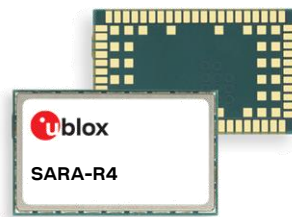


# SARA-R4 series

**Multi-band LTE-M / NB-IoT / EGPRS modules**

System integration manual



## Abstract

This document describes the features and the integration of the size-optimized SARA-R4 series cellular modules. These modules are a complete, cost efficient, performance optimized, multi-mode and multi-band LTE-M / NB-IoT / EGPRS solution in the compact SARA form factor.

# Document information

|                               |   |             |
|-------------------------------|---|-------------|
| <b>Title</b>                  | <b>SARA-R4 series</b>                     |             |
| <b>Subtitle</b>               | Multi-band LTE-M / NB-IoT / EGPRS modules |             |
| <b>Document type</b>          | System integration manual                 |             |
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| <b>Product status</b>                | <b>Corresponding content status</b> |  |
|--------------------------------------|-------------------------------------|--|
| <b>Functional sample</b>             | Draft                               | For functional testing. Revised and supplementary data will be published later.        |
| <b>In development / Prototype</b>    | Objective specification             | Target values. Revised and supplementary data will be published later.                 |
| <b>Engineering sample</b>            | Advance information                 | Data based on early testing. Revised and supplementary data will be published later.   |
| <b>Initial production</b>            | Early production information        | Data from product verification. Revised and supplementary data may be published later. |
| <b>Mass production / End of life</b> | Production information              | Document contains the final product specification.                                     |

This document applies to the following products:

| Product name  | Type number          | Modem version    | Application version | PCN reference | Product status     |
|---------------|----------------------|------------------|---------------------|---------------|--------------------|
| SARA-R410M    | SARA-R410M-01B-00    | L0.0.00.00.02.03 |                     | UBX-18059854  | Obsolete           |
|               | SARA-R410M-02B-00    | L0.0.00.00.05.06 | A02.00              | UBX-18010263  | Obsolete           |
|               |                      | L0.0.00.00.05.06 | A02.01              | UBX-18070443  | Obsolete           |
|               | SARA-R410M-02B-01    | L0.0.00.00.05.08 | A02.04              | UBX-19041392  | End of life        |
|               | SARA-R410M-02B-02    | L0.0.00.00.05.11 | A.02.16             | UBX-20033274  | End of life        |
|               | SARA-R410M-02B-03    | L0.0.00.00.05.12 | A.02.19             | UBX-20058104  | End of life        |
|               | SARA-R410M-02B-04    | L0.0.00.00.05.12 | A.02.21             | UBX-22005059  | Mass production    |
|               | SARA-R410M-52B-00    | L0.0.00.00.06.05 | A02.06              | UBX-18045915  | Obsolete           |
|               | SARA-R410M-52B-01    | L0.0.00.00.06.08 | A02.11              | UBX-19024506  | Mass production    |
|               | SARA-R410M-52B-02    | L0.0.00.00.06.11 | A.02.16             | UBX-20033274  | Mass production    |
|               | SARA-R410M-63B-00    | L0.08.12         | A.01.11             | UBX-20006293  | Obsolete           |
|               | SARA-R410M-63B-01    | L0.08.12         | A.01.12             | UBX-22038590  | End of life        |
|               | SARA-R410M-73B-00    | L0.08.12         | A.01.11             | UBX-20006294  | Obsolete           |
|               | SARA-R410M-73B-01    | L0.08.12         | A.01.12             | UBX-20049254  | Obsolete           |
|               | SARA-R410M-73B-02    | L0.08.12         | A.01.13             | UBX-22038591  | End of life        |
|               | SARA-R410M-83B-00    | L0.08.12         | A01.11              | UBX-20027231  | Obsolete           |
|               | SARA-R410M-83B-01    | L0.08.12         | A.01.12             | UBX-22013661  | End of life        |
| SARA-R412M    | SARA-R412M-02B-00    | M0.09.00         | A.02.11             | UBX-19004091  | Obsolete           |
|               | SARA-R412M-02B-01    | M0.10.00         | A.02.14             | UBX-19016568  | End of life        |
|               | SARA-R412M-02B-02    | M0.11.01         | A.02.17             | UBX-20031249  | End of life        |
|               | SARA-R412M-02B-03    | M0.12.00         | A.02.19             | UBX-20058105  | End of life        |
|               | SARA-R412M-02B-04    | M0.12.00         | A.02.21             | UBX-22005058  | Mass production    |
| SARA-R422     | SARA-R422-00B-00     | 00.12            | A00.00              | UBX-21016086  | Mass production    |
|               | SARA-R422-01B-00     | 01.24            | A01.00              | UBX-22022409  | Initial Production |
| SARA-R422S    | SARA-R422S-00B-00    | 00.12            | A00.00              | UBX-21016086  | Mass production    |
|               | SARA-R422S-01B-00    | 01.24            | A01.00              | UBX-22022409  | Initial Production |
| SARA-R422M8S  | SARA-R422M8S-00B-00  | 00.12            | A00.00              | UBX-21016086  | Mass production    |
| SARA-R422M10S | SARA-R422M10S-01B-00 | 01.24            | A01.00              | UBX-22022409  | Initial Production |

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# 1 System description

## 1.1 Overview

The SARA-R4 series modules are a multi-band LTE-M / NB-IoT / EGPRS multi-mode solution in the miniature SARA LGA form factor (26.0 x 16.0 mm, 96-pin). They allow an easy integration into compact designs and a seamless drop-in migration from other u-blox cellular module families.

SARA-R4 series modules provide software-based multi-band configurability enabling international multi-regional coverage in LTE-M / NB-IoT and IGPRS radio access technologies.

SARA-R4 series modules offer data communications over an extended operating temperature range of -40 °C to +85 °C, with low power consumption, and with coverage enhancement for deeper range into buildings and basements (and underground with NB-IoT).

SARA-R4 series modules are form-factor compatible with the u-blox LISA, LARA and TOBY cellular module families and are pin-to-pin compatible with the u-blox SARA-N, SARA-G and SARA-U cellular module families. This facilitates migration from other u-blox LPWA, GSM/GPRS, CDMA, UMTS/HSPA and higher LTE categories modules, maximizing customer investments, simplifying logistics, and enabling very short time-to-market.

With many interface options and an integrated IP stack, SARA-R4 series modules are the optimal choice for LPWA applications with low to medium data throughput rates, as well as devices that require long battery lifetimes, such as used in smart metering, smart lighting, telematics, asset tracking, remote monitoring, alarm panels, and connected health.

Secure cloud product versions are available within the SARA-R4 series modules, including a unique and immutable root-of-trust. This provides the foundation for a trusted set of advanced security functionalities. The scalable, pre-shared key management system offers best-in-class data encryption and decryption, both on-device as well as from device-to-cloud. Utilizing the latest (D)TLS stack and cipher suites with hardware-based crypto acceleration provides robust, efficient, and protected communication.

Furthermore, the SARA-R422 series modules support a comprehensive set of 3GPP Rel. 14 features for LTE Cat M1 and Cat NB2 that are relevant for IoT applications.

The dedicated SARA-R422M8S and SARA-R422M10S modules are pre-integrated with the u-blox M8 and with the u-blox M10 GNSS receiver chip respectively and a separate GNSS antenna interface which provides highly reliable, accurate positioning data simultaneously with LTE communication. In addition, the module offers unique hybrid positioning, in which the GNSS position is enhanced with u-blox CellLocate® data, providing location always and everywhere.

Customers can future-proof their solutions by means of Over-The-Air firmware updates, thanks to the uFOTA client/server solution that utilizes LWM2M, a light and compact protocol ideal for IoT.

SARA-R4 series modules will also support VoLTE over Cat M1 and CSFB over 2G RAT. The flexibility extends further through dynamic mode selection as M1-only/preferred or NB-IoT-only/preferred.

| Product version   | Region            | RAT   | Positioning  | Interfaces                                       | Features   | Grade                                  |
|-------------------|-------------------|---|--|--|--|--|
|                   |                   | 3GPP release baseline<br>3GPP LTE category<br>LTE FDD bands<br>(E)GPRS 4-band | Integrated GNSS receiver<br>External GNSS control via modem<br>AssistNow software<br>CellLocate® | UART<br>USB<br>SPI<br>SDIO<br>DDC (I2C)<br>GPIOs | Security services<br>Root of trust: secure element<br>Ultra-low power consumption in PSM<br>Embedded TCP/UDP stack<br>Embedded HTTPS, FTPS, TLS<br>DTLS<br>FW update via serial<br>u-blox Firmware update Over the Air<br>LwM2M device management<br>MQTT<br>Last gasp<br>Jamming detection<br>Antenna dynamic tuning<br>Antenna and SIM detection | Standard<br>Professional<br>Automotive |
| SARA-R410M-01B    | North America     | 13 M1 2,4 5,12  |  | • • • •  | • • • • • • • • • •  | •                                      |
| SARA-R410M-02B    | Multi region      | 13 M1 NB1 *   | • • •  | • • • •  | • • • • • • • • • •  | •                                      |
| SARA-R410M-52B    | North America     | 13 M1 2,4,5 12,13   | • •  | • • • •  | • • • • • • • • • •  | •                                      |
| SARA-R410M-63B    | Japan             | 13 M1 1,8,19  | • • •  | • • • •  | • • • • • • • • • •  | •                                      |
| SARA-R410M-73B    | Korea             | 13 M1 3,5 26  | • • •  | • • • •  | • • • • • • • • • •  | •                                      |
| SARA-R410M-83B    | APAC Multi Region | 13 M1 NB1 3,5,8 20,28   | • • •  | • • • •  | • • • • • • • • • •  | •                                      |
| SARA-R412M-02B    | Multi region      | 13 M1 NB1 **  | • • •  | • • • •  | • • • • • • • • • •  | •                                      |
| SARA-R422-00B     | Multi region      | 14 M1 NB2 ***   | • • •  | • ■ • •  | • • • • • • • • • •  | •                                      |
| SARA-R422-01B     | Multi region      | 14 M1 NB2 ****  | • • •  | • ■ • •  | • • • • • • • • • •  | •                                      |
| SARA-R422S-00B    | Multi region      | 14 M1 NB2 ***   | • • •  | • ■ • •  | • • • • • • • • • •  | •                                      |
| SARA-R422S-01B    | Multi region      | 14 M1 NB2 ****  | • • •  | • ■ • •  | • • • • • • • • • •  | •                                      |
| SARA-R422M8S-00B  | Multi region      | 14 M1 NB2 ***   | • • •  | • ■ • •  | • • • • • • • • • •  | •                                      |
| SARA-R422M10S-01B | Multi region      | 14 M1 NB2 ****  | • • •  | • ■ • •  | • • • • • • • • • •  | •                                      |

• = supported by available FW version

■ = supported for FW update and diagnostic only

\* = LTE bands may include 1, 2, 3, 4, 5, 8, 12, 13, 18, 19, 20, 25, 26, 28

\*\* = LTE bands may include 2, 3, 4, 5, 8, 12, 13, 20, 26, 28

\*\*\* = LTE bands include 1, 2, 3, 4, 5, 8, 12, 13, 20, 25, 26, 28, 66, 85 in M1 and NB2

\*\*\*\* = LTE bands include 1, 2, 3, 4, 5, 8, 12, 13, 18, 19, 20, 25, 26, 28, 66, 85 in M1 and NB2

**Table 1: SARA-R4 series main features summary**


- See [Table 2](#) for the detailed list of Radio Access Technologies (RATs) and bands supported by each product version of the SARA-R4 series modules.
- See [Table 50](#), [Table 52](#), [Table 53](#) and [Table 54](#) for the detailed list of RATs and bands included in each certification approval of the SARA-R4 series modules product versions.
- See [Table 51](#) for the specific model / marketing name of some of the SARA-R41 series modules product versions, as identified by various certification bodies.



SARA-R4 series modules include the following variants / product versions:

- SARA-R410M-01B LTE Cat M1 module,  
mainly designed for operation in LTE bands 2, 4, 5, 12
- SARA-R410M-02B LTE Cat M1 / NB1 module,  
mainly designed for operation in LTE bands 1, 2, 3, 4, 5, 8, 12, 13, 18, 19, 20, 25, 26, 28
- SARA-R410M-52B LTE Cat M1 module,  
mainly designed for operation in LTE bands 2, 4, 5, 12, 13
- Secure Cloud SARA-R410M-63B LTE Cat M1 module,  
mainly designed for operation in LTE bands 1, 8, 19
- Secure Cloud SARA-R410M-73B LTE Cat M1 module,  
mainly designed for operation in LTE bands 3, 5, 26
- Secure Cloud SARA-R410M-83B LTE Cat M1 / NB1 module,  
mainly designed for operation in LTE bands 3, 5, 8, 20, 28
  
- SARA-R412M-02B LTE Cat M1 / NB1 and 2G module,  
mainly designed for operation in LTE bands 2, 3, 4, 5, 8, 12, 13, 20, 28 and 2G 4-band
  
- SARA-R422-00B LTE Cat M1 / NB2 and 2G module,  
designed for operation in LTE bands 1, 2, 3, 4, 5, 8, 12, 13, 20, 25, 26, 28, 66, 85 and 2G 4-band
- SARA-R422-01B LTE Cat M1 / NB2 and 2G module,  
designed for operation in LTE bands 1, 2, 3, 4, 5, 8, 12, 13, 18, 19, 20, 25, 26, 28, 66, 85 and 2G 4-band
- Secure Cloud SARA-R422S-00B LTE Cat M1 / NB2 and 2G module,  
designed for operation in LTE bands 1, 2, 3, 4, 5, 8, 12, 13, 20, 25, 26, 28, 66, 85 and 2G 4-band
- Secure Cloud SARA-R422S-01B LTE Cat M1 / NB2 and 2G module,  
designed for operation in LTE bands 1, 2, 3, 4, 5, 8, 12, 13, 18, 19, 20, 25, 26, 28, 66, 85 and 2G 4-band
- Secure Cloud SARA-R422M8S LTE Cat M1 / NB2 and 2G module with UBX-M8 GNSS inside,  
designed for operation in LTE bands 1, 2, 3, 4, 5, 8, 12, 13, 20, 25, 26, 28, 66, 85 and 2G 4-band
- Secure Cloud SARA-R422M10S LTE Cat M1 / NB2 and 2G module with UBX-M10 GNSS inside,  
designed for operation in LTE bands 1, 2, 3, 4, 5, 8, 12, 13, 18, 19, 20, 25, 26, 28, 66, 85 and 2G 4-band

[Table 2](#) summarizes cellular radio access technologies characteristics and features of the modules.

 See [Table 50](#), [Table 52](#), [Table 53](#) and [Table 54](#) for the detailed list of RATs and bands included in each certification approval of the SARA-R4 series modules product versions.

| Item           | SARA-R410M  | SARA-R412M  | SARA-R422 / SARA-R422S<br>SARA-R422M8S / SARA-R422M10S   |
|----------------|---|---|--|
| Protocol stack | 3GPP Release 13   | 3GPP Release 13   | 3GPP Release 14  |
| RAT            | LTE Cat M1<br>LTE Cat NB1 <sup>1, 3, 4, 6</sup>   | LTE Cat M1<br>LTE Cat NB1<br>2G GPRS / EGPRS  | LTE Cat M1<br>LTE Cat NB2<br>2G GPRS / EGPRS   |
| LTE FDD bands  | Band 1 (2100 MHz) <sup>1, 4, 7</sup><br>Band 2 (1900 MHz) <sup>6, 7</sup><br>Band 3 (1800 MHz) <sup>1, 4</sup><br>Band 4 (1700 MHz) <sup>6, 7</sup><br>Band 5 (850 MHz)<br>Band 8 (900 MHz) <sup>1, 4</sup><br>Band 12 (700 MHz) <sup>6, 7</sup><br>Band 13 (750 MHz) <sup>1, 6, 7</sup><br>Band 18 (850 MHz) <sup>1, 3, 4, 6, 7</sup><br>Band 19 (850 MHz) <sup>1, 3, 4, 7</sup><br>Band 20 (800 MHz) <sup>1, 4, 6</sup><br>Band 25 (1900 MHz) <sup>1, 2, 3, 4, 5, 6, 7</sup><br>Band 26 (850 MHz) <sup>1, 3, 4, 7</sup><br>Band 28 (700 MHz) <sup>1, 4, 6</sup> | Band 2 (1900 MHz)<br>Band 3 (1800 MHz)<br>Band 4 (1700 MHz)<br>Band 5 (850 MHz)<br>Band 8 (900 MHz)<br>Band 12 (700 MHz)<br>Band 13 (750 MHz)<br>Band 20 (800 MHz)<br>Band 26 (850 MHz) <sup>8</sup><br>Band 28 (700 MHz) <sup>8</sup>                                      | Band 1 (2100 MHz)<br>Band 2 (1900 MHz)<br>Band 3 (1800 MHz)<br>Band 4 (1700 MHz)<br>Band 5 (850 MHz)<br>Band 8 (900 MHz)<br>Band 12 (700 MHz)<br>Band 13 (750 MHz)<br>Band 18 (850 MHz) <sup>9</sup><br>Band 19 (850 MHz) <sup>9</sup><br>Band 20 (800 MHz)<br>Band 25 (1900 MHz)<br>Band 26 (850 MHz)<br>Band 28 (700 MHz)<br>Band 66 (1700 MHz)<br>Band 85 (700 MHz) |
| 2G bands       |   | GSM 850 MHz<br>E-GSM 900 MHz<br>DCS 1800 MHz<br>PCS 1900 MHz  | GSM 850 MHz<br>E-GSM 900 MHz<br>DCS 1800 MHz<br>PCS 1900 MHz   |
| Power class    | LTE Cat M1 / NB1 <sup>10</sup> :<br>Class 3 (23 dBm)  | LTE category M1 / NB1:<br>Class 3 (23 dBm)<br>2G GMSK:<br>Class 4 (33 dBm) in 850/900,<br>Class 1 (30 dBm) in 1800/1900<br>2G 8-PSK:<br>Class E2 (27 dBm) in 850/900,<br>Class E2 (26 dBm) in 1800/1900   | LTE category M1 / NB2:<br>Class 3 (23 dBm)<br>2G GMSK:<br>Class 4 (33 dBm) in 850/900,<br>Class 1 (30 dBm) in 1800/1900<br>2G 8-PSK:<br>Class E2 (27 dBm) in 850/900,<br>Class E2 (26 dBm) in 1800/1900  |
| Data rate      | LTE category M1:<br>up to 375 kb/s UL, 300 kb/s DL<br>LTE category NB1 <sup>10</sup> :<br>up to 62.5 kb/s UL, 27.2 kb/s DL  | LTE category M1:<br>up to 375 kb/s UL, 300 kb/s DL<br>LTE category NB1:<br>up to 62.5 kb/s UL, 27.2 kb/s DL<br>GPRS multi-slot class 33 <sup>11</sup> :<br>up to 85.6 kb/s UL, 107 kb/s DL<br>EGPRS multi-slot class 33 <sup>11</sup> :<br>up to 236.8 kb/s UL, 296 kb/s DL | LTE category M1:<br>up to 1119 kbit/s UL, 588 kbit/s DL<br>LTE category NB2:<br>up to 158.5 kbit/s UL, 127 kbit/s DL<br>GPRS multi-slot class 33 <sup>11</sup> :<br>up to 85.6 kb/s UL, 107 kb/s DL<br>EGPRS multi-slot class 33 <sup>11</sup> :<br>up to 236.8 kb/s UL, 296.0 kb/s DL   |
| GNSS receiver  |   |   | SARA-R422M8S only:<br>u-blox M8, up to 3 concurrent GNSS<br>(GPS, GLONASS, BeiDou, Galileo)<br>SARA-R422M10S only:<br>u-blox M10, up to 4 concurrent GNSS<br>(GPS, GLONASS, BeiDou, Galileo)   |

**Table 2: SARA-R4 series modules cellular and GNSS characteristics summary**
<sup>1</sup> Not supported by the SARA-R410M-01B product version.

<sup>2</sup> Not supported by the SARA-R410M-02B-00 product version.

<sup>3</sup> Not supported by the SARA-R410M-52B-00 product version.

<sup>4</sup> Not supported by the SARA-R410M-52B-01 and SARA-R410M-52B-02 product version.

<sup>5</sup> Not supported in NB-IoT by SARA-R410M-02B-01, SARA-R410M-02B-02, SARA-R410M-02B-03, or SARA-R410M-02B-04.

<sup>6</sup> Not supported by the SARA-R410M-63B or SARA-R410M-73B product versions.

<sup>7</sup> Not supported by the SARA-R410M-83B product version.

<sup>8</sup> Not supported by the SARA-R412M-02B-00 product version.

<sup>9</sup> Not supported by the SARA-R422-00B, SARA-R422S-00B, or SARA-R422M8S-00B product versions.

<sup>10</sup> LTE Cat NB1 not supported by SARA-R410M-01B, SARA-R410M-52B, SARA-R410M-63B, or SARA-R410M-73B versions.

<sup>11</sup> GPRS/EGPRS multi-slot class 33 implies a maximum of 5 slots in Down-Link and 4 slots in Up-Link with 6 slots in total.

## 1.2 Architecture

Figure 1 summarizes the internal architecture of SARA-R410M and SARA-R412M modules.

