequency of a microcontroller in the application.

Integration cross-talk can be solved in a number of ways:

- Shift the clock frequency of the interfering signal to avoid the GNSS bands.
- Use shielding tape with conductive adhesive.
- Shield radiating circuits, preferably all around.
- Put digital signals in inner layers of the application board.
- Change the antenna location by experimentation.
- Enable the interference mitigation feature of the GNSS receiver. Narrow spectral peaks can be eliminated with the notch filters (see the **setNotchFiltering** command). Intermittent wide-band cross-talk can often be eliminated with the wide band interference canceller (see the **setWBIMitigation** command).

The mosaic-X5 module has been designed to minimize radiation and can be used close to an antenna without additional shielding.