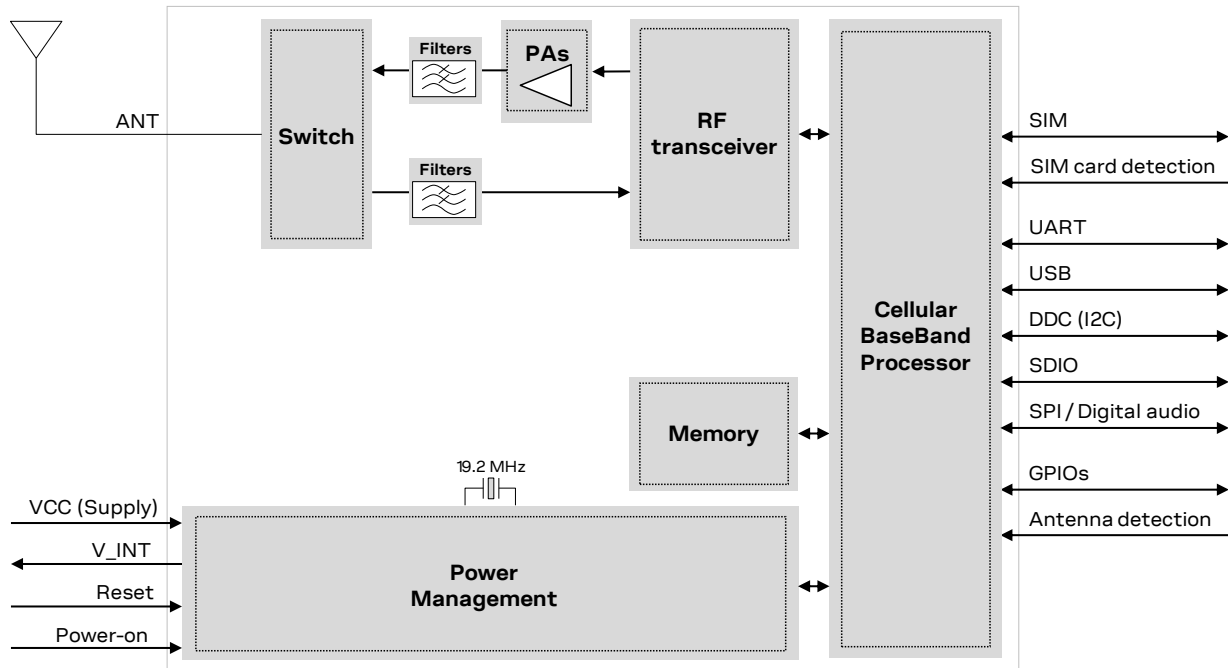


Figure 1: SARA-R410M and SARA-R412M modules simplified block diagram

The SARA-R410M-01B modules, i.e. the “01B” product version of the SARA-R410M modules, do not support the following interfaces, which should be left unconnected and should not be driven by external devices:

- DDC (I2C) interface
- SDIO interface
- SPI interface
- Digital audio interface

The SARA-R410M-02B, the SARA-R410M-52B, the SARA-R410M-63B, the SARA-R410M-73B, the SARA-R410M-83B, the SARA-R412M-02B modules, i.e. the “02B”, “52B”, “63B”, “73B” and “83B” product versions of the SARA-R410M and SARA-R412M modules, do not support the following interfaces, which should be left unconnected and should not be driven by external devices:

- SDIO interface
- SPI interface
- Digital audio interface

Figure 2 summarizes the internal architecture of SARA-R422-00B and SARA-R422S-00B modules.

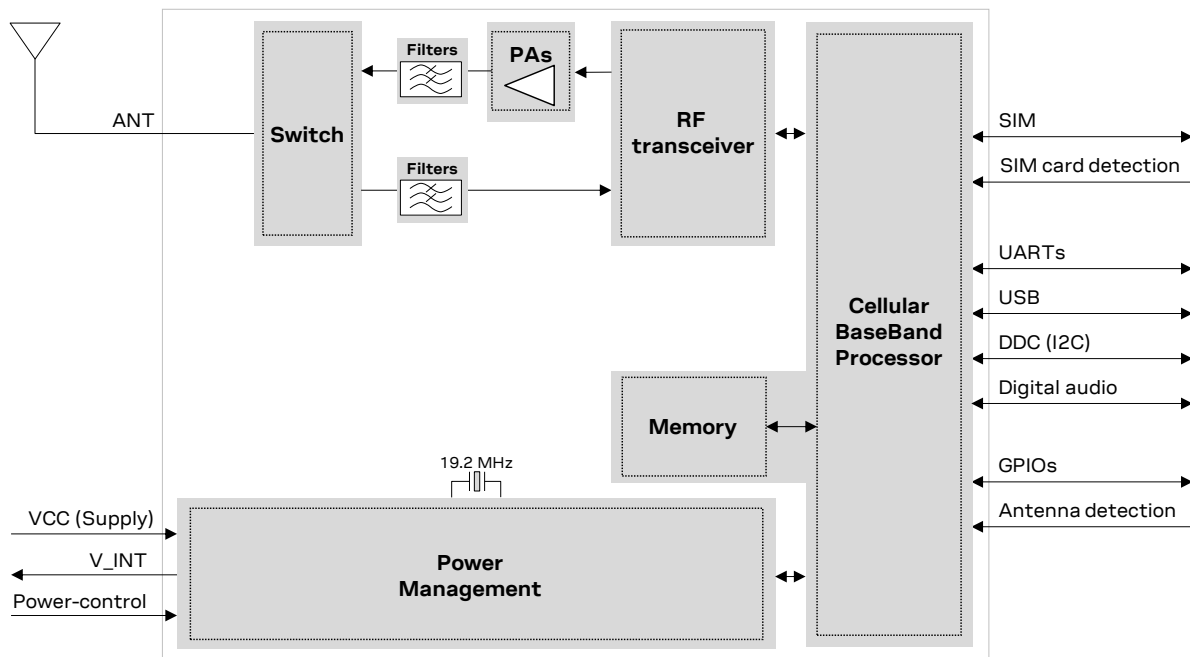


Figure 2: SARA-R422-00B and SARA-R422S-00B modules simplified block diagram

Figure 3 summarizes the internal architecture of SARA-R422M8S modules.

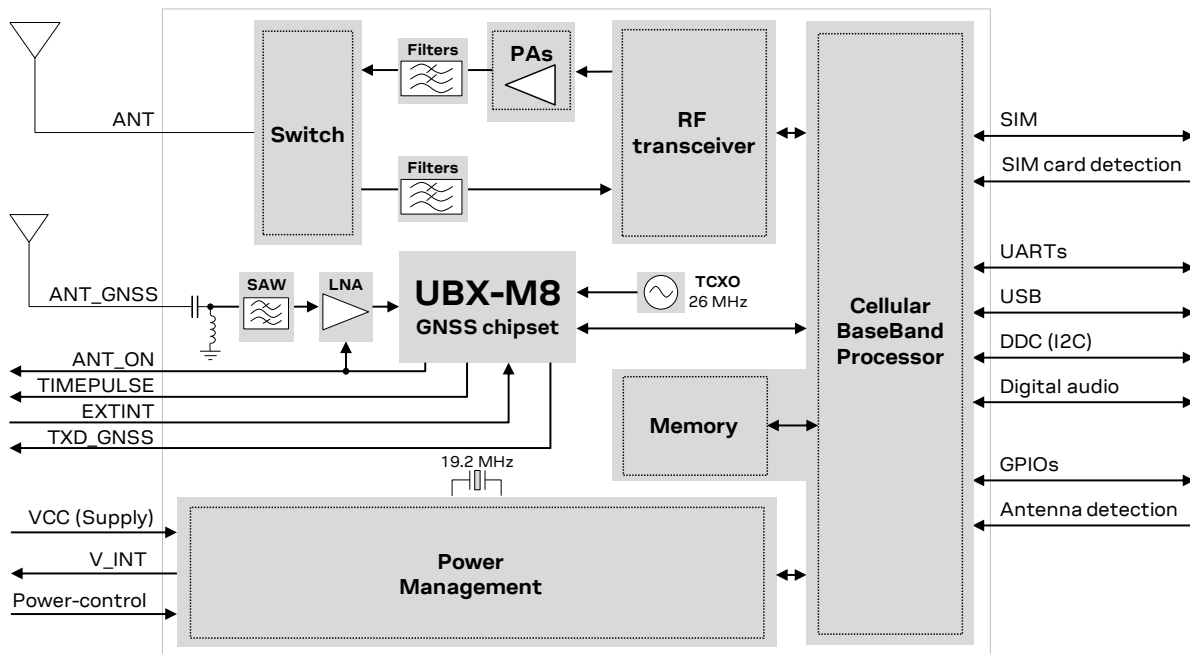


Figure 3: SARA-R422M8S modules simplified block diagram

SARA-R422-00B, SARA-R422S-00B and SARA-R422M8S-00B modules, i.e. the “00B” product versions of SARA-R422, SARA-R422S and SARA-R422M8S modules, do not support the following interfaces, which should be left unconnected and should not be driven by external devices:

- Digital audio interface

Figure 4 summarizes the internal architecture of SARA-R422-01B and SARA-R422S-01B modules.

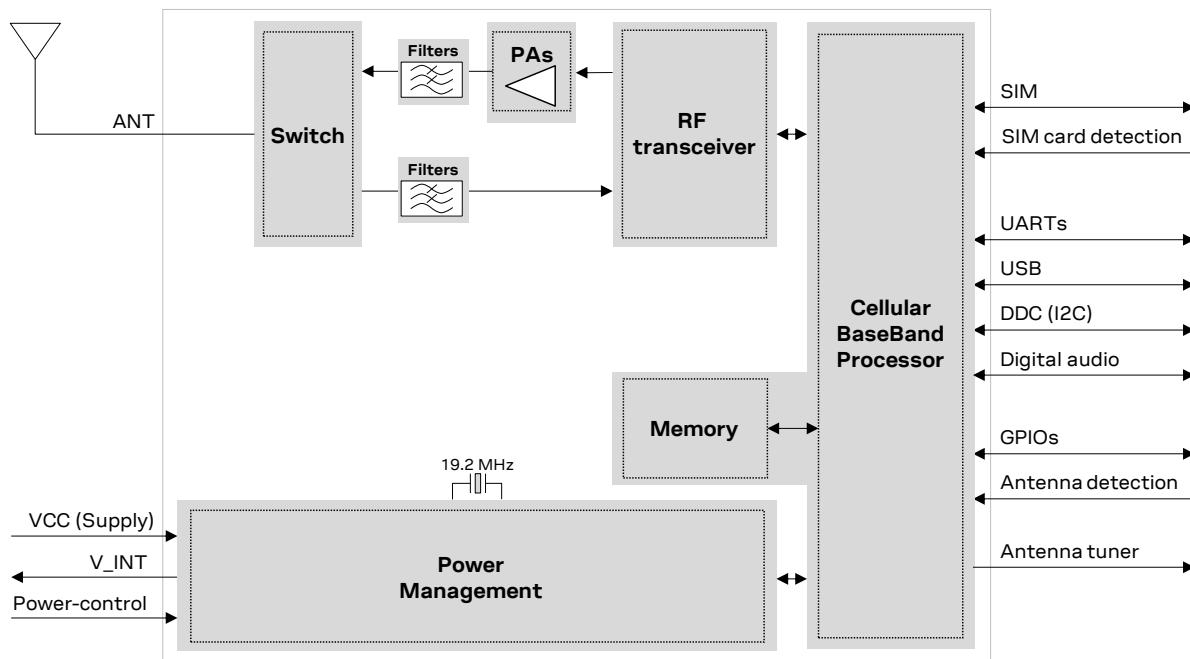


Figure 4: SARA-R422-01B and SARA-R422S-01B modules' simplified block diagram

Figure 5 summarizes the internal architecture of SARA-R422M10S modules.

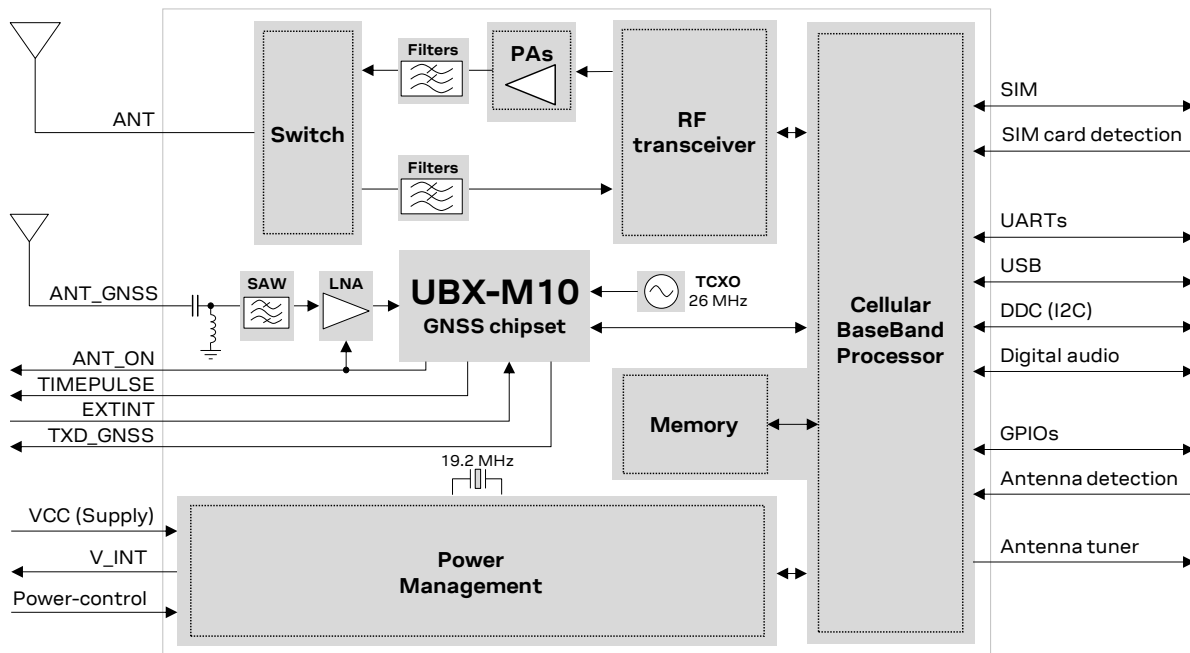


Figure 5: SARA-R422M10S modules' simplified block diagram

The SARA-R422-01B, the SARA-R422S-01B, and the SARA-R422M10S-01B modules, i.e. the “01B” product versions of these SARA-R4 series modules, do not support the following interfaces, which should be left unconnected and should not be driven by external devices:

- Digital audio interface

Below is a detailed description of SARA-R4 series modules sections shown in figures above.

### Cellular RF section

The cellular RF section is composed of the following main elements:

- RF switch connecting the antenna port (**ANT**) to the suitable RF Tx / Rx paths
- Power Amplifiers (PA) amplifying the Tx signal modulated and pre-amplified by the RF transceiver
- RF filters along the Tx and Rx signal paths providing RF filtering
- RF transceiver, performing modulation, up-conversion and pre-amplification of baseband signals for transmission, and performing down-conversion and demodulation of RF signals for reception
- 19.2 MHz crystal oscillator generating the reference clock signal for the RF transceiver and the baseband system, when the related system is in active mode or connected mode.

### Baseband and power management section

The baseband and power management section, is composed of the following main elements:

- On-chip modem processor, vector signal processor, with dedicated hardware assistance for signal processing and system timing
- On-chip modem processor, with interfaces control functions
- On-chip voltage regulators to derive all the internal or external (**V\_SIM**, **V\_INT**) supply voltages from the module supply input **VCC**
- Dedicated flash memory IC
- Calibrated low frequency RC oscillator to provide the clock reference in the low power idle mode, which can be enabled using the +UPSV AT command, and in the PSM / eDRX deep-sleep mode, which can be enabled using the +CPSMS / +UPSMVER AT commands

### GNSS section (SARA-R422M8S and SARA-R422M10S modules only)

The GNSS section, is composed of the following main elements illustrated in [Figure 6](#):

- u-blox UBX-M8030-CT concurrent GNSS chipset with SPG 3.01 FW version on SARA-R422M8S
- u-blox UBX-M10050-KB concurrent GNSS chipset with SPG 5.10 FW version on SARA-R422M10S
- Dedicated SAW filter and additional Low Noise Amplifier (LNA)
- 26 MHz Temperature-Controlled Crystal Oscillator (TCXO) generating the GNSS reference clock

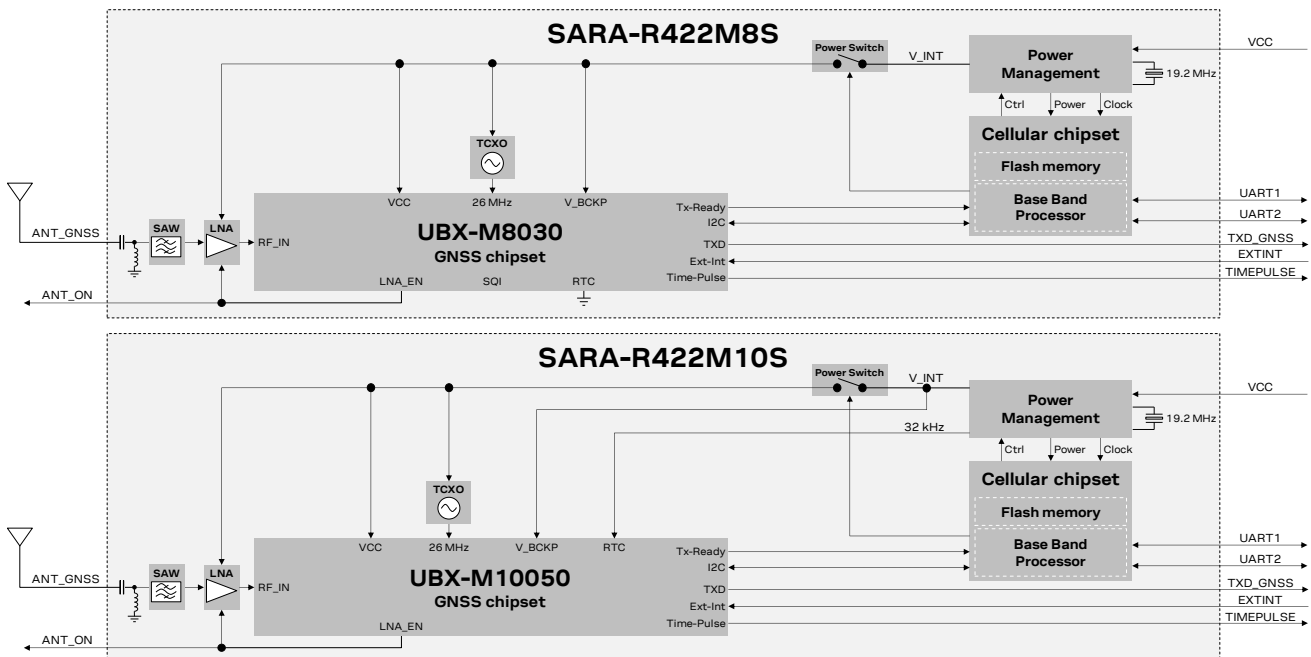


Figure 6: SARA-R422M8S and SARA-R422M10S modules GNSS section block diagram

## 1.3 Pin-out

Table 3 lists the pin-out of the SARA-R4 series modules, with pins grouped by function.

| Function | Pin Name               | Pin No  | I/O | Description                              | Remarks  |
|----------|------------------------|---|-----|--|--|
| Power    | VCC                    | 51,52,53  | I   | Module supply input                      | VCC supply circuit affects the RF performance and compliance of the device integrating the module with applicable required certification schemes.<br>See section 1.5.1 for functional description / requirements.<br>See section 2.2.1 for external circuit design-in.   |
|          | GND                    | 1,3,5,14, 20-22,30, 32,43,50, 54,55, 57-61, 63-96 | N/A | Ground                                   | GND pins are internally connected each other.<br>External ground connection affects the RF and thermal performance of the device.<br>See section 1.5.1 for functional description.<br>See section 2.2.1 for external circuit design-in.  |
|          | V_INT                  | 4   | O   | Generic digital interfaces supply output | V_INT = 1.8 V (typical) generated by internal regulator when the module is switched on, outside the low power PSM deep sleep mode.<br>Test-Point for diagnostic / FW update strongly recommended.<br>See section 1.5.2 for functional description.<br>See section 2.2.2 for external circuit design-in.                          |
| System   | PWR_ON <sup>12</sup>   | 15  | I   | Power-on / -off input                    | Internal 200 kΩ pull-up resistor.<br>Test-Point for diagnostic / FW update strongly recommended.<br>See section 1.6.1 and 1.6.2 for functional description.<br>See section 2.3.1 for external circuit design-in.   |
|          | PWR_CTRL <sup>13</sup> | 15  | I   | Power-on / -off / Reset input            | Internal pull-up resistor.<br>Test-Point for diagnostic / FW update strongly recommended.<br>See section 1.6.1, 1.6.2 and 1.6.3 for functional description.<br>See section 2.3.1 for external circuit design-in.   |
|          | RESET_N <sup>12</sup>  | 18  | I   | Reset input                              | Internal 37 kΩ pull-up resistor.<br>Test-Point for diagnostic access is recommended.<br>See section 1.6.3 for functional description.<br>See section 2.3.2 for external circuit design-in.   |
| Antenna  | ANT                    | 56  | I/O | Cellular antenna RF input/output         | RF input/output for external Cellular antenna.<br>50 Ω nominal characteristic impedance.<br>Antenna circuit affects the RF performance and application device compliance with required certification schemes.<br>See section 1.7.1 for functional description / requirements.<br>See section 2.4 for external circuit design-in. |
|          | ANT_GNSS <sup>14</sup> | 31  | I   | GNSS antenna RF input                    | RF input for external GNSS antenna.<br>50 Ω nominal characteristic impedance.<br>See section 1.7.2 for functional description / requirements.<br>See section 2.4.3 for external circuit design-in.   |
|          | ANT_DET                | 62  | I   | Antenna detection                        | ADC for antenna presence detection function<br>See section 1.7.3 for functional description.<br>See section 2.4.5 for external circuit design-in.  |

<sup>12</sup> SARA-R410M, SARA-R412M modules only

<sup>13</sup> SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules only

<sup>14</sup> SARA-R422M8S, SARA-R422M10S modules only

| Function | Pin Name | Pin No | I/O   | Description                | Remarks   |
|----------|----------|--------|-------|----------------------------|---|
| SIM      | VSIM     | 41     | O     | SIM supply output          | Supply output for external SIM / UICC.<br>See section 1.8 for functional description.<br>See section 2.5 for external circuit design-in.  |
|          | SIM_IO   | 39     | I/O   | SIM data                   | Data input/output for external SIM / UICC.<br>Internal 4.7 kΩ pull-up to VSIM.<br>See section 1.8 for functional description.<br>See section 2.5 for external circuit design-in.  |
|          | SIM_CLK  | 38     | O     | SIM clock                  | Clock output for external SIM / UICC<br>See section 1.8 for functional description.<br>See section 2.5 for external circuit design-in.  |
|          | SIM_RST  | 40     | O     | SIM reset                  | Reset output for 1.8 V / 3 V SIM<br>See section 1.8 for functional description.<br>See section 2.5 for external circuit design-in.  |
| UART     | RXD      | 13     | O     | UART data output           | 1.8 V output, Circuit 104 (RXD) in ITU-T V.24,<br>for AT commands, data communication, FOAT.<br>See section 1.9.1 for functional description.<br>See section 2.6.1 for external circuit design-in.  |
|          | TXD      | 12     | I     | UART data input            | 1.8 V input, Circuit 103 (TXD) in ITU-T V.24,<br>for AT commands, data communication, FOAT.<br>Internal pull-down to GND on the SARA-R410M-02B version<br>Internal pull-up to V_INT on other product versions<br>See section 1.9.1 for functional description.<br>See section 2.6.1 for external circuit design-in. |
|          | CTS      | 11     | O     | UART clear to send output  | 1.8 V output, Circuit 106 (CTS) in ITU-T V.24.<br>Not supported by SARA-R410M-01B, SARA-R410M-02B-00.<br>See section 1.9.1 for functional description.<br>See section 2.6.1 for external circuit design-in.   |
|          | RTS      | 10     | I     | UART ready to send input   | 1.8 V input, Circuit 105 (RTS) in ITU-T V.24.<br>Internal active pull-up to V_INT.<br>Not supported by SARA-R410M-01B, SARA-R410M-02B-00.<br>See section 1.9.1 for functional description.<br>See section 2.6.1 for external circuit design-in.   |
|          | DSR      | 6      | O / I | UART DSR / AUX UART RTS    | 1.8 V, Circuit 107 (Data Set Ready output) in ITU-T V.24,<br>configurable as Second Auxiliary UART RTS input. <sup>15</sup><br>See section 1.9.1 for functional description.<br>See section 2.6.1 for external circuit design-in.   |
|          | RI       | 7      | O / O | UART RI / AUX UART CTS     | 1.8 V, Circuit 125 (Ring Indicator output) in ITU-T V.24,<br>configurable as Second Auxiliary UART CTS output. <sup>15</sup><br>See section 1.9.1 for functional description.<br>See section 2.6.1 for external circuit design-in.  |
|          | DTR      | 9      | I / I | UART DTR / AUX UART input  | 1.8 V, Circuit 108/2 (Data Terminal Ready input) in ITU-T V.24,<br>configurable as Second Auxiliary UART data input. <sup>15</sup><br>Internal active pull-up to V_INT.<br>See section 1.9.1 for functional description.<br>See section 2.6.1 for external circuit design-in.                                       |
|          | DCD      | 8      | O / O | UART DCD / AUX UART output | 1.8 V, Circuit 109 (Data carrier detect output) in ITU-T V.24,<br>configurable as Second Auxiliary UART data output. <sup>15</sup><br>See section 1.9.1 for functional description.<br>See section 2.6.1 for external circuit design-in.  |

<sup>15</sup> The Second Auxiliary UART interface is not supported by SARA-R410M and SARA-R412M modules



| Function | Pin Name                         | Pin No | I/O | Description      | Remarks  |
|----------|----------------------------------|--------|-----|------------------|--|
| USB      | VUSB_DET <sup>16</sup>           | 17     | I   | USB detect input | VBUS (5 V typ.) sense input pin to enable the USB interface.<br>Test-Point for diagnostic / FW update strongly recommended.<br>See section 1.9.2 for functional description.<br>See section 2.6.2 for external circuit design-in.  |
|          | USB_5V0 <sup>17</sup>            | 17     | I   | USB detect input | VBUS (5 V typ.) sense input pin to enable the USB interface.<br>Test-Point for diagnostic / FW update strongly recommended.<br>See section 1.9.2 for functional description.<br>See section 2.6.2 for external circuit design-in.  |
|          | USB_3V3 <sup>17</sup>            | 2      | I   | USB 3V3 input    | 3.3 V (typical) supply input pin to supply the USB interface.<br>Test-Point for diagnostic / FW update strongly recommended.<br>See section 1.9.2 for functional description.<br>See section 2.6.2 for external circuit design-in.   |
|          | USB_D-                           | 28     | I/O | USB Data Line D- | USB interface for AT commands, data communication, FOAT, FW update by u-blox tool, diagnostics.<br>90 $\Omega$ nominal differential impedance ( $Z_0$ )<br>30 $\Omega$ nominal common mode impedance ( $Z_{CM}$ )<br>Pull-up or pull-down resistors and external series resistors as required by the USB 2.0 specifications [6] are part of the USB pin driver and need not be provided externally.<br>Test-Point for diagnostic / FW update strongly recommended.<br>See section 1.9.2 for functional description.<br>See section 2.6.2 for external circuit design-in. |
|          | USB_D+                           | 29     | I/O | USB Data Line D+ | USB interface for AT commands, data communication, FOAT, FW update by u-blox tool, diagnostics.<br>90 $\Omega$ nominal differential impedance ( $Z_0$ )<br>30 $\Omega$ nominal common mode impedance ( $Z_{CM}$ )<br>Pull-up or pull-down resistors and external series resistors as required by the USB 2.0 specifications [6] are part of the USB pin driver and need not be provided externally.<br>Test-Point for diagnostic / FW update strongly recommended.<br>See section 1.9.2 for functional description.<br>See section 2.6.2 for external circuit design-in. |
|          | RSVD                             | 33     | N/A | RESERVED pin     | This pin can be connected to GND by 0 $\Omega$ series jumper.<br>Test-Point for diagnostic strongly recommended.   |
| SPI      | I2S_WA / SPI_MOSI <sup>16</sup>  | 34     | O   | SPI MOSI         | SPI data output,<br>alternatively configurable as 2S word alignment<br>SPI and I2S are not supported by current product versions.<br>See section 1.9.3 for functional description.<br>See section 2.6.3 for external circuit design-in.  |
|          | I2S_RXD / SPI_MISO <sup>16</sup> | 37     | I   | SPI MISO         | SPI data input,<br>alternatively configurable as 2S receive data<br>SPI and I2S are not supported by current product versions.<br>See section 1.9.3 for functional description.<br>See section 2.6.3 for external circuit design-in.   |
|          | I2S_CLK / SPI_CLK <sup>16</sup>  | 36     | O   | SPI clock        | SPI clock, alternatively configurable as I2S clock<br>SPI and I2S are not supported by current product versions.<br>See section 1.9.3 for functional description.<br>See section 2.6.3 for external circuit design-in.   |
|          | I2S_TXD / SPI_CS <sup>16</sup>   | 35     | O   | SPI Chip Select  | SPI Chip Select, alternatively settable as I2S transmit data<br>SPI and I2S are not supported by current product versions.<br>See section 1.9.3 for functional description.<br>See section 2.6.3 for external circuit design-in.   |

<sup>16</sup> SARA-R410M, SARA-R412M modules only

<sup>17</sup> SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules only

| Function | Pin Name               | Pin No | I/O | Description          | Remarks   |
|----------|------------------------|--------|-----|----------------------|---|
| SDIO     | SDIO_D0 <sup>18</sup>  | 47     | I/O | SDIO serial data [0] | SDIO interface is not supported by current product versions. See section 1.9.4 for functional description. See section 2.6.4 for external circuit design-in.  |
|          | SDIO_D1 <sup>18</sup>  | 49     | I/O | SDIO serial data [1] | SDIO interface is not supported by current product versions. See section 1.9.4 for functional description. See section 2.6.4 for external circuit design-in.  |
|          | SDIO_D2 <sup>18</sup>  | 44     | I/O | SDIO serial data [2] | SDIO interface is not supported by current product versions. See section 1.9.4 for functional description. See section 2.6.4 for external circuit design-in.  |
|          | SDIO_D3 <sup>18</sup>  | 48     | I/O | SDIO serial data [3] | SDIO interface is not supported by current product versions. See section 1.9.4 for functional description. See section 2.6.4 for external circuit design-in.  |
|          | SDIO_CLK <sup>18</sup> | 45     | O   | SDIO serial clock    | SDIO interface is not supported by current product versions. See section 1.9.4 for functional description. See section 2.6.4 for external circuit design-in.  |
|          | SDIO_CMD <sup>18</sup> | 46     | I/O | SDIO command         | SDIO interface is not supported by current product versions. See section 1.9.4 for functional description. See section 2.6.4 for external circuit design-in.  |
| DDC      | SCL                    | 27     | O   | I2C bus clock line   | 1.8 V open drain, for communication with I2C devices. Internal pull-up to V_INT: external pull-up is not required. Not supported by SARA-R410M-01B product version. See section 1.9.5 for functional description. See section 2.6.5 for external circuit design-in. |
|          | SDA                    | 26     | I/O | I2C bus data line    | 1.8 V open drain, for communication with I2C devices. Internal pull-up to V_INT: external pull-up is not required. Not supported by SARA-R410M-01B product version. See section 1.9.5 for functional description. See section 2.6.5 for external circuit design-in. |
| Audio    | I2S_TXD <sup>19</sup>  | 35     | O   | I2S transmit data    | I2S digital audio interface transmit data output<br>I2S interface not supported by current product versions. See section 1.9.5 for functional description. See section 2.7 for external circuit design-in.  |
|          | I2S_RXD <sup>19</sup>  | 37     | I   | I2S receive data     | I2S digital audio interface receive data input<br>I2S interface not supported by current product versions. See section 1.9.5 for functional description. See section 2.7 for external circuit design-in.  |
|          | I2S_CLK <sup>19</sup>  | 36     | I/O | I2S clock            | I2S digital audio interface clock<br>I2S interface not supported by current product versions. See section 1.9.5 for functional description. See section 2.7 for external circuit design-in.   |
|          | I2S_WA <sup>19</sup>   | 34     | I/O | I2S word alignment   | I2S digital audio interface word alignment<br>I2S interface not supported by current product versions. See section 1.9.5 for functional description. See section 2.7 for external circuit design-in.  |

<sup>18</sup> SARA-R410M, SARA-R412M modules only

<sup>19</sup> SARA-R422S, SARA-R422M8S, SARA-R422M10S modules only

| Function     | Pin Name                | Pin No          | I/O | Description             | Remarks   |
|--------------|-------------------------|-----------------|-----|-------------------------|---|
| GPIO         | GPIO1                   | 16              | I/O | GPIO                    | 1.8 V GPIO with alternatively configurable functions.<br>See section 1.11 for functional description.<br>See section 2.8 for external circuit design-in.        |
|              | GPIO2                   | 23              | I/O | GPIO                    | 1.8 V GPIO with alternatively configurable functions.<br>See section 1.11 for functional description.<br>See section 2.8 for external circuit design-in.        |
|              | GPIO3                   | 24              | I/O | GPIO                    | 1.8 V GPIO with alternatively configurable functions.<br>See section 1.11 for functional description.<br>See section 2.8 for external circuit design-in.        |
|              | GPIO4                   | 25              | I/O | GPIO                    | 1.8 V GPIO with alternatively configurable functions.<br>See section 1.11 for functional description.<br>See section 2.8 for external circuit design-in.        |
|              | GPIO5                   | 42              | I/O | GPIO                    | 1.8 V GPIO with alternatively configurable functions.<br>See section 1.11 for functional description.<br>See section 2.8 for external circuit design-in.        |
|              | GPIO6                   | 19              | I/O | GPIO                    | 1.8 V GPIO with alternatively configurable functions.<br>See section 1.11 for functional description.<br>See section 2.8 for external circuit design-in.        |
| GNSS<br>PIOs | TXD_GNSS <sup>20</sup>  | 47              | O   | GNSS data output        | GNSS UART data output from internal u-blox GNSS chipset.<br>Test-Point for diagnostic access is recommended.<br>See section 1.13 for functional description.    |
|              | EXTINT <sup>20</sup>    | 46              | I   | GNSS external interrupt | GNSS external interrupt connected to u-blox GNSS chipset.<br>See section 1.13 for functional description.   |
|              | TIMEPULSE <sup>20</sup> | 45              | O   | GNSS Time Pulse         | GNSS time pulse output driven by u-blox GNSS chipset.<br>See section 1.13 for functional description.   |
|              | ANT_ON <sup>20</sup>    | 44              | O   | Antenna / LNA enable    | External GNSS active antenna and/or LNA on/off signal driven by u-blox GNSS chipset, connected to internal LNA.<br>See section 1.13 for functional description. |
| Reserved     | RSVD <sup>21</sup>      | 2               | N/A | Reserved pin            | Internally not connected.<br>See sections 1.14 and 2.10   |
|              | RSVD <sup>22</sup>      | 31              | N/A | Reserved pin            | Internally not connected.<br>See sections 1.14 and 2.10   |
|              | RSVD <sup>23</sup>      | 18,<br>48,49    | N/A | Reserved pin            | Internally not connected.<br>See sections 1.14 and 2.10   |
|              | RSVD <sup>24</sup>      | 34,35,<br>36,37 | N/A | Reserved pin            | Leave unconnected.<br>See sections 1.14 and 2.10  |
|              | RSVD <sup>25</sup>      | 44,45,<br>46,47 | N/A | Reserved pin            | Internally not connected.<br>See sections 1.14 and 2.10   |

**Table 3: SARA-R4 series modules pin definition, grouped by function**
<sup>20</sup> SARA-R422M8S, SARA-R422M10S modules only

<sup>21</sup> SARA-R410M, SARA-R412M modules only

<sup>22</sup> SARA-R410M, SARA-R412M, SARA-R422, SARA-R422S modules only

<sup>23</sup> SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules only

<sup>24</sup> SARA-R422 modules only

<sup>25</sup> SARA-R422, SARA-R422S modules only

## 1.4 Operating modes

SARA-R4 series modules have several operating modes. The operating modes are defined in [Table 4](#) and described in detail in [Table 5](#), providing general guidelines for operation.

| General status   | Operating mode          | Definition   |
|------------------|-------------------------|--|
| Power-down       | <b>Not-powered mode</b> | VCC supply not present or below operating range: module is switched off.         |
|                  | <b>Power-off mode</b>   | VCC supply within operating range and module is switched off.                    |
| Normal Operation | <b>Deep-sleep mode</b>  | Only the RTC runs. The processor and other parts of the module are switched off. |
|                  | <b>Idle mode</b>        | Module processor runs at the minimum frequency to save power consumption.        |
|                  | <b>Active mode</b>      | Module processor runs at normal operating frequency to enable related functions. |
|                  | <b>Connected mode</b>   | RF Tx/Rx enabled with processor running at related operating frequency.          |

**Table 4: SARA-R4 series modules operating modes definition**

| Mode        | Description  | Transition between operating modes   |
|-------------|--|--|
| Not-Powered | Module is switched off.<br>Application interfaces are not accessible.  | When VCC supply is removed, the modules enter not-powered mode.<br>When in not-powered mode, the module can enter power-off mode applying VCC supply (see <a href="#">1.6.1</a> ).   |
| Power-Off   | Module is switched off: normal shutdown by an appropriate power-off event (see <a href="#">1.6.2</a> ).<br>Application interfaces are not accessible.  | The modules enter power-off mode from active mode when the host processor implements a clean switch-off procedure, by sending the +CPWROFF AT command or by using the PWR_ON / PWR_CTRL pin (see <a href="#">1.6.2</a> ).<br>When in power-off mode, the modules can be switched on by the host processor using the PWR_ON / PWR_CTRL input pin (see <a href="#">1.6.1</a> ).<br>When in power-off mode, the modules enter not-powered mode by removing VCC supply.  |
| Deep-Sleep  | Module is in RTC-only mode: only the internal Real Time Clock is active.<br>The RF section and the application interfaces are temporarily disabled and switched off: the module is temporarily not ready to communicate with an external device by means of the application interfaces as configured to reduce the current consumption to the minimum possible (see section <a href="#">1.5.1.4</a> ). | The modules automatically switch from the active mode to the ultra low power deep sleep mode whenever possible, upon expiration of the T3324 active timer set by the network (entering the Power Saving Mode defined in 3GPP Rel.13, depending on the configuration set by +CPSMS AT command), upon expiration of the 6 s AT inactivity timer (depending on the configuration set by the +UPSV AT command), in-between eDRX cycles when not listening to paging (depending on the configuration set by the +UPSMVER AT command), if no concurrent GNSS activities are executed (considering the SARA-R422M10S, SARA-R422M8S and SARA-R422S modules).<br>When the module is in the ultra low power deep sleep mode, it automatically switches on to the active mode upon expiration of the T3412 periodic TAU timer set by the network according to the Power Saving Mode defined in 3GPP Rel.13, it automatically switches on in-between eDRX cycles when listening to paging according to the timing set by the network, or it can be switched on to the active mode by the host processor using the PWR_ON / PWR_CTRL input pin (see <a href="#">1.6.1</a> ).<br>For further details, see u-blox application development guide <a href="#">[4]</a> and the u-blox AT commands manual <a href="#">[2]</a> . |

| Mode      | Description  | Transition between operating modes   |
|-----------|--|--|
| Idle      | Module is switched on with application interfaces temporarily disabled: the module is temporarily not ready to communicate with an external device by means of the application interfaces as configured to reduce the current consumption (see section 1.5.1.5). | <p>The modules automatically switch from the active mode to low power idle mode whenever possible, depending on concurrent activities executed by the module, upon expiration of the 6 seconds AT inactivity timer (with AT+UPSV=4 setting), or upon DTR set to OFF (with AT+UPSV=3 setting), if low power configuration is enabled (see the SARA-R4 series AT commands manual [2], +UPSV AT command).</p> <p>When in low power idle mode, the module switches to the active mode upon data reception over UART serial interface (with AT+UPSV=4 setting, and in this case the first character received in low power idle mode wakes up the system, it is not recognized as valid communication character, and the recognition of the subsequent characters occurs only after the complete system wake-up), or upon DTR set to ON (with AT+UPSV=3 setting).</p>  |
| Active    | Module is switched on with application interfaces enabled or not suspended: the module is ready to communicate with an external device by means of the application interfaces, with related necessary current consumption (see section 1.5.1.6).                 | <p>The modules enter active mode from power-off mode when the host processor implements a clean switch-on procedure by using the PWR_ON / PWR_CTRL pin (see 1.6.1).</p> <p>The modules enter active mode from the ultra low power deep sleep mode upon expiration of the T3412 periodic TAU timer set by the network, to receive the paging in-between eDRX cycles according to the timing set by the network, or if the host processor wakes up the module using the PWR_ON / PWR_CTRL input pin (see 1.6.1).</p> <p>The modules enter power-off mode from active mode when the host processor implements a switch-off procedure (see 1.6.2).</p> <p>The modules automatically switch from active to ultra low power deep sleep mode whenever possible, upon expiration of the T3324 active timer set by the network (depending on +CPSMS AT command setting), upon expiration of the 6 s AT inactivity timer (depending on the +UPSV AT command setting), in-between eDRX cycles when not listening to paging (depending on the +UPSMVER AT command setting), if no concurrent GNSS activities are executed (for SARA-R422M10S, SARA-R422M8S and SARA-R422S).</p> <p>The module switches from active to connected mode when a RF Tx/Rx data connection is initiated or when RF Tx/Rx activity is required due to a connection previously initiated.</p> <p>The module switches from connected to active mode when a RF Tx/Rx data connection is terminated or suspended.</p> |
| Connected | <p>RF Tx/Rx data connection is in progress, with related necessary current consumption (see sections 1.5.1.2 and 1.5.1.3).</p> <p>The module is prepared to accept data signals from an external device.</p>   | <p>When a data connection is initiated, the module enters connected mode from active mode.</p> <p>Connected mode is suspended if Tx/Rx data is not in progress. In such cases the module automatically switches from connected to active mode and then, depending on the +UPSV, +CPSMS and +UPSMVER AT commands settings, the module automatically switches to the low power idle mode and/or to the ultra low power deep sleep mode whenever possible. Vice-versa, the module wakes up from low power idle mode and/or from ultra low power deep sleep mode to active mode and then connected mode if RF Tx/Rx activity is necessary.</p> <p>When a data connection is terminated, the module returns to the active mode.</p>   |

**Table 5: SARA-R4 series modules operating modes description**

The initial operating mode of SARA-R4 series modules is the one with **VCC** supply not present or below the operating range: the modules are switched off in not-powered mode.

Once a valid **VCC** supply is applied to the SARA-R4 series modules, they remain switched off in the power-off mode. Then the proper toggling of the **PWR\_ON** / **PWR\_CTRL** input line is necessary to trigger the switch-on routine of the modules that subsequently enter the active mode.

SARA-R4 series modules are ready to operate when in active mode: the available communication interfaces are completely functional and the module can accept and respond to AT commands, entering connected mode upon cellular RF signal reception / transmission.

The internal GNSS can be concurrently enabled on SARA-R422M8S / SARA-R422M10S modules by the dedicated +UGPS AT command, as well as the external GNSS can be concurrently enabled using SARA-R410M, SARA-R412M or SARA-R422S modules by the same AT command.

SARA-R4 series modules switch from active mode to the low power idle mode whenever possible, if the low power configuration is enabled by the dedicated +UPSV AT command. The low power idle mode can last for different time periods according to the specific +UPSV AT command setting, according to the DRX / eDRX setting, and according to the concurrent activities executed by the module, as in particular according to the concurrent GNSS activities.

SARA-R4 series modules enter the User Equipment (UE) power saving mode (PSM) defined in 3GPP Rel.13 whenever possible, if PSM is enabled by the +CPSMS / +UCPSMS AT commands, and according to the +UMNOPROF AT command settings. The PSM can last for different time periods according to the T3412 periodic TAU timer set by the network. Then, the modules enter the ultra-low power deep-sleep mode whenever possible, if no other concurrent activities are executed by the module, in particular if no GNSS activities are executed by SARA-R422M8S / SARA-R422M10S.

SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules may automatically enter the ultra low power deep sleep mode in-between eDRX cycles, whenever possible, if the functionality is enabled using the +UPSMVER AT command.

Once the modules enter the ultra-low power deep-sleep mode, the available communication interfaces are not functional: a wake-up event, consisting in proper toggling of the **PWR\_ON** / **PWR\_CTRL** input line or the expiration of the timer set by the network, is necessary to trigger the wake-up routine of the modules that subsequently enter back into the active mode.

SARA-R4 series modules can be gracefully switched off by the dedicated +CPWROFF AT command, or by proper toggling of the **PWR\_ON** / **PWR\_CTRL** input.

Figure 7 describes the transition between the different operating modes.

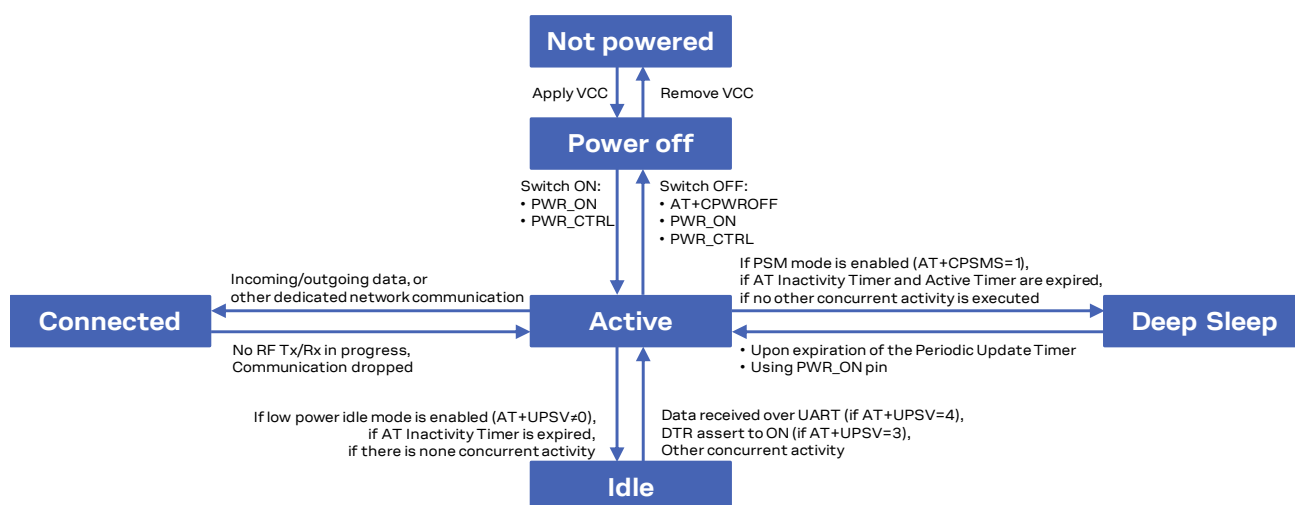


Figure 7: SARA-R4 series modules operating modes transitions

## 1.5 Supply interfaces

### 1.5.1 Module supply input (VCC)

The modules must be supplied via the three **VCC** pins that represent the module power supply input.

Voltage must be stable, because during operation, the current drawn by the SARA-R4 series modules through the **VCC** pins can vary by several orders of magnitude, depending on the operating mode and state (as described in sections [1.5.1.2](#), [1.5.1.3](#), [1.5.1.4](#) and [1.5.1.6](#)).

It is important that the supply source is able to withstand both the maximum pulse current occurring during a transmit burst at maximum power level and the average current consumption occurring during Tx / Rx call at maximum RF power level (see the SARA-R4 series data sheet [\[1\]](#)).

SARA-R412M, SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules, supporting 2G radio access technology, provide separate supply inputs over the three **VCC** pins:

- **VCC** pins #52 and #53 represent the supply input for the internal RF power amplifier, demanding most of the total current drawn of the module when RF transmission is enabled during a call
- **VCC** pin #51 represents the supply input for the internal baseband power management unit, demanding minor part of the total current drawn of the module when RF transmission is enabled during a call

The 3 **VCC** pins of SARA-R410M modules are internally connected each other to both the internal RF Power Amplifier and the internal baseband power management unit.

[Figure 8](#) provides a simplified block diagram of SARA-R4 series modules' internal VCC supply routing.

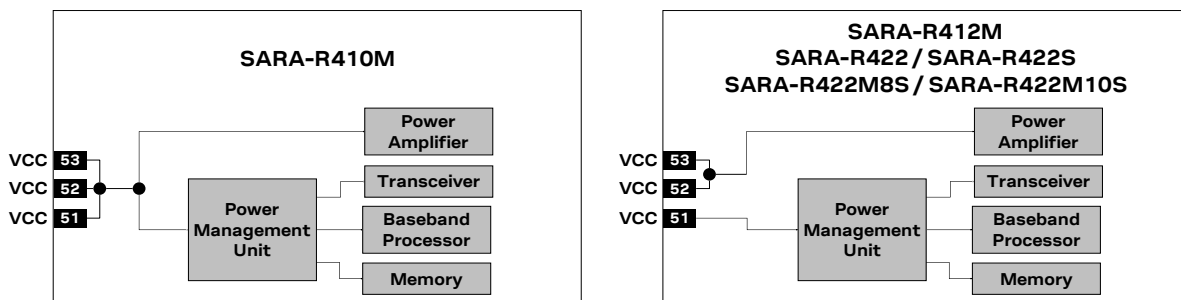



Figure 8: Block diagram of SARA-R4 series modules' internal VCC supply routing



### 1.5.1.1 VCC supply requirements

**Table 6** summarizes the requirements for the VCC modules supply. See section [2.2.1](#) for suggestions to correctly design a **VCC** supply circuit compliant with the requirements listed in **Table 6**.

 The supply circuit affects the RF compliance of the device integrating SARA-R4 series modules with applicable required certification schemes as well as antenna circuit design. RF performance is optimized by fulfilling the requirements summarized in the **Table 6**.

| Item   | Requirement  | Remark   |
|--|--|--|
| <b>VCC nominal voltage</b>                           | Within <b>VCC</b> normal operating range:<br>SARA-R410M:<br>3.2 V / 4.2 V<br>SARA-R412M and SARA-R42 series:<br>3.2 V / 4.5 V  | Operating within 3GPP / ETSI specifications: RF performance is optimized when <b>VCC</b> PA voltage is inside the normal operating range limits.   |
| <b>VCC voltage during normal operation</b>           | Within <b>VCC</b> extended operating range:<br>SARA-R410M:<br>3.0 V / 4.2 V<br>SARA-R412M and SARA-R42 series:<br>3.0 V / 4.5 V  | Operating with possible slight deviation in RF performance outside normal operating range.<br><b>VCC</b> voltage must be above the extended operating range minimum limit to switch-on the module and to avoid possible switch-off of the module.<br>Operation above <b>VCC</b> extended operating range is not recommended and may affect device reliability. |
| <b>VCC average current</b>                           | Support with adequate margin the highest averaged <b>VCC</b> current consumption value in connected mode conditions specified in the SARA-R4 series data sheet <a href="#">[1]</a> | The maximum average current consumption can be greater than the specified value according to the actual antenna mismatching, temperature and supply voltage.<br>Section <a href="#">1.5.1.2</a> describes current consumption profiles in connected mode.  |
| <b>VCC peak current</b>                              | Support with adequate margin the highest peak <b>VCC</b> current consumption value in Tx connected mode conditions specified in the SARA-R4 series data sheet <a href="#">[1]</a>  | The maximum peak Tx current consumption can be greater than the specified value according to the actual antenna mismatching, temperature and supply voltage.<br>Section <a href="#">1.5.1.2</a> describes current consumption profiles in connected mode.  |
| <b>VCC voltage drop during Tx slots</b>              | Lower than 400 mV  | <b>VCC</b> voltage drop directly affects the RF compliance with applicable certification schemes.<br><a href="#">Figure 11</a> describes <b>VCC</b> voltage drop during 2G Tx slots.   |
| <b>VCC voltage ripple during Tx</b>                  | Noise in the supply pins must be minimized   | High supply voltage ripple values during RF transmissions in connected mode directly affect the RF compliance with the applicable certification schemes.   |
| <b>VCC under/over-shoot at start/end of Tx slots</b> | Absent or at least minimized   | <b>VCC</b> under/over-shoot directly affects the RF compliance with applicable certification schemes.<br><a href="#">Figure 11</a> describes <b>VCC</b> voltage under/over-shoot.  |

**Table 6: VCC modules supply requirements**



### 1.5.1.2 VCC current consumption in LTE connected mode

During an LTE connection, the SARA-R4 series modules transmit and receive in half duplex mode.

The current consumption depends on output RF power, which is always regulated by the network (the current base station) sending power control commands to the module. These power control commands are logically divided into a slot of 0.5 ms (time length of one Resource Block), thus the rate of power change can reach a maximum rate of 2 kHz.

Figure 9 shows an example of SARA-R4 series modules' current consumption profile versus time in connected mode: transmission is enabled for one sub-frame (1 ms) according to LTE Category M1 half-duplex connected mode.

Detailed current consumption values can be found in the SARA-R4 series data sheet [1].

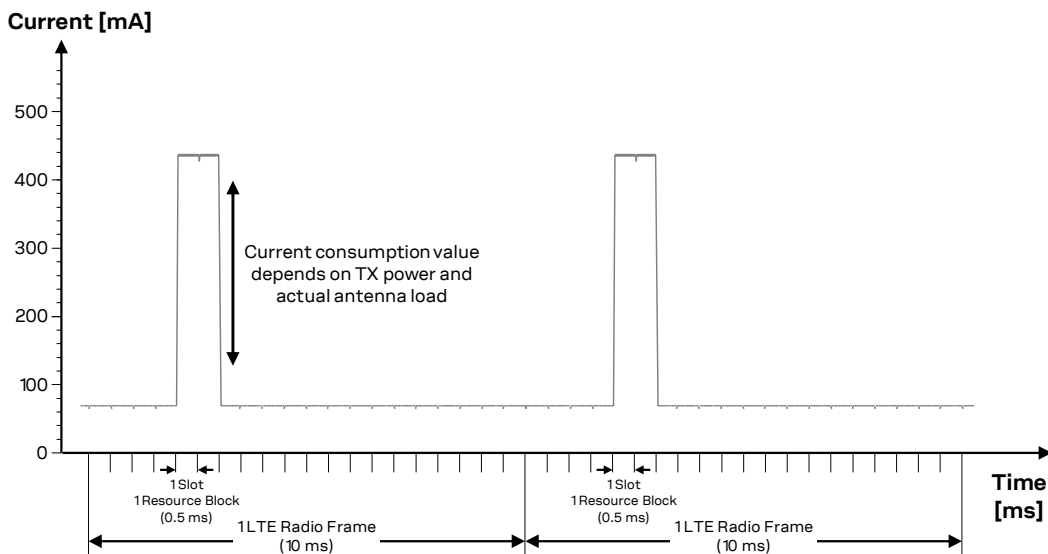


Figure 9: VCC current consumption profile versus time during LTE Cat M1 half-duplex connection

### 1.5.1.3 VCC current consumption in 2G connected mode

When a 2G call is established, the **VCC** consumption is determined by the current consumption profile typical of the 2G transmitting and receiving bursts.

The current consumption peak during a transmission slot is strictly dependent on the transmitted power, which is regulated by the network. The transmitted power in the transmit slot is also the more relevant factor for determining the average current consumption.

If the module is transmitting in 2G single-slot mode in the 850 or 900 MHz bands at the maximum RF power control level (approximately 2 W or 33 dBm in the Tx slot/burst), then the current consumption can reach a high peak / pulse (see the SARA-R4 series data sheet [1]) for 576.9  $\mu$ s (width of the transmit slot/burst) with a periodicity of 4.615 ms (width of 1 frame = 8 slots/burst), that is, with a 1/8 duty cycle according to GSM TDMA (Time Division Multiple Access).

If the module is transmitting in 2G single-slot mode in the 1800 or 1900 MHz bands, the current consumption figures are much lower than during transmission in the low bands, due to the 3GPP transmitter output power specifications.

During a 2G call, current consumption is not significantly high while receiving or in monitor bursts, and it is low in the bursts unused to transmit / receive.

Figure 10 shows an example of the module current consumption profile versus time in 2G single-slot.

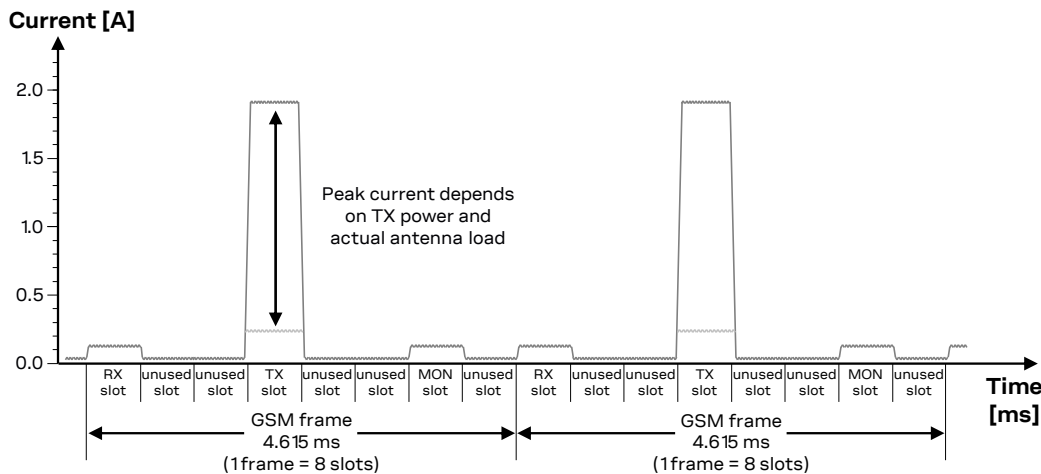


Figure 10: VCC current consumption profile versus time during a GSM call (1 TX slot, 1 RX slot)

Figure 11 illustrates the VCC voltage profile versus time during a 2G single-slot call, according to the related VCC current consumption profile described in Figure 10.

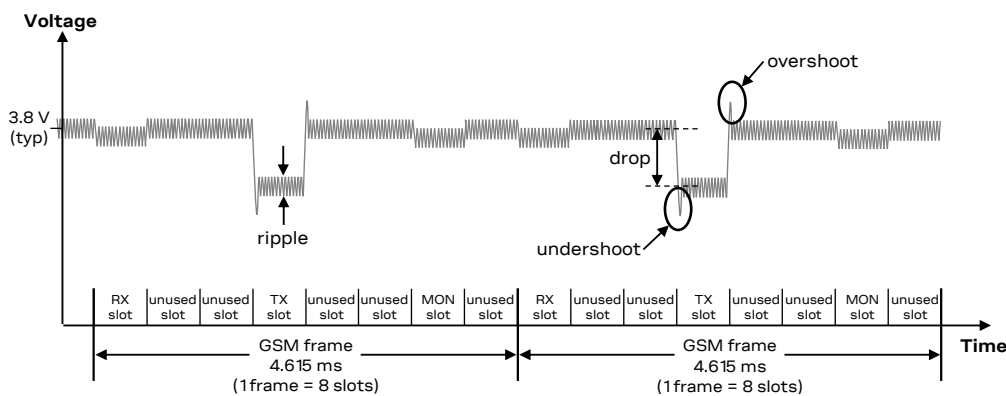


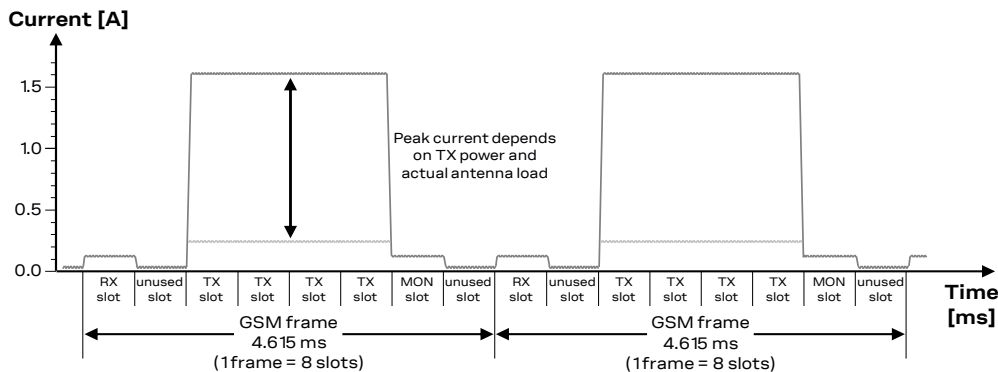
Figure 11: VCC voltage profile versus time during a 2G single-slot call (1 TX slot, 1 RX slot)

When a GPRS connection is established, more than one slot can be used to transmit and/or more than one slot can be used to receive. The transmitted power depends on network conditions, which set the peak current consumption. But according to GPRS specifications, the maximum transmitted RF power is reduced if more than one slot is used to transmit, so the maximum peak of current is not as high as it can be in the case of a GSM call.

If the module transmits in GPRS multi-slot class 12, in 850 or 900 MHz bands, at maximum RF power level, the consumption can reach a quite a high peak but lower than the one achievable in 2G single-slot mode. This happens for 2.308 ms (width of the 4 Tx slots/bursts) in the case of multi-slot class 12, with a periodicity of 4.615 ms (width of 1 frame = 8 slots/bursts), so with a 1/2 duty cycle, according to GSM TDMA.

If the module is in GPRS connected mode in the 1800 or 1900 MHz bands, consumption figures are lower than in the 850 or 900 MHz band because of the 3GPP Tx power specifications.

Figure 12 illustrates the current consumption profiles in GPRS connected mode, in 850 or 900 MHz bands, with 4 slots used to transmit and 1 slot used to receive, as for the GPRS multi-slot class 12.



**Figure 12: VCC current consumption profile versus time during a GPRS multi-slot class 12 connection (4 TX slots, 1 RX slot)**

In case of EGPRS (i.e. EDGE) connections, the VCC current consumption profile is similar to that during GPRS connections: the current consumption profile in GPRS multi-slot class 12 connected mode illustrated in Figure 12 is representative for the EDGE multi-slot class 12 connected mode.

#### 1.5.1.4 VCC current consumption in ultra low power deep sleep mode

The UE power saving mode (PSM) defined in 3GPP Rel.13 is by default disabled, but can be enabled by the +CPSMS AT command, see the SARA-R4 series AT commands manual [2] and the application development guide [4]. When PSM is enabled, the module automatically enters the PSM and the ultra low power deep sleep mode whenever possible.

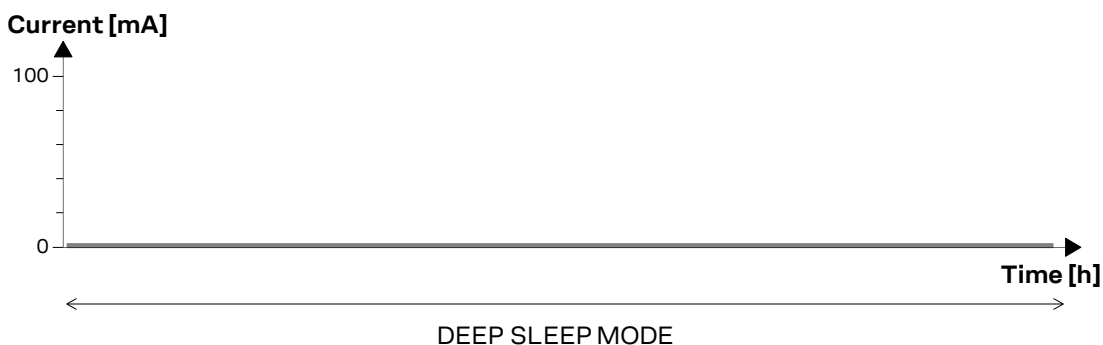
SARA-R42 series modules may automatically enter the ultra low power deep sleep mode in-between eDRX cycles, whenever possible, if the functionality is enabled by the +UPSMVER AT command, see the AT commands manual [2] and application development guide [4].

In ultra low power deep sleep mode, the current consumption is reduced down to a steady value in the  $\mu$ A range: only the RTC runs with internal reference clock frequency.

See detailed current consumption values in the SARA-R4 series data sheet [1].

Due to RTC running during PSM mode, the Cal-RC turns on the crystal every ~10 s to calibrate the RC oscillator, as a consequence, a very low spike in current consumption will be observed.

Figure 13 shows VCC current consumption profile in ultra low power deep sleep mode, with PSM enabled (AT+CPSMS $\neq$ 0). The module is registered to the network and is in ultra low power deep sleep mode, with no concurrent activities on. It does not periodically wake up for paging block reception, but wakes up upon the expiration of the periodic update timer set by the network, or due to proper toggling of the PWR\_ON / PWR\_CTRL input line.



**Figure 13: Example of VCC current consumption profile in ultra low power deep sleep mode with PSM (AT+CPSMS $\neq$ 0)**

### 1.5.1.5 VCC current consumption in low power idle mode

The low power idle mode configuration is by default disabled, but it can be enabled using the +UPSV AT command (see the SARA-R4 series AT commands manual [2]).

When low power idle mode is enabled, the module automatically enters the low power mode whenever possible, but it must periodically monitor the paging channel of the current base station (paging block reception), in accordance to the 2G/LTE system requirements, even if connected mode is not enabled by the application. When the module monitors the paging channel, it wakes up to the active mode to enable the reception of the paging block. In between, the module switches to low power mode. This is known as discontinuous reception (DRX) or extended discontinuous reception (eDRX).

Figure 14 illustrates an example of the module current consumption profile when low power mode configuration is enabled. The module is registered to the network. It automatically enters the low power idle mode, and periodically wakes up to active mode to monitor the paging channel for the paging block reception in discontinuous reception (DRX) mode.

See detailed current consumption values in the SARA-R4 series data sheet [1].

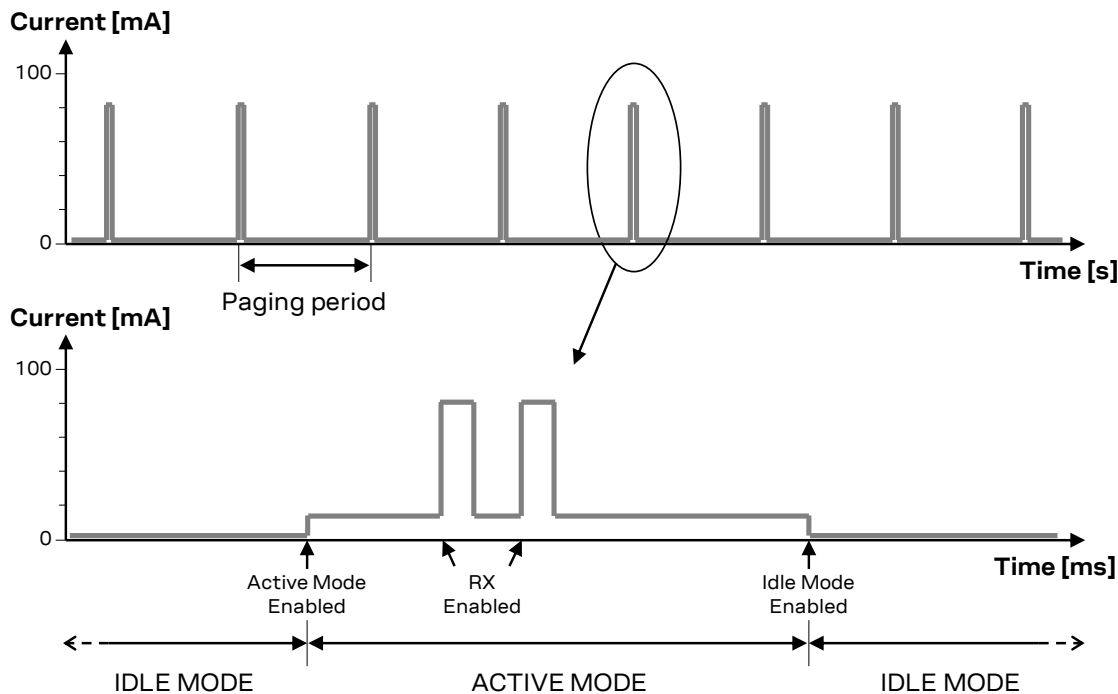


Figure 14: Example of VCC current consumption profile with low power mode enabled (AT+UPSV≠0)

### 1.5.1.6 VCC current consumption in active mode (PSM / low power disabled)

The active mode is the state where the module is switched on and ready to communicate with an external device by means of the application interfaces (as the USB or the UART serial interface). The module processor core is active, and the 19.2 MHz reference clock frequency is used.

If power saving mode and/or low power mode configurations are disabled, as it is by default (see the SARA-R4 series AT commands manual [2], +CPSMS, +UCPSMS, +UPSMVER, +UPSV AT commands for details), the module remains in active mode. Otherwise, if PSM mode and/or low power mode configurations are enabled, the module enters PSM mode and/or low power mode whenever possible.

Figure 15 illustrates a typical example of the module current consumption profile when the module is in active mode. The module is registered to the network. When active mode is maintained, the receiver is periodically activated to monitor the paging channel for paging block reception.

Detailed current consumption values can be found in the SARA-R4 series data sheet [1].

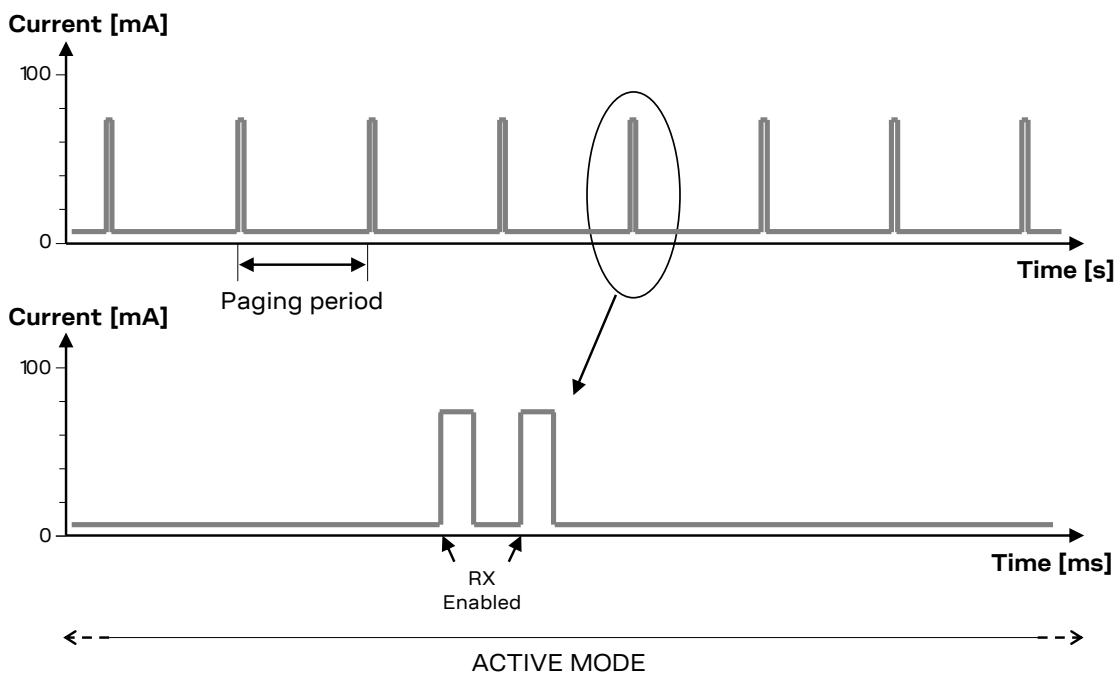


Figure 15: Example of VCC current consumption profile with low power mode disabled (AT+UPSV=0))

### 1.5.2 Generic digital interfaces supply output (V\_INT)

The V\_INT output pin of the SARA-R4 series modules is generated by the module internal power management circuitry when the module is switched on and it is not in the deep sleep power saving mode.

The typical operating voltage is 1.8 V, whereas the current capability is specified in the SARA-R4 series data sheet [1]. The V\_INT voltage domain can be used in place of an external discrete regulator as a reference voltage rail for external components.

## 1.6 System function interfaces

### 1.6.1 Module power-on

When the SARA-R4 series modules are in the not-powered mode (i.e. the **VCC** module supply is not applied), they can be switched on as follows:

- Rising edge on the **VCC** input pins to a valid voltage level, and then a low logic level needs to be set at the **PWR\_ON / PWR\_CTRL** input pin for a valid time.

When the SARA-R4 series modules are in the power-off mode (i.e. switched off) or in the Power Saving Mode (PSM), with a valid **VCC** supply applied, they can be switched on as follows:

- Low pulse on the **PWR\_ON / PWR\_CTRL** pin for a valid time period

The **PWR\_ON / PWR\_CTRL** input pin is equipped with an internal active pull-up resistor. Detailed characteristics with voltages and timings are described in the SARA-R4 series data sheet [1].

Figure 16 shows the module switch-on sequence from the not-powered mode, with following phases:

- The external power supply is applied to the **VCC** module pins
- The **PWR\_ON / PWR\_CTRL** pin is held low for a valid time
- All the generic digital pins are tri-stated until the switch-on of their supply source (**V\_INT**).
- The internal reset signal is held low: the baseband core and all digital pins are held in reset state. When the internal reset signal is released, any digital pin is set in the correct sequence from the reset state to the default operational configured state. The duration of this phase differs within generic digital interfaces and USB interface due to host / device enumeration timings.
- The module is ready to operate after all interfaces are configured.

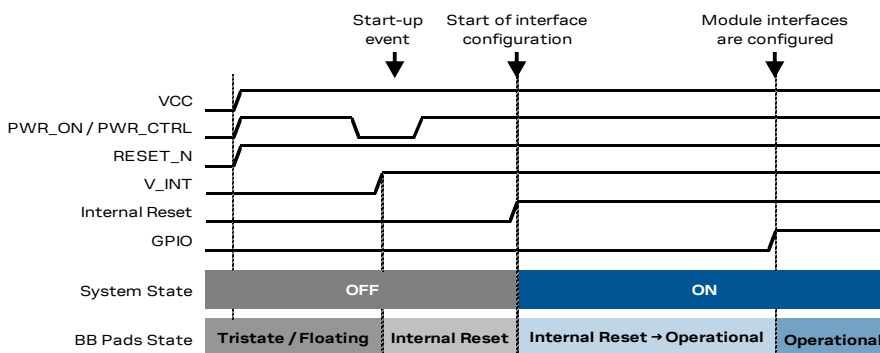


Figure 16: SARA-R4 series switch-on sequence description

- ✎ The Internal Reset signal is not available on a module pin, but it is highly recommended to monitor:
  - the **V\_INT** pin, to sense the start of the SARA-R4 series module switch-on sequence
  - the **GPIO** pin configured to provide the module operating status indication (see SARA-R4 series commands manual [2], +UGPIOC AT command), to sense when the module is ready to operate
- ✎ Before the switch-on of the generic digital interface supply (**V\_INT**) of the module, no voltage driven by an external application should be applied to any generic digital interface of the module.
- ✎ Before the SARA-R4 series module is ready to operate, the host application processor should not send any AT command over AT communication interfaces (USB, UART) of the module.
- ✎ The duration of the SARA-R4 series modules' switch-on routine can largely vary depending on the application / network settings and the concurrent module activities.
- ⚠ An abrupt removal of the **VCC** supply, or forcing an abrupt emergency reset / switch off by asserting the **RESET\_N / PWR\_CTRL** input, once the boot of SARA-R4 series modules has been triggered may lead to an unrecoverable faulty state!

## 1.6.2 Module power-off


SARA-R4 series modules can be gracefully switched off by:

- AT+CPWROFF command (see SARA-R4 series AT commands manual [2]).
- Low pulse on the **PWR\_ON / PWR\_CTRL** pin for a valid time period (for detailed characteristics see the SARA-R4 series data sheet [1]).


These events listed above trigger the storage of the current parameter settings in the non-volatile memory of the module, and a clean network detach procedure.


A faster and safe power-off procedure of the SARA-R422, SARA-R422S, SARA-R422M8S, and SARA-R422M10S modules, with storage of the current parameter settings in the non-volatile memory of the module, and without proper network detach, can be triggered by:

- AT+CFUN=10 command (see SARA-R4 series AT commands manual [2])
- Toggling the GPIO input pin configured with the fast and safe power-off function (see section 1.11)


 The graceful switched off procedure triggered by the +CPWROFF AT command or by proper low pulse at the **PWR\_ON / PWR\_CTRL** input pin must be preferred rather than the faster and safe power-off procedure triggered by the AT+CFUN=10 command or by toggling the configured GPIO pin, as performing frequent switch off without proper network detach is not recommended.


An abrupt under-voltage shutdown occurs on SARA-R4 series modules when the **VCC** module supply is removed. If this occurs, it is not possible to perform the storing of the current parameter settings in the module's non-volatile memory or to perform the clean network detach.

 It is highly recommended to avoid an abrupt removal of the **VCC** supply during SARA-R4 series modules normal operations.

 An abrupt removal of the **VCC** supply during SARA-R4 series modules normal operations may lead to an unrecoverable faulty state!

An abrupt hardware shutdown occurs on SARA-R410M and SARA-R412M modules when a low level is applied on **RESET\_N** pin. In this case, the current parameter settings are not saved in the module's non-volatile memory and a clean network detach is not performed.

 It is highly recommended to avoid an abrupt hardware shutdown of the module by forcing a low level on the **RESET\_N** input pin during module normal operation: the **RESET\_N** line should be set low only if reset or shutdown via AT commands fails or if the module does not reply to a specific AT command after a time period longer than the one defined in SARA-R4 series AT commands manual [2].

 Forcing a low level on the **RESET\_N** input during SARA-R4 series modules normal operations may lead to an unrecoverable faulty state!

SARA-R4 series modules automatically switch off, with storage of the current parameter settings in the module's internal non-volatile memory and a clean network detach, after having sent the last gasp, once the feature is enabled and triggered (see the SARA-R4 series AT commands manual [2], +ULGASP AT command).

Figure 17 and Figure 18 show the SARA-R4 series modules switch-off sequence started by means of the AT+CPWROFF command and by the **PWR\_ON** / **PWR\_CTRL** input pin respectively, allowing storage of current parameter settings in the module's non-volatile memory and a clean network detach, with the following phases:

- When the +CPWROFF AT command is sent, or when a low pulse with appropriate time duration (see the SARA-R4 series data sheet [1]) is applied at the **PWR\_ON** / **PWR\_CTRL** input pin, the module starts the switch-off routine.
- Then, if the +CPWROFF AT command has been sent, the module replies OK on the AT interface: the switch-off routine is in progress.
- At the end of the switch-off routine, all the digital pins are tri-stated and all the internal voltage regulators are turned off, including the generic digital interfaces supply (**V\_INT**).
- Then, the module remains in switch-off mode as long as a switch on event does not occur (e.g. applying a low level to **PWR\_ON** / **PWR\_CTRL** input pin), and it enters not-powered mode if the **VCC** supply is removed.

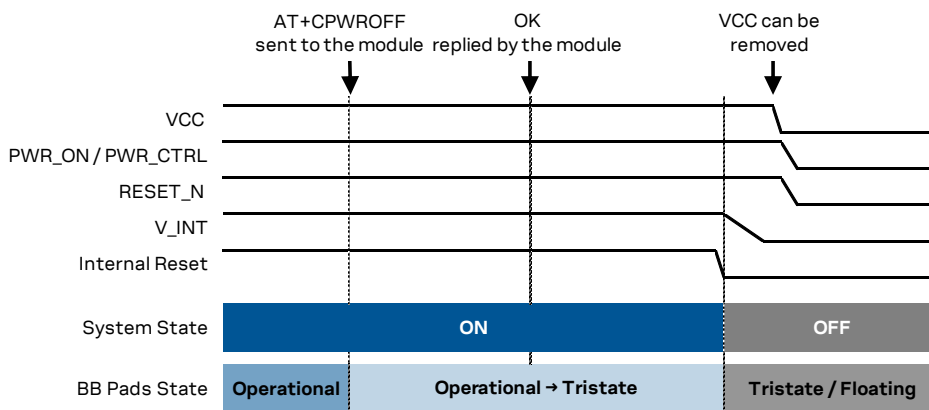


Figure 17: SARA-R4 series modules switch-off sequence by means of AT+CPWROFF command

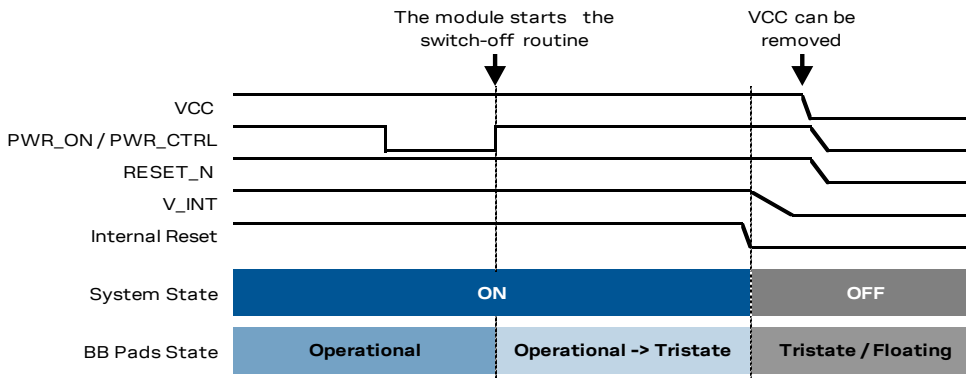


Figure 18: SARA-R4 series modules switch-off sequence by means of PWR\_ON / PWR\_CTRL pin

- The Internal Reset signal is not available on a module pin, but it is highly recommended to monitor the **V\_INT** pin to sense the end of the switch-off sequence.
- VCC** supply can be removed only after **V\_INT** goes low: an abrupt removal of the **VCC** supply during SARA-R4 series modules normal operations may lead to an unrecoverable faulty state!
- The duration of each phase in the SARA-R4 series modules' switch-off routines can largely vary depending on the application / network settings and the concurrent module activities.




### 1.6.3 Module reset


SARA-R4 series modules can be cleanly reset (rebooted) by:

- +CFUN AT command (see the SARA-R4 series AT commands manual [2]).


In the case above an “internal” or “software” reset of the module is executed: the current parameter settings are saved in the module’s non-volatile memory and a clean network detach is performed.


An abrupt hardware reset (reboot) occurs on the SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules when a low level is applied on **PWR\_CTRL** input pin for a long time period (see the SARA-R4 series data sheet [1]). In this case, the current parameter settings are not saved in the module’s non-volatile memory and a clean network detach is not performed.

 It is highly recommended to avoid an abrupt hardware reset (reboot) of the module by forcing a low level for a long time period on the **PWR\_CTRL** input pin during modules normal operation: the abrupt hardware reset (reboot) should be performed only if reset or shutdown via AT commands fails or if the module does not provide a reply to a specific AT command after a time period longer than the one defined in the SARA-R4 series AT commands manual [2].

 Forcing an abrupt hardware reset (reboot) during SARA-R4 series modules normal operations may lead to an unrecoverable faulty state!

An abrupt hardware shutdown occurs on SARA-R410M and SARA-R412M modules when a low level is applied on **RESET\_N** input pin for a valid time period. In this case, the current parameter settings are not saved in the module’s non-volatile memory and a clean network detach is not performed. Then, the module remains in power-off mode as long as a switch on event does not occur applying an appropriate low level to the **PWR\_ON** input.

 It is highly recommended to avoid an abrupt hardware shutdown of the module by forcing a low level on the **RESET\_N** input during modules normal operation: the **RESET\_N** line should be set low only if reset or shutdown via AT commands fails or if the module does not provide a reply to a specific AT command after a time period longer than the one defined in the SARA-R4 series AT commands manual [2].

 Forcing a low level on the **RESET\_N** input during SARA-R4 series modules normal operations may lead to an unrecoverable faulty state!

The **RESET\_N** and **PWR\_CTRL** input pins are directly connected to the power management unit IC, with an integrated pull-up to an internal supply domain, in order to perform an abrupt hardware shutdown / reset when asserted for a specific time period. Detailed electrical characteristics with voltages and timings are described in the SARA-R4 series data sheet [1].

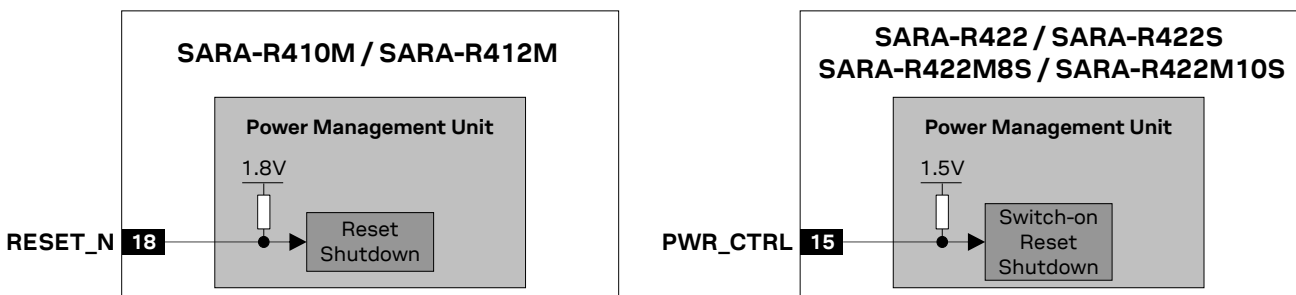


Figure 19: RESET\_N and PWR\_CTRL input pins description

## 1.7 Antenna interfaces


### 1.7.1 Cellular antenna RF interface (ANT)

SARA-R4 series modules provide an RF interface for connecting the external cellular antenna. The **ANT** pin represents the primary RF input/output for transmission and reception of cellular RF signals.

The **ANT** pin has a nominal characteristic impedance of 50  $\Omega$  and must be connected to the cellular Tx/Rx antenna system through a 50  $\Omega$  transmission line to allow clear RF transmission and reception.

#### 1.7.1.1 Cellular antenna RF interface requirements



Table 7 summarizes the requirements for the antenna RF interface. See section 2.4.2 for suggestions to correctly design antennas circuits compliant with these requirements.

 The antenna circuits affect the RF compliance of the device integrating SARA-R4 series modules with applicable required certification schemes (for more details see section 4). RF performance is optimized by fulfilling the cellular antenna RF interface requirements summarized in Table 7.

| Item                   | Requirements   | Remarks  |
|------------------------|--|--|
| <b>Impedance</b>       | 50 $\Omega$ nominal characteristic impedance   | The impedance of the antenna RF connection must match the 50 $\Omega$ impedance of the <b>ANT</b> port.  |
| <b>Frequency Range</b> | See the SARA-R4 series data sheet [1]  | The required frequency range of the antenna connected to <b>ANT</b> port depends on the operating bands of the used cellular module and the used mobile network.   |
| <b>Return Loss</b>     | $S_{11} < -10$ dB (VSWR < 2:1) recommended<br>$S_{11} < -6$ dB (VSWR < 3:1) acceptable | The Return loss or the $S_{11}$ , as the VSWR, refers to the amount of reflected power, measuring how well the antenna RF connection matches the 50 $\Omega$ characteristic impedance of the <b>ANT</b> port.<br>The impedance of the antenna termination must match as much as possible the 50 $\Omega$ nominal impedance of the <b>ANT</b> port over the operating frequency range, reducing as much as possible the amount of reflected power.  |
| <b>Efficiency</b>      | > -1.5 dB ( > 70% ) recommended<br>> -3.0 dB ( > 50% ) acceptable                      | The radiation efficiency is the ratio of the radiated power to the power delivered to antenna input: the efficiency is a measure of how well an antenna receives or transmits.<br>The radiation efficiency of the antenna connected to the <b>ANT</b> port needs to be enough high over the operating frequency range to comply with the Over-The-Air (OTA) radiated performance requirements, as Total Radiated Power (TRP) and the Total Isotropic Sensitivity (TIS), specified by applicable related certification schemes. |
| <b>Maximum Gain</b>    | According to radiation exposure limits   | The power gain of an antenna is the radiation efficiency multiplied by the directivity: the gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source.<br>The maximum gain of the antenna connected to <b>ANT</b> port must not exceed the herein stated value to comply with regulatory agencies radiation exposure limits. For additional info see sections 4.2.2.  |
| <b>Input Power</b>     | > 24 dBm ( > 0.25 W ) for R410M<br>> 33 dBm ( > 2.0 W ) for R412M and SARA-R42 series  | The antenna connected to the <b>ANT</b> port must support with adequate margin the maximum power transmitted by the modules.   |

Table 7: Tx/Rx antenna RF interface requirements

## 1.7.2 GNSS antenna RF interface (ANT\_GNSS)

-  The GNSS antenna RF interface is supported by SARA-R422M8S / SARA-R422M10S only.
-  For additional information and guidelines regarding the GNSS system, see the u-blox SARA-R4 / SARA-R5 positioning implementation application note [\[21\]](#).

SARA-R422M8S and SARA-R422M10S modules provide an RF interface for connecting the external GNSS antenna. The **ANT\_GNSS** pin represents the RF input reception of GNSS RF signals.

The **ANT\_GNSS** pin has a nominal characteristic impedance of 50  $\Omega$  and must be connected to the Rx GNSS antenna through a 50  $\Omega$  transmission line to allow proper RF reception. As shown in [Figure 6](#), the GNSS RF interface is designed with an internal DC block, and is suitable for both active and/or passive GNSS antennas due to the built-in SAW filter followed by an additional LNA in front of the integrated high performing u-blox GNSS concurrent position engine.

### 1.7.2.1 GNSS antenna RF interface requirements

[Table 8](#) summarizes the requirements for the GNSS antenna RF interface. See section [2.4.3](#) for suggestions to correctly design antennas circuits compliant with these requirements.

| Item                                 | Requirements   | Remarks   |
|--------------------------------------|--|---|
| <b>Impedance</b>                     | 50 $\Omega$ nominal characteristic impedance   | The impedance of the antenna RF connection must match the 50 $\Omega$ impedance of the <b>ANT_GNSS</b> port.  |
| <b>Frequency range</b>               | BeiDou 1561 MHz / 1575 MHz<br>GPS / SBAS / QZSS / Galileo 1575 MHz<br>GLONASS 1602 MHz | The required frequency range of the antenna connected to <b>ANT_GNSS</b> port depends on the selected GNSS constellations.  |
| <b>Return loss</b>                   | $S_{11} < -10$ dB (VSWR < 2:1) recommended<br>$S_{11} < -6$ dB (VSWR < 3:1) acceptable | The return loss or the $S_{11}$ , as the VSWR, refers to the amount of reflected power, measuring how well the antenna RF connection matches the 50 $\Omega$ characteristic impedance of the <b>ANT_GNSS</b> port.<br>The impedance of the antenna termination must match as much as possible the 50 $\Omega$ nominal impedance of the <b>ANT_GNSS</b> port over the operating frequency range, reducing as much as possible the amount of reflected power. |
| <b>Gain (passive antenna)</b>        | > 4 dBic   | The antenna gain defines how efficient the antenna is at receiving the signal. It is important providing good antenna visibility to the sky, using antennas with good radiation pattern in the sky direction, according to related antenna placement.   |
| <b>Gain (active antenna)</b>         | 17 dB minimum, 30 dB maximum   | The antenna gain defines how efficient the antenna is at receiving the signal. It is directly related to the overall C/No.  |
| <b>Noise figure (active antenna)</b> | < 2 dB   | Since GNSS signals are very weak, any amount of noise degrades all the sensitivity figures of the receiver: active antennas with LNA with a low noise figure are recommended.   |
| <b>Axial ratio</b>                   | < 3 dB recommended   | GNSS signals are circularly polarized. The purity of the antenna circular polarization is stated in terms of axial ratio (AR), defined as the ratio of the vertical electric field to the horizontal electric field on polarization ellipse at zenith.  |

**Table 8: GNSS antenna RF interface requirements**

### 1.7.3 Antenna detection interface (ANT\_DET)

The antenna detection is based on ADC measurement. The **ANT\_DET** pin is an Analog to Digital Converter (ADC) provided to sense the antenna presence.

The antenna detection function provided by **ANT\_DET** pin is an optional feature that can be implemented if the application requires it. The antenna detection is forced by the +UANTR AT command. See the SARA-R4 series AT commands manual [\[2\]](#) for more details on this feature.

The **ANT\_DET** pin generates a DC current (for detailed characteristics see the SARA-R4 series data sheet [\[1\]](#)) and measures the resulting DC voltage, thus determining the resistance from the antenna connector provided on the application board to GND. So, the requirements to achieve antenna detection functionality are the following:

- an RF antenna assembly with a built-in resistor (diagnostic circuit) must be used
- an antenna detection circuit must be implemented on the application board

See section [2.4.5](#) for antenna detection circuit on application board and diagnostic circuit on antenna assembly design-in guidelines.

## 1.8 SIM interface

### 1.8.1 SIM interface

SARA-R4 series modules provide a SIM interface on the **VSIM**, **SIM\_IO**, **SIM\_CLK**, **SIM\_RST** pins to connect an external SIM card or UICC chip.

SARA-R410M and SARA-R412M modules support both 1.8 V and 3.0 V types of SIM / UICC, with automatic voltage switch implemented according to related specifications.

SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules support only the 1.8 V type of SIM / UICC.

### 1.8.2 SIM detection interface

The **GPIO5** pin is configured as an external interrupt to detect the SIM card mechanical / physical presence. The pin is configured as input with an internal active pull-down enabled, and it can sense SIM card presence only if cleanly connected to the mechanical switch of a SIM card holder as described in section [2.5](#):

- Low logic level at **GPIO5** input pin is recognized as SIM card not present
- High logic level at **GPIO5** input pin is recognized as SIM card present

For more details, see the SARA-R4 series AT commands manual [\[2\]](#), +UGPIOC, +CIND and +CMER AT commands.

## 1.9 Data communication interfaces

SARA-R4 series modules provide the following serial communication interfaces:


- UART interfaces: asynchronous serial interface supporting AT commands, data communication, GNSS tunneling, FW update by means of FOAT. See section 1.9.1.
- USB interface: High-Speed USB 2.0 compliant serial interface supporting AT commands<sup>26</sup>, data communication<sup>26</sup>, FW update by means of the FOAT feature<sup>26</sup>, FW update by means of the u-blox EasyFlash tool and diagnostic trace logging. See section 1.9.2.
- SPI interface<sup>27</sup>: Serial Peripheral Interface for compatible devices. See section 1.9.3.
- SDIO interface<sup>27</sup>: Secure Digital Input Output interface for compatible device. See section 1.9.4.
- DDC interface: I2C bus compatible interface supporting communication with external u-blox GNSS positioning chips or modules<sup>28</sup> and with external I2C devices. See section 1.9.5.


### 1.9.1 UART interfaces


#### 1.9.1.1 UART features


SARA-R4 series modules include a primary main UART interface (UART) for communication with an application host processor, supporting AT commands, data communication, multiplexer protocol functionality (see 1.9.1.3), FW update by means of FOAT, with settings configurable by dedicated AT commands (for more details, see the SARA-R4 series AT commands manual [2]):

- 8-wire serial port with RS-232 functionality conforming to ITU-T V.24 recommendation [7], with CMOS compatible signal levels (0 V for low data bit / ON state, 1.8 V for high data bit / OFF state)
  - Data lines (**RXD** as data output, **TXD** as data input)
  - HW flow control lines (**CTS** as flow control output, **RTS** as flow control input)
  - Modem status and control lines (**DTR** input, **DSR** output, **DCD** output, **RI** output)<sup>29</sup>
- The default baud rate is 115,200 b/s
- The default frame format is 8N1 (8 data bits, no parity, 1 stop bit)

 The UART is available only if the USB is not enabled as AT command / data communication interface: UART and USB cannot be concurrently used for this purpose.

 UART signal names of the cellular modules conform to the ITU-T V.24 recommendation [7]: e.g. **TXD** line represents data transmitted by the DTE (host processor output) and received by the DCE (module input).

 Hardware flow control is not supported by the SARA-R410M-01B or the SARA-R410M-02B-00 product versions. The **RTS** input line needs to be set low (= ON state) to communicate over the UART on the SARA-R410M-01B product versions.

 **DTR** input of the module must be set low (= ON state) to have URCs presented over UART interface on the SARA-R410M-01B, SARA-R410M-02B, SARA-R410M-52B and SARA-R412M-02B product versions of SARA-R4 series modules.

<sup>26</sup> Not supported by SARA-R422, SARA-R422S, SARA-R422M8S, or SARA-R422M10S modules

<sup>27</sup> Not supported by the current product versions of the SARA-R410M or SARA-R412M modules. Not available on the SARA-R422, SARA-R422S, SARA-R422M8S or SARA-R422M10S modules.

<sup>28</sup> Dedicated AT commands to communicate with external u-blox GNSS receiver are not supported by SARA-R410M-01B, SARA-R422, SARA-R422M8S or SARA-R422M10S product versions

<sup>29</sup> **DTR**, **DSR**, **DCD** and **RI** pins can be alternatively configured, in mutually exclusive way, as second auxiliary UART interface (UART AUX) on SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules.

SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules include a second auxiliary UART interface (UART AUX) for communication with an application host processor, supporting AT commands, data, GNSS tunneling<sup>30</sup>, FW update by means of FOAT, with settings configurable by dedicated AT commands (for more details, see the SARA-R4 series AT commands manual [2]):

- 4-wire serial port with RS-232 functionality conforming to ITU-T V.24 recommendation [7], with CMOS compatible signal levels (0 V for low data bit / ON state, 1.8 V for high data bit / OFF state)
  - Data lines (**DCD** as data output, **DTR** as data input)
  - HW flow control lines (**RI** as flow control output, **DSR** as flow control input)
- The default baud rate is 115,200 b/s
- The default frame format is 8N1 (8 data bits, no parity, 1 stop bit)

SARA-R4 series modules' UART interface is by default configured in AT command mode, if the USB interface is not enabled as AT command / data communication interface (UART and USB cannot be concurrently used for this purpose): the module waits for AT command instructions and interprets all the characters received as commands to execute. All the functionalities supported by SARA-R4 series modules can be in general set and configured by AT commands:

- AT commands according to 3GPP TS 27.007 [8], 3GPP TS 27.005 [9], 3GPP TS 27.010 [10]
- u-blox AT commands (see the SARA-R4 series AT commands manual [2])

The default baud rate is 115200 b/s, while the default frame format is 8N1 (8 data bits, No parity, 1 stop bit: see Figure 20). Baud rates can be configured by AT command (see the SARA-R4 series AT commands manual [2]).



Automatic baud rate detection and automatic frame format recognition are not supported.

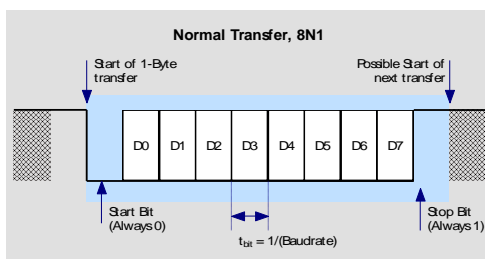


Figure 20: UART 8N1 frame format (8 data bits, no parity, 1 stop bit)

### 1.9.1.2 UART signals behavior

At the end of the module boot sequence (see Figure 16), the module is by default in active mode, and the UART interface is initialized and enabled as AT commands interface only if the USB interface is not enabled as AT command / data communication interface: UART and USB cannot be concurrently used for this purpose.

The configuration and behavior of the UART signals after the boot sequence are described below:

- The module data output line (**RXD**) is set by default to the OFF state (high level) at UART initialization. The module holds **RXD** in the OFF state until the module transmits some data.
- The module data input line (**TXD**) is assumed to be controlled by the external host once UART is initialized and if UART is used in the application. The **TXD** data input line has an internal active pull-down enabled on the SARA-R410M-02B product version, and an internal active pull-up enabled on the other product version of SARA-R4 series modules.

<sup>30</sup> Not supported by SARA-R422-00B modules

### 1.9.1.3 UART multiplexer protocol

SARA-R4 series modules include multiplexer functionality as per 3GPP TS 27.010 [10], on the primary main UART physical link. This is a data link protocol which uses HDLC-like framing and operates between the module (DCE) and the application processor (DTE) and allows a number of simultaneous sessions over the primary main UART physical link. The following virtual channels are defined:

- Channel 0: for Multiplexer control
- Channel 1: for all AT commands, and non-Dial Up Network (non-DUN) data connections. UDP, TCP data socket / data call connections via relevant AT commands.
- Channel 2: for Dial Up Network (DUN) data connection. It requires the host to have and use its own TCP/IP stack. The DUN can be initiated on modem side or terminal/host side.
- Channel 3: for u-blox GNSS data tunneling (not supported by SARA-R410M-01B product version and SARA-R422 product versions).

## 1.9.2 USB interface

### 1.9.2.1 USB features

SARA-R4 series modules include a high-speed USB 2.0 compliant interface with a maximum 480 Mb/s data rate according to the USB 2.0 specification [6]. The module itself acts as a USB device and can be connected to any USB host equipped with compatible drivers.

The USB is the most suitable interface for transferring high speed data between the SARA-R410M and SARA-R412M modules and an external host processor, available for AT / data communication, FW upgrade by means of the FOAT feature.


The USB is the interface of SARA-R4 series modules available for FW upgrade by means of the u-blox EasyFlash tool and for diagnostic purposes.


SARA-R410M and SARA-R412M modules provide the following USB lines:


- the **USB\_D+** / **USB\_D-** lines, carrying the USB data and signaling
- the **VUSB\_DET** input pin to enable the USB interface by applying an external voltage (5.0 V typical)


SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S provide the following USB lines:

- the **USB\_D+** / **USB\_D-** lines, carrying the USB data and signaling
- the **USB\_5V0** input pin to enable the USB interface by applying an external 5.0 V typical voltage
- the **USB\_3V3** input pin to supply the USB interface by applying an external 3.3 V typical voltage

 The USB interface is available as an AT / data communication interface on the SARA-R410M and SARA-R412M modules only if an external valid USB VBUS voltage (5.0 V typical) is applied at the **VUSB\_DET** input of the module since the switch-on of the module, and then held during normal operations. In this case, the UART will not be available.

 AT command / data communication are not supported over USB on SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S: the USB interface is available on these modules product versions for FW upgrade by means of the u-blox EasyFlash tool and for diagnostic purposes only.

 If the USB interface is enabled, the module does not enter the low power deep sleep mode: the external voltage needs to be removed from the **VUSB\_DET** / **USB\_5V0** and **USB\_3V3** input pins of the module to let it enter the Power Saving Mode defined in 3GPP Rel.13.

 It is highly recommended to provide accessible test points directly connected to the **V\_INT**, **PWR\_ON** / **PWR\_CTRL**, **VUSB\_DET** / **USB\_5V0**, **USB\_3V3**, **USB\_D+**, **USB\_D-**, **RSVD #33** pins for FW upgrade and/or for diagnostic purpose.



The SARA-R4 series module itself acts as a USB device and can be connected to a USB host such as a Personal Computer or an embedded application microprocessor equipped with compatible drivers.

The **USB\_D+/USB\_D-** lines carry USB serial bus data and signaling according to the Universal Serial Bus revision 2.0 specification [6], while the **VUSB\_DET / USB\_5V0** input pin senses the VBUS USB supply presence (nominally 5 V at the source) to detect the host connection and enable the interface. Neither the USB interface, nor the whole module is supplied by the **VUSB\_DET/USB\_5V0** input, which senses the USB supply voltage and absorbs few microamperes.

The USB interface of SARA-R410M and SARA-R412M modules is controlled and operated with:

- AT commands according to 3GPP TS 27.007 [8], 3GPP TS 27.005 [9]
- u-blox AT commands (see the SARA-R4 series AT commands manual [2])

SARA-R410M and SARA-R412M modules provide the following USB functions:

- AT commands and data communication
- Diagnostic log
- FW upgrade by means of the u-blox EasyFlash tool


SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S provide the following USB function:

- Diagnostic log
- FW upgrade by means of the u-blox EasyFlash tool


The USB profile of SARA-R4 series modules identifies itself by dedicated VID (Vendor ID) and PID (Product ID) combination, included in the USB device descriptor following USB 2.0 specifications [6]:

- VID = 0x05C6
- PID = 0x90B2


### 1.9.3 SPI interface

 The SPI interface is not supported by current product versions: SPI interface pins of SARA-R410M and SARA-R412M modules (**I2S\_WA / SPI\_MOSI**, **I2S\_RXD / SPI\_MISO**, **I2S\_CLK / SPI\_CLK**, and **I2S\_TXD / SPI\_CS**) should not be driven by any external device.

### 1.9.4 SDIO interface

 The SDIO interface is not supported by current product versions: the SDIO interface pins of the SARA-R410M and SARA-R412M modules (**SDIO\_D0**, **SDIO\_D1**, **SDIO\_D2**, **SDIO\_D3**, **SDIO\_CLK**, and **SDIO\_CMD**) should not be driven by any external device.

### 1.9.5 DDC (I2C) interface

 The I2C interface is not supported by SARA-R410M-01B product version: the I2C interface pins should not be driven by any external device.

SARA-R4 series modules include an I2C-bus compatible DDC interface (**SDA**, **SCL** lines) available to communicate with an external u-blox GNSS receiver<sup>31</sup> and with external I2C devices as an audio codec: the SARA-R4 series module acts as an I2C host which can communicate with I2C devices in accordance with the I2C bus specifications [11].

The **SDA** and **SCL** pins have internal pull-up to **V\_INT**, so there is no need of additional pull-up resistors on the external application board.

<sup>31</sup> Dedicated AT commands for external u-blox GNSS receiver communication and control are not supported by SARA-R410M-01B, SARA-R422, SARA-R422M8S or SARA-R422M10S product versions



## 1.10 Audio

 Audio is not supported by current product versions.

## 1.11 General Purpose Input/Output

SARA-R4 series modules include pins which can be configured as General Purpose Input/Output or to provide custom functions via u-blox AT commands (for more details see the SARA-R4 series AT commands manual [2], +UGPIOC, +UGPIOR, +UGPIOW AT commands), as summarized in Table 9.

| Function                                | Description   | Default GPIO | Configurable GPIOs                       |
|---|---|--------------|--|
| Network status indication               | Network status: registered / data transmission, no service                                      | --           | GPIO1                                    |
| GNSS supply enable <sup>32</sup>        | Enable/disable the supply of a u-blox GNSS receiver connected to the cellular module by the I2C | --           | GPIO2                                    |
| GNSS data ready <sup>32</sup>           | Sense when a u-blox GNSS receiver connected to the module is ready for sending data by the I2C  | --           | GPIO3                                    |
| SIM card detection                      | SIM card physical presence detection  | --           | GPIO5                                    |
| Ring Indicator <sup>33</sup>            | Events indicator  | --           | RI                                       |
| Module status indication                | Module switched off or in PSM low power deep sleep mode, versus active or connected mode        | --           | GPIO1, GPIO2, GPIO3, GPIO4, GPIO5, GPIO6 |
| Last gasp <sup>33</sup>                 | Input to trigger last gasp notification   | --           | GPIO3, GPIO4, GPIO6 <sup>34</sup>        |
| Faster and safe power-off <sup>35</sup> | Input to trigger emergency faster and safe shutdown of the module (as triggered by AT+CFUN=10)  | --           | GPIO3, GPIO4                             |
| LwM2M pulse <sup>36</sup>               | Output to notify a settable LwM2M event with a configurable pulse                               | --           | GPIO1, GPIO2, GPIO3, GPIO4, GPIO5, GPIO6 |
| General purpose input                   | Input to sense high or low digital level  | --           | GPIO1, GPIO2, GPIO3, GPIO4, GPIO5, GPIO6 |
| General purpose output                  | Output to set the high or the low digital level   | --           | GPIO1, GPIO2, GPIO3, GPIO4, GPIO6        |
| Pin disabled                            | Tri-state with an internal active pull-down enabled   | All          | All                                      |

**Table 9: SARA-R4 series modules GPIO custom functions configuration**

<sup>32</sup> Not supported by SARA-R410M-01B, SARA-R422, SARA-R422M8S, or SARA-R422M10S product versions


<sup>33</sup> Not supported by SARA-R410M-01B, SARA-R410M-02B-00, or SARA-R422 product versions

<sup>34</sup> Not supported by SARA-R422S, SARA-R422M8S, or SARA-R422M10S product versions

<sup>35</sup> Not supported by SARA-R410M, or SARA-R412M product versions

<sup>36</sup> Not supported by SARA-R410M-01B, SARA-R410M-02B-00, SARA-R410M-02B-01, SARA-R410M-02B-02, SARA-R410M-52B, SARA-R412M-02B-00, SARA-R412M-02B-01, or SARA-R412M-02B-02 product versions

## 1.12 Cellular antenna dynamic tuner interface


 The cellular antenna dynamic tuner interface is not supported by SARA-R410M, SARA-R412M, SARA-R422-00B, SARA-R422S-00B and SARA-R422M8S-00B modules product versions.

SARA-R422-01B, SARA-R422S-01B and SARA-R422M10S modules product versions includes two output pins (named **I2S\_TXD** and **I2S\_WA**) that can be configured, as optional feature, to control in real time an external antenna tuning IC, changing their output value dynamically according to the specific actual cellular band in use by the module as indicated in [Table 10](#).

| I2S_TXD | I2S_WA | LTE frequency band in use                   | 2G frequency band in use            |
|---------|--------|---|-------------------------------------|
| 0       | 0      | -   | -                                   |
| 0       | 1      | B12, B13, B28, B85 ( 700..800 MHz )         | -                                   |
| 1       | 0      | B5, B8, B18, B19, B20, B26 ( 800..900 MHz ) | GSM 850, E-GSM 900 ( 800..900 MHz ) |
| 1       | 1      | B1, B2, B3, B4, B25, B66 ( > 1000 MHz )     | DCS 1800, PCS 1900 ( > 1000 MHz )   |

Table 10: SARA-R422-01B, SARA-R422S-01B and SARA-R422M10S modules antenna dynamic tuning truth table

## 1.13 GNSS peripheral input output


 The GNSS peripheral input output pins are not supported by the SARA-R410M, SARA-R412M, SARA-R422 and SARA-R422S modules.

SARA-R422M8S and SARA-R422M10S modules provides the following 1.8 V peripheral input output pins directly connected to the internal u-blox M8 GNSS chipset, as illustrated in [Figure 3](#), or directly connected to the internal u-blox M10 GNSS chipset as illustrated in [Figure 5](#):

- The **TXD\_GNSS** pin consisting in the UART data output of the internal u-blox GNSS chipset.
- The **EXTINT** external interrupt pin that can be used for control of the GNSS receiver or for aiding.
- The **TIMEPULSE** output pin that can generate pulse trains synchronized with GPS or UTC time grid with intervals configurable over a wide frequency range. Thus, it may be used as a low frequency time synchronization pulse or as a high frequency reference signal.
- The **ANT\_ON** output pin that can provide optional control for switching off power to an external active GNSS antenna or an external separate LNA. This facility is provided to help minimize power consumption in power save mode operation.

## 1.14 Reserved pins (RSVD)

SARA-R4 series modules have pins reserved for future use, marked as **RSVD**, which can all be left unconnected on the application board, except for the **RSVD** pin number **33** that can be externally connected to ground by 0  $\Omega$  series jumper, making available an accessible Test-Point to this pin for the SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules.

 It is highly recommended to provide an accessible test point directly connected to the **RSVD #33** pin for diagnostic purposes. It is also highly recommended to provide access to the **V\_INT**, **PWR\_ON** / **PWR\_CTRL**, **VUSB\_DET** / **USB\_5V0**, **USB\_3V3**, **USB\_D+**, **USB\_D-** pins for FW update and/or for diagnostic purposes using accessible dedicated Test-Points that are directly connected to each of these pins, or using a dedicated connector / circuit.

## 2 Design-in

### 2.1 Overview

For an optimal integration of the SARA-R4 series modules in the final application board, follow the design guidelines stated in this section.

Every application circuit must be suitably designed to ensure the correct functionality of the relative interface, but a number of points require greater attention during the design of the application device.

The following list provides a rank of importance in the application design, starting from the highest relevance:

1. Module antenna(s) connection: **ANT**, **ANT\_GNSS**, and **ANT\_DET** pins.  
Cellular antenna circuit directly affects the RF compliance of the device integrating a SARA-R4 series module with applicable certification schemes. Follow the suggestions provided in the relative section [2.4](#) for the schematic and layout design.
2. Module supply: **VCC** and **GND** pins.  
The supply circuit affects the RF compliance of the device integrating a SARA-R4 series module with the applicable required certification schemes as well as the antenna circuit design. Very carefully follow the suggestions provided in the relative section [2.2.1](#) for the schematic and layout design.
3. SIM interface: **VSIM**, **SIM\_CLK**, **SIM\_IO**, **SIM\_RST** pins.  
Accurate design is required to ensure SIM card functionality reducing the risk of RF coupling. Carefully follow the suggestions provided in relative section [2.5](#) for schematic and layout design.
4. System functions: **RESET\_N** and **PWR\_ON / PWR\_CTRL** pins.  
Accurate design is required to ensure that the voltage level is well defined during operation. Carefully follow the suggestions provided in relative section [2.3](#) for schematic and layout design.
5. USB interface: **USB\_D+**, **USB\_D-** and **VUSB\_DET / USB\_5V0**, **USB\_3V3** pins.  
Accurate design is required to ensure USB 2.0 high-speed interface functionality. Carefully follow the suggestions provided in the relative section [2.6.2](#) for the schematic and layout design.
6. Other digital interfaces: UART, SPI, SDIO, I2C, I2S, GPIOs, GNSS PIOs and reserved pins.  
Accurate design is required to ensure correct functionality and reduce the risk of digital data frequency harmonics coupling. Follow the suggestions provided in sections [2.6.1](#), [2.6.2](#), [2.6.3](#), [2.6.4](#), [2.6.5](#), [2.7](#), [2.8](#) and [2.10](#) for the schematic and layout design.
7. Other supplies: **V\_INT** generic digital interfaces supply.  
Accurate design is required to ensure correct functionality. Follow the suggestions provided in the corresponding section [2.2.2](#) for the schematic and layout design.

 It is recommended to follow the specific design guidelines provided by each manufacturer of any external part selected for the application board integrating the u-blox cellular modules.

## 2.2 Supply interfaces

### 2.2.1 Module supply (VCC)

#### 2.2.1.1 General guidelines for VCC supply circuit selection and design

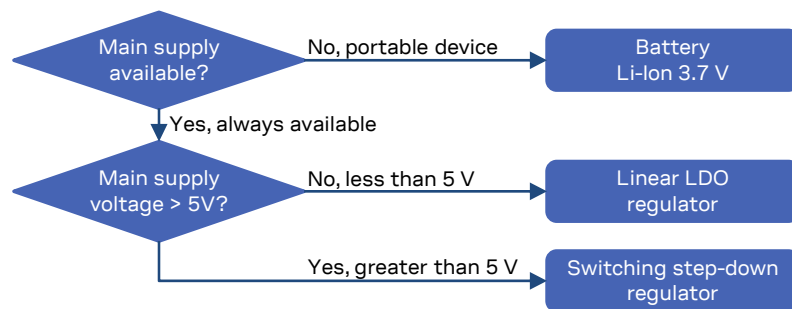
All the available **VCC** pins have to be connected to the external supply minimizing the power loss due to series resistance.

**GND** pins are internally connected. Application design shall connect all the available pads to solid ground on the application board, since a good (low impedance) connection to external ground can minimize power loss and improve RF and thermal performance.

SARA-R4 series modules must be sourced through the **VCC** pins with a suitable DC power supply that should meet the following prerequisites to comply with the modules' **VCC** requirements summarized in [Table 6](#).

The appropriate DC power supply can be selected according to the application requirements (see [Figure 21](#)) between the different possible supply sources types, which most common ones are the following:

- Switching regulator
- Low Drop-Out (LDO) linear regulator
- Rechargeable Lithium-ion (Li-Ion) or Lithium-ion polymer (Li-Pol) battery
- Primary (disposable) battery



**Figure 21: VCC supply concept selection**

The switching step-down regulator is the typical choice when primary supply source has a nominal voltage much higher (e.g. greater than 5 V) than the operating supply voltage of SARA-R4 series. The use of switching step-down provides the best power efficiency for the overall application and minimizes current drawn from the main supply source. See section [2.2.1.2](#) for design-in.

The use of an LDO linear regulator becomes convenient for a primary supply with a relatively low voltage (e.g. less or equal than 5 V). In this case, the typical 90% efficiency of the switching regulator diminishes the benefit of voltage step-down and no true advantage is gained in input current savings. On the opposite side, linear regulators are not recommended for high voltage step-down as they dissipate a considerable amount of energy in thermal power. See section [2.2.1.3](#) for design-in.

If SARA-R4 series modules are deployed in a mobile unit where no permanent primary supply source is available, then a battery will be required to provide **VCC**. A standard 3-cell Li-Ion or Li-Pol battery pack directly connected to **VCC** is the usual choice for battery-powered devices. During charging, batteries with Ni-MH chemistry typically reach a maximum voltage that is above the maximum rating for **VCC**, and should therefore be avoided. See sections [2.2.1.4](#), [2.2.1.5](#), [2.2.1.6](#) and [2.2.1.7](#) for specific design-in.

Keep in mind that the use of rechargeable batteries requires the implementation of a suitable charger circuit, which is not included in the modules. The charger circuit needs to be designed to prevent over-

voltage on **VCC** pins, and it should be selected according to the application requirements. A DC/DC switching charger is the typical choice when the charging source has a high nominal voltage (e.g. ~12 V), whereas a linear charger is the typical choice when the charging source has a relatively low nominal voltage (~5 V). If both a permanent primary supply / charging source (e.g. ~12 V) and a rechargeable back-up battery (e.g. 3.7 V Li-Pol) are available at the same time as possible supply source, then a suitable charger / regulator with integrated power path management function can be selected to supply the module while simultaneously and independently charging the battery. See sections 2.2.1.6 and 2.2.1.7 for specific design-in.

An appropriate primary (not rechargeable) battery can be selected taking into account the maximum current specified in the SARA-R4 series data sheet [1] during connected mode, considering that primary cells might have weak power capability. See section 2.2.1.5 for specific design-in.

The usage of more than one DC supply at the same time should be carefully evaluated: depending on the supply source characteristics, different DC supply systems can result as mutually exclusive.

The selected regulator or battery must be able to support with adequate margin the highest averaged current consumption value specified in the SARA-R4 series data sheet [1].

The following sections highlight some design aspects for each of the supplies listed above providing application circuit design-in compliant with the module **VCC** requirements summarized in Table 6.

### 2.2.1.2 Guidelines for VCC supply circuit design using a switching regulator

The use of a switching regulator is suggested when the difference from the available supply rail source to the **VCC** value is high, since switching regulators provide good efficiency transforming a 12 V or greater voltage supply to the typical 3.8 V value of the **VCC** supply.

The characteristics of the switching regulator connected to **VCC** pins should meet the following prerequisites to comply with the module **VCC** requirements summarized in Table 6:

- **Power capability:** the switching regulator with its output circuit must be capable of providing a voltage value to the **VCC** pins within the specified operating range and must be capable of delivering to **VCC** pins the maximum current consumption occurring during transmissions at the maximum power, as specified in the SARA-R4 series data sheet [1].
- **Low output ripple:** the switching regulator together with its output circuit must be capable of providing a clean (low noise) **VCC** voltage profile.
- **High switching frequency:** for best performance and for smaller applications it is recommended to select a switching frequency  $\geq 600$  kHz (since L-C output filter is typically smaller for high switching frequency). The use of a switching regulator with a variable switching frequency or with a switching frequency lower than 600 kHz must be carefully evaluated since this can produce noise in the **VCC** profile and therefore negatively impact modulation spectrum performance.
- **PWM mode operation:** it is preferable to select regulators with Pulse Width Modulation (PWM) mode. While in connected mode, the Pulse Frequency Modulation (PFM) mode and PFM/PWM modes transitions must be avoided to reduce noise on **VCC** voltage profile. Switching regulators can be used that are able to switch between low ripple PWM mode and high ripple PFM mode, provided that the mode transition occurs when the module changes status from the active mode to connected mode. It is permissible to use a regulator that switches from the PWM mode to the burst or PFM mode at an appropriate current threshold.

Figure 22 and the components listed in Table 11 show an example of a high reliability power supply circuit for the SARA-R4 series modules that support 2G radio access technology. This circuit is also suitable for the other SARA-R4 series modules, where the module VCC input is supplied by a step-down switching regulator capable of delivering the highest peak / pulse current specified for the 2G use-case, with low output ripple and with fixed switching frequency in PWM mode operation greater than 1 MHz.

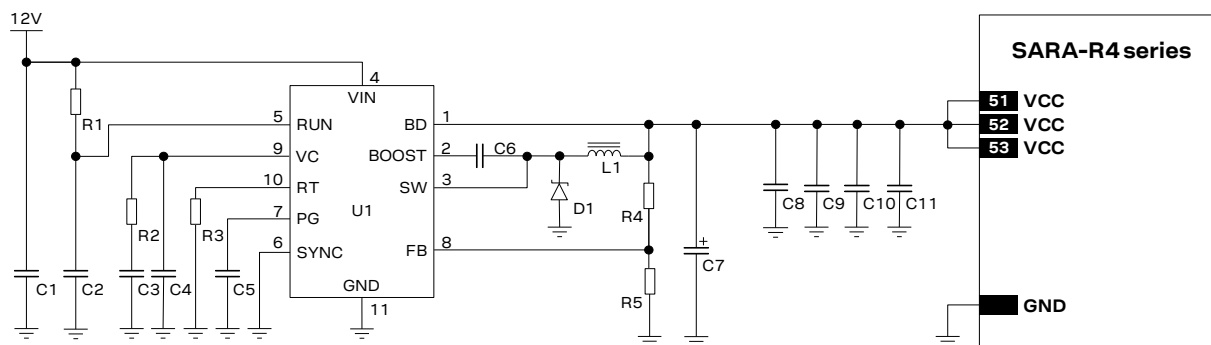


Figure 22: Example of high reliability VCC supply circuit for SARA-R4 series modules, using a step-down regulator

| Reference | Description   | Part Number - Manufacturer         |
|-----------|---|------------------------------------|
| C1        | 10 $\mu$ F Capacitor Ceramic X7R 5750 15% 50 V              | Generic manufacturer               |
| C2        | 10 nF Capacitor Ceramic X7R 0402 10% 16 V                   | Generic manufacturer               |
| C3        | 680 pF Capacitor Ceramic X7R 0402 10% 16 V                  | Generic manufacturer               |
| C4        | 22 pF Capacitor Ceramic C0G 0402 5% 25 V                    | Generic manufacturer               |
| C5        | 10 nF Capacitor Ceramic X7R 0402 10% 16 V                   | Generic manufacturer               |
| C6        | 470 nF Capacitor Ceramic X7R 0603 10% 25 V                  | Generic manufacturer               |
| C7        | 100 $\mu$ F Capacitor Tantalum B_SIZE 20% 6.3V 15m $\Omega$ | T520B107M006ATE015 – Kemet         |
| C8        | 100 nF Capacitor Ceramic X7R 16 V                           | GRM155R71C104KA01 - Murata         |
| C9        | 10 nF Capacitor Ceramic X7R 16 V                            | GRM155R71C103KA01 - Murata         |
| C10       | 68 pF Capacitor Ceramic C0G 0402 5% 50 V                    | GRM1555C1E680JA01 - Murata         |
| C11       | 15 pF Capacitor Ceramic C0G 0402 5% 50 V                    | GRM1555C1E150JA01 - Murata         |
| D1        | Schottky Diode 40 V 3 A                                     | MBRA340T3G - ON Semiconductor      |
| L1        | 10 $\mu$ H Inductor 744066100 30% 3.6 A                     | 744066100 - Wurth Electronics      |
| R1        | 470 k $\Omega$ Resistor 0402 5% 0.1 W                       | Generic manufacturer               |
| R2        | 15 k $\Omega$ Resistor 0402 5% 0.1 W                        | Generic manufacturer               |
| R3        | 22 k $\Omega$ Resistor 0402 5% 0.1 W                        | Generic manufacturer               |
| R4        | 390 k $\Omega$ Resistor 0402 1% 0.063 W                     | Generic manufacturer               |
| R5        | 100 k $\Omega$ Resistor 0402 5% 0.1 W                       | Generic manufacturer               |
| U1        | Step-Down Regulator MSOP10 3.5 A 2.4 MHz                    | LT3972IMSE#PBF - Linear Technology |

Table 11: Components for high reliability VCC supply circuit for SARA-R4 series modules, using a step-down regulator

See the section 2.2.1.10, and in particular Figure 33 / Table 21, for the parts recommended to be provided if the application device integrates an internal antenna.

Figure 23 and the components listed in Table 12 show an example of a high reliability power supply circuit for SARA-R410M modules, which do not support the 2G radio access technology. In this example, the module VCC is supplied by a step-down switching regulator capable of delivering the maximum peak / pulse current specified for the LTE use-case, with low output ripple and with fixed switching frequency in PWM mode operation greater than 1 MHz.

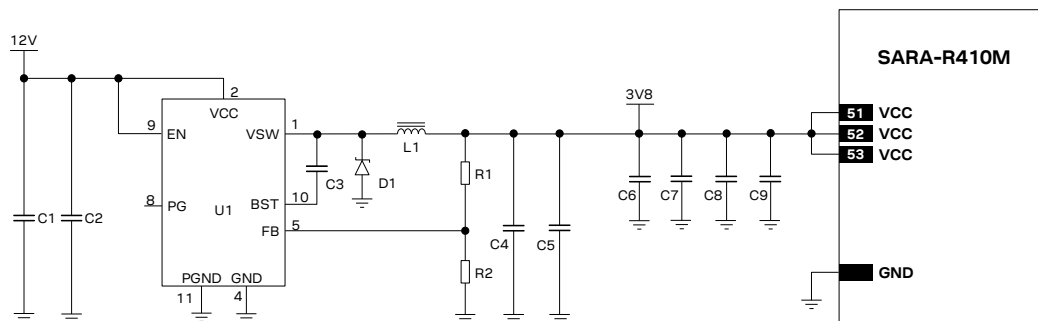


Figure 23: Example of high reliability VCC supply circuit for SARA-R410M, using a step-down regulator

| Reference | Description                              | Part Number - Manufacturer      |
|-----------|--|---------------------------------|
| C1        | 10 $\mu$ F Capacitor Ceramic X7R 50 V    | Generic manufacturer            |
| C2        | 10 nF Capacitor Ceramic X7R 16 V         | Generic manufacturer            |
| C3        | 22 nF Capacitor Ceramic X7R 16 V         | Generic manufacturer            |
| C4        | 22 $\mu$ F Capacitor Ceramic X5R 25 V    | Generic manufacturer            |
| C5        | 22 $\mu$ F Capacitor Ceramic X5R 25 V    | Generic manufacturer            |
| C6        | 100 nF Capacitor Ceramic X7R 16 V        | GRM155R71C104KA01 - Murata      |
| C7        | 10 nF Capacitor Ceramic X7R 16 V         | GRM155R71C103KA01 - Murata      |
| C8        | 68 pF Capacitor Ceramic C0G 0402 5% 50 V | GRM1555C1E680JA01 - Murata      |
| C9        | 15 pF Capacitor Ceramic C0G 0402 5% 50 V | GRM1555C1E150JA01 - Murata      |
| D1        | Schottky Diode 30 V 2 A                  | MBR230LSFT1G - ON Semiconductor |
| L1        | 4.7 $\mu$ H Inductor 20% 2 A             | SLF7045T-4R7M2R0-PF - TDK       |
| R1        | 470 k $\Omega$ Resistor 0.1 W            | Generic manufacturer            |
| R2        | 150 k $\Omega$ Resistor 0.1 W            | Generic manufacturer            |
| U1        | Step-Down Regulator 1 A 1 MHz            | TS30041 - Semtech               |

Table 12: High reliability VCC supply circuit components for SARA-R410M, using a step-down regulator

See the section 2.2.1.10, and in particular Figure 33 / Table 21, for the parts recommended to be provided if the application device integrates an internal antenna.

Figure 24 and the components listed in Table 13 show an example of a low cost power supply circuit suitable for all the SARA-R4 series modules, where the module **VCC** is supplied by a step-down switching regulator capable of delivering the highest peak / pulse current specified for the 2G use-case, transforming a 12 V supply input.

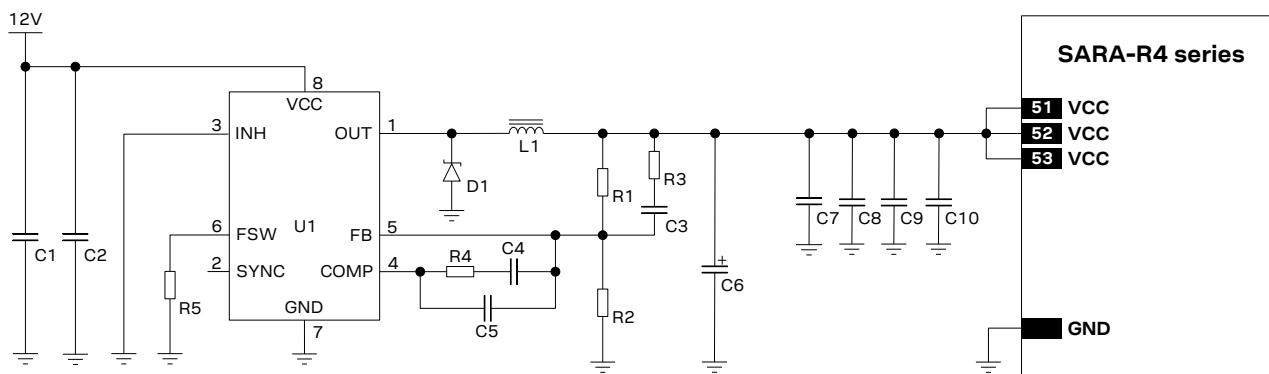


Figure 24: Example of low cost VCC supply circuit for SARA-R4 series modules, using a step-down regulator

| Reference | Description   | Part Number - Manufacturer    |
|-----------|---|-------------------------------|
| C1        | 22 $\mu$ F Capacitor Ceramic X5R 1210 10% 25 V              | Generic manufacturer          |
| C2        | 220 nF Capacitor Ceramic X7R 0603 10% 25 V                  | Generic manufacturer          |
| C3        | 5.6 nF Capacitor Ceramic X7R 0402 10% 50 V                  | Generic manufacturer          |
| C4        | 6.8 nF Capacitor Ceramic X7R 0402 10% 50 V                  | Generic manufacturer          |
| C5        | 56 pF Capacitor Ceramic C0G 0402 5% 50 V                    | Generic manufacturer          |
| C6        | 100 $\mu$ F Capacitor Tantalum B_SIZE 20% 6.3V 15m $\Omega$ | T520B107M006ATE015 – Kemet    |
| C7        | 100 nF Capacitor Ceramic X7R 16 V                           | GRM155R71C104KA01 - Murata    |
| C8        | 10 nF Capacitor Ceramic X7R 16 V                            | GRM155R71C103KA01 - Murata    |
| C9        | 68 pF Capacitor Ceramic C0G 0402 5% 50 V                    | GRM1555C1E680JA01 - Murata    |
| C10       | 15 pF Capacitor Ceramic C0G 0402 5% 50 V                    | GRM1555C1E150JA01 - Murata    |
| D1        | Schottky Diode 25V 2 A                                      | STPS2L25 – STMicroelectronics |
| L1        | 5.2 $\mu$ H Inductor 30% 5.28A 22 m $\Omega$                | MSS1038-522NL – Coilcraft     |
| R1        | 4.7 k $\Omega$ Resistor 0402 1% 0.063 W                     | Generic manufacturer          |
| R2        | 910 $\Omega$ Resistor 0402 1% 0.063 W                       | Generic manufacturer          |
| R3        | 82 $\Omega$ Resistor 0402 5% 0.063 W                        | Generic manufacturer          |
| R4        | 8.2 k $\Omega$ Resistor 0402 5% 0.063 W                     | Generic manufacturer          |
| R5        | 39 k $\Omega$ Resistor 0402 5% 0.063 W                      | Generic manufacturer          |
| U1        | Step-Down Regulator 8-VFQFPN 3 A 1 MHz                      | L5987TR – ST Microelectronics |

Table 13: Suggested components for low cost VCC circuit for SARA-R4 series modules, using a step-down regulator

See the section 2.2.1.10, and in particular Figure 33 / Table 21, for the parts recommended to be provided if the application device integrates an internal antenna.



### 2.2.1.3 Guidelines for VCC supply circuit design using LDO linear regulator

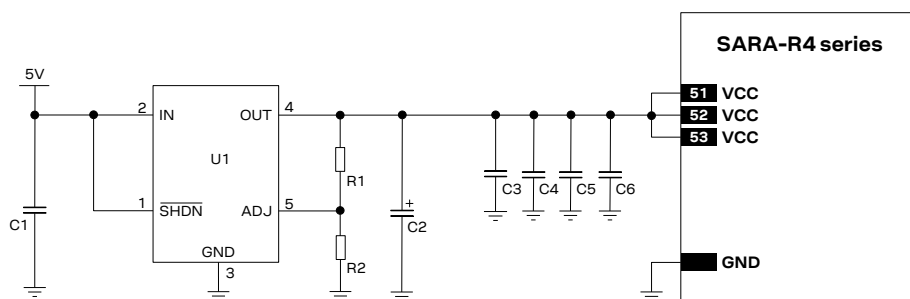
The use of a linear regulator is suggested when the difference from the available supply rail source and the **VCC** value is low. The linear regulators provide high efficiency when transforming a 5 VDC supply to a voltage value within the module **VCC** normal operating range.

The characteristics of the Low Drop-Out (LDO) linear regulator connected to **VCC** pins should meet the following prerequisites to comply with the module **VCC** requirements summarized in [Table 6](#):

- **Power capabilities:** the LDO linear regulator with its output circuit must be capable of providing a voltage value to the **VCC** pins within the specified operating range and must be capable of delivering to **VCC** pins the maximum current consumption occurring during a transmission at the maximum Tx power, as specified in the SARA-R4 series data sheet [\[1\]](#).
- **Power dissipation:** the power handling capability of the LDO linear regulator must be checked to limit its junction temperature to the rated range (i.e. check the voltage drop from the maximum input voltage to the minimum output voltage to evaluate the power dissipation of the regulator).

[Figure 25](#) and the components listed in [Table 14](#) show an example of a high reliability power supply circuit for SARA-R4 series modules supporting the 2G radio access technology. This example is also suitable for the other SARA-R4 series modules, where the **VCC** module supply is provided by an LDO linear regulator capable of delivering the highest peak / pulse current specified for the 2G use-case, with an appropriate power handling capability. The regulator described in this example supports a wide input voltage range, and it includes internal circuitry for reverse battery protection, current limiting, thermal limiting and reverse current protection.

It is recommended to configure the LDO linear regulator to generate a voltage supply value slightly below the maximum limit of the module **VCC** normal operating range (e.g. ~4.1 V as in the circuit described in [Figure 26](#) and [Table 15](#)). This reduces the power on the linear regulator and improves the whole thermal design of the supply circuit.



**Figure 25: Example of high reliability VCC supply circuit for SARA-R4 series modules, using an LDO linear regulator**

| Reference | Description   | Part Number - Manufacturer        |
|-----------|---|-----------------------------------|
| C1        | 10 $\mu$ F Capacitor Ceramic X5R 0603 20% 6.3 V             | Generic manufacturer              |
| C2        | 100 $\mu$ F Capacitor Tantalum B_SIZE 20% 6.3V 15m $\Omega$ | T520B107M006ATE015 – Kemet        |
| C3        | 100 nF Capacitor Ceramic X7R 16 V                           | GRM155R71C104KA01 - Murata        |
| C4        | 10 nF Capacitor Ceramic X7R 16 V                            | GRM155R71C103KA01 - Murata        |
| C5        | 68 pF Capacitor Ceramic C0G 0402 5% 50 V                    | GRM1555C1E680JA01 - Murata        |
| C6        | 15 pF Capacitor Ceramic C0G 0402 5% 50 V                    | GRM1555C1E150JA01 - Murata        |
| R1        | 9.1 k $\Omega$ Resistor 0402 5% 0.1 W                       | Generic manufacturer              |
| R2        | 3.9 k $\Omega$ Resistor 0402 5% 0.1 W                       | Generic manufacturer              |
| U1        | LDO Linear Regulator ADJ 3.0 A                              | LT1764AEQ#PBF - Linear Technology |

**Table 14: Suggested components for high reliability VCC circuit for SARA-R4 series modules, using an LDO regulator**

See the section [2.2.1.10](#), and in particular [Figure 33](#) / [Table 21](#), for the parts recommended to be provided if the application device integrates an internal antenna.

Figure 26 and the components listed in Table 15 show an example of a high reliability power supply circuit for SARA-R410M modules, which do not support the 2G radio access technology, where the module **VCC** is supplied by an LDO linear regulator capable of delivering maximum peak/pulse current specified for LTE use-case, with suitable power handling capability.

It is recommended to configure the LDO linear regulator to generate a voltage supply value slightly below the maximum limit of the module **VCC** normal operating range (e.g. ~4.1 V for the **VCC**, as in the circuits described in Figure 26 and Table 15). This reduces the power on the linear regulator and improves the thermal design of the circuit.

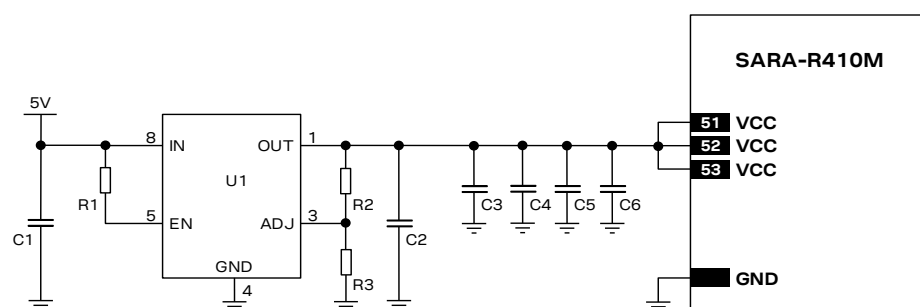


Figure 26: Example of high reliability VCC supply circuit for SARA-R410M, using an LDO linear regulator

| Reference | Description                              | Part Number - Manufacturer   |
|-----------|--|------------------------------|
| C1        | 1 µF Capacitor Ceramic X5R 6.3 V         | Generic manufacturer         |
| C2        | 22 µF Capacitor Ceramic X5R 25 V         | Generic manufacturer         |
| C3        | 100 nF Capacitor Ceramic X7R 16 V        | GRM155R71C104KA01 - Murata   |
| C4        | 10 nF Capacitor Ceramic X7R 16 V         | GRM155R71C103KA01 - Murata   |
| C5        | 68 pF Capacitor Ceramic C0G 0402 5% 50 V | GRM1555C1E680JA01 - Murata   |
| C6        | 15 pF Capacitor Ceramic C0G 0402 5% 50 V | GRM1555C1E150JA01 - Murata   |
| R1        | 47 kΩ Resistor 0.1 W                     | Generic manufacturer         |
| R2        | 41 kΩ Resistor 0.1 W                     | Generic manufacturer         |
| R3        | 10 kΩ Resistor 0.1 W                     | Generic manufacturer         |
| U1        | LDO Linear Regulator 1.0 A               | AP7361 – Diodes Incorporated |

Table 15: Components for high reliability VCC supply circuit for SARA-R410M, using an LDO linear regulator

See the section 2.2.1.10, and in particular Figure 33 / Table 21, for the parts recommended to be provided if the application device integrates an internal antenna.

Figure 27 and the components listed in Table 16 show an example of a low cost power supply circuit, where the **VCC** module supply is provided by an LDO linear regulator capable of delivering the specified highest peak / pulse current, with an appropriate power handling capability. The regulator described in this example supports a limited input voltage range and it includes internal circuitry for current and thermal protection.

It is recommended to configure the LDO linear regulator to generate a voltage supply value slightly below the maximum limit of the module VCC normal operating range (e.g. ~4.1 V as in the circuit described in Figure 27 and Table 16). This reduces the power on the linear regulator and improves the whole thermal design of the supply circuit.

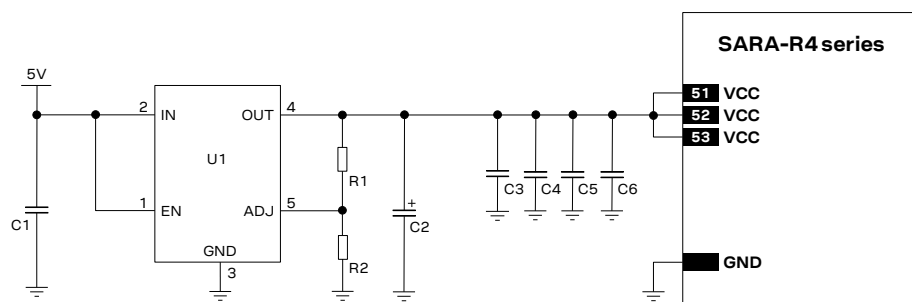


Figure 27: Example of low cost VCC supply circuit for SARA-R4 series modules, using an LDO linear regulator

| Reference | Description   | Part Number - Manufacturer             |
|-----------|---|--|
| C1        | 10 $\mu$ F Capacitor Ceramic X5R 0603 20% 6.3 V             | Generic manufacturer                   |
| C2        | 100 $\mu$ F Capacitor Tantalum B_SIZE 20% 6.3V 15m $\Omega$ | T520B107M006ATE015 – Kemet             |
| C3        | 100 nF Capacitor Ceramic X7R 16 V                           | GRM155R71C104KA01 - Murata             |
| C4        | 10 nF Capacitor Ceramic X7R 16 V                            | GRM155R71C103KA01 - Murata             |
| C5        | 68 pF Capacitor Ceramic C0G 0402 5% 50 V                    | GRM1555C1E680JA01 - Murata             |
| C6        | 15 pF Capacitor Ceramic C0G 0402 5% 50 V                    | GRM1555C1E150JA01 - Murata             |
| R1        | 27 k $\Omega$ Resistor 0402 5% 0.1 W                        | Generic manufacturer                   |
| R2        | 4.7 k $\Omega$ Resistor 0402 5% 0.1 W                       | Generic manufacturer                   |
| U1        | LDO Linear Regulator ADJ 3.0 A                              | LP38501ATJ-ADJ/NOPB - Texas Instrument |

Table 16: Suggested components for low cost VCC supply circuit for SARA-R4 modules, using an LDO linear regulator

See the section 2.2.1.10, and in particular Figure 33 / Table 21, for the parts recommended to be provided if the application device integrates an internal antenna.

### 2.2.1.4 Guidelines for VCC supply circuit design using a rechargeable battery

Rechargeable Li-Ion or Li-Pol batteries connected to the **VCC** pins should meet the following prerequisites to comply with the module **VCC** requirements summarized in [Table 6](#):

- **Maximum pulse and DC discharge current:** the rechargeable Li-Ion battery with its related output circuit connected to the **VCC** pins must be capable of delivering the maximum current occurring during a transmission at maximum Tx power, as specified in the SARA-R4 series data sheet [\[1\]](#). The maximum discharge current is not always reported in the data sheets of batteries, but the maximum DC discharge current is typically almost equal to the battery capacity in Amp-hours divided by 1 hour.
- **DC series resistance:** the rechargeable Li-Ion battery with its output circuit must be capable of avoiding a VCC voltage drop below the operating range summarized in [Table 6](#) during transmit bursts.

### 2.2.1.5 Guidelines for VCC supply circuit design using a primary battery

The characteristics of a primary (non-rechargeable) battery connected to **VCC** pins should meet the following prerequisites to comply with the module **VCC** requirements summarized in [Table 6](#):

- **Maximum pulse and DC discharge current:** the non-rechargeable battery with its related output circuit connected to the **VCC** pins must be capable of delivering the maximum current consumption occurring during a transmission at maximum Tx power, as specified in SARA-R4 series data sheet [\[1\]](#). The maximum discharge current is not always reported in the data sheets of batteries, but the maximum DC discharge current is typically almost equal to the battery capacity in Amp-hours divided by 1 hour.
- **DC series resistance:** the non-rechargeable battery with its output circuit must be capable of avoiding a VCC voltage drop below the operating range summarized in [Table 6](#) during transmit bursts.

### 2.2.1.6 Guidelines for external battery charging circuit

SARA-R4 series modules do not have an on-board charging circuit. [Figure 28](#) provides an example of a battery charger design, suitable for applications that are battery powered with a Li-Ion (or Li-Polymer) cell.

In the application circuit, a rechargeable Li-Ion (or Li-Polymer) battery cell, that features the correct pulse and DC discharge current capabilities and the appropriate DC series resistance, is directly connected to the **VCC** supply input of the module. Battery charging is completely managed by the Battery Charger IC, which from a USB power source (5.0 V typ.), linearly charges the battery in three phases:

- **Pre-charge constant current** (active when the battery is deeply discharged): the battery is charged with a low current.
- **Fast-charge constant current:** the battery is charged with the maximum current, configured by the value of an external resistor.
- **Constant voltage:** when the battery voltage reaches the regulated output voltage, the Battery Charger IC starts to reduce the current until the charge termination is done. The charging process ends when the charging current reaches the value configured by an external resistor or when the charging timer reaches the factory set value.

Using a battery pack with an internal NTC resistor, the Battery Charger IC can monitor the battery temperature to protect the battery from operating under unsafe thermal conditions.

The Battery Charger IC, as linear charger, is more suitable for applications where the charging source has a relatively low nominal voltage ( $\sim 5$  V), so that a switching charger is suggested for applications where the charging source has a relatively high nominal voltage (e.g.  $\sim 12$  V, see section 2.2.1.7 for the specific design-in).

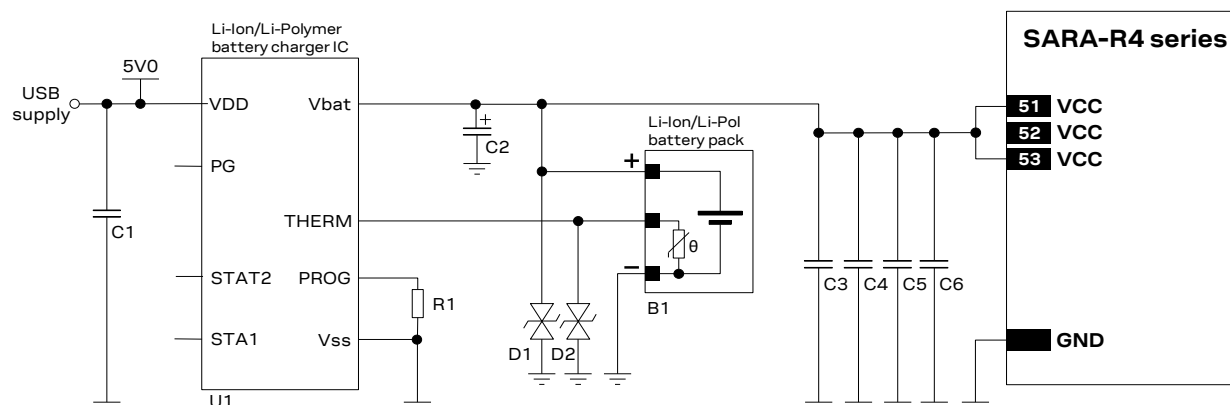


Figure 28: Li-Ion (or Li-Polymer) battery charging application circuit

| Reference | Description   | Part Number - Manufacturer |
|-----------|---|----------------------------|
| B1        | Li-Ion (or Li-Polymer) battery pack with 470 $\Omega$ NTC   | Generic manufacturer       |
| C1        | 1 $\mu$ F Capacitor Ceramic X7R 16 V                        | Generic manufacturer       |
| C2        | 100 $\mu$ F Capacitor Tantalum B_SIZE 20% 6.3V 15m $\Omega$ | T520B107M006ATE015 – Kemet |
| C3        | 15 pF Capacitor Ceramic C0G 0402 5% 50 V                    | GRM1555C1H150JA01 - Murata |
| C4        | 68 pF Capacitor Ceramic C0G 0402 5% 50 V                    | GRM1555C1H680JA01 - Murata |
| C5        | 10 nF Capacitor Ceramic X7R 0402 10% 16 V                   | GRM155R71C103KA01 - Murata |
| C6        | 100 nF Capacitor Ceramic X7R 0402 10% 16 V                  | GRM155R71C104KA01 - Murata |
| D1, D2    | Low Capacitance ESD Protection                              | CG0402MLE-18G - Bourns     |
| R1        | 10 k $\Omega$ Resistor 0.1 W                                | Generic manufacturer       |
| U1        | Single Cell Li-Ion (or Li-Polymer) Battery Charger IC       | MCP73833 - Microchip       |

Table 17: Suggested components for the Li-Ion (or Li-Polymer) battery charging application circuit

See the section 2.2.1.10, and in particular Figure 33 / Table 21, for the parts recommended to be provided if the application device integrates an internal antenna.

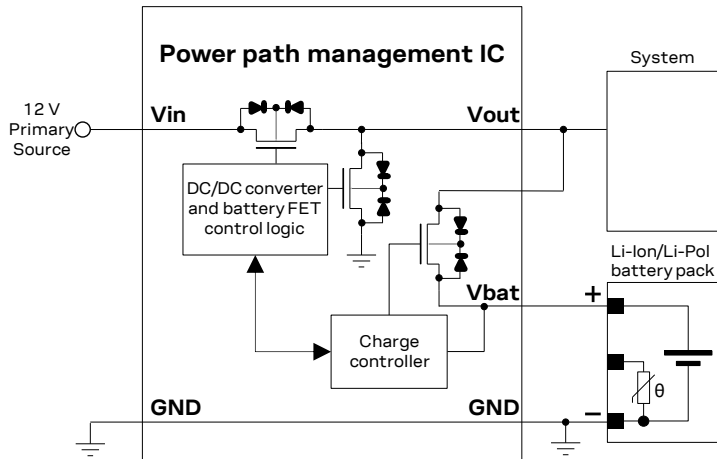
## 2.2.1.7 Guidelines for external charging and power path management circuit

Application devices where both a permanent primary supply / charging source (e.g.  $\sim 12$  V) and a rechargeable back-up battery (e.g. 3.7 V Li-Pol) are available at the same time as a possible supply source, should implement a suitable charger / regulator with integrated power path management function to supply the module and the whole device while simultaneously and independently charging the battery.

Figure 29 reports a simplified block diagram circuit showing the working principle of a charger / regulator with integrated power path management function. This component allows the system to be powered by a permanent primary supply source (e.g.  $\sim 12$  V) using the integrated regulator, which simultaneously and independently recharges the battery (e.g. 3.7 V Li-Pol) that represents the back-up supply source of the system. The power path management feature permits the battery to supplement the system current requirements when the primary supply source is not available or cannot deliver the peak system currents.

A power management IC should meet the following prerequisites to comply with the module **VCC** requirements summarized in [Table 6](#):

- High efficiency internal step down converter, with characteristics as indicated in [section 2.2.1.2](#)
- Low internal resistance in the active path  $V_{out} - V_{bat}$ , typically lower than 50 mΩ
- High efficiency switch mode charger with separate power path control



**Figure 29: Charger / regulator with integrated power path management circuit block diagram**

[Figure 30](#) and the parts listed in [Table 18](#) provide an application circuit example where the MPS MP2617H switching charger / regulator with integrated power path management function provides the supply to the cellular module. At the same time it also concurrently and autonomously charges a suitable Li-Ion (or Li-Polymer) battery with the correct pulse and DC discharge current capabilities and the appropriate DC series resistance according to the rechargeable battery recommendations described in [section 2.2.1.4](#).

The MP2617H IC constantly monitors the battery voltage and selects whether to use the external main primary supply / charging source or the battery as supply source for the module, and starts a charging phase accordingly.

The MP2617H IC normally provides a supply voltage to the module regulated from the external main primary source allowing immediate system operation even under missing or deeply discharged battery: the integrated switching step-down regulator is capable to provide up to 3 A output current with low output ripple and fixed 1.6 MHz switching frequency in PWM mode operation. The module load is satisfied in priority, then the integrated switching charger will take the remaining current to charge the battery.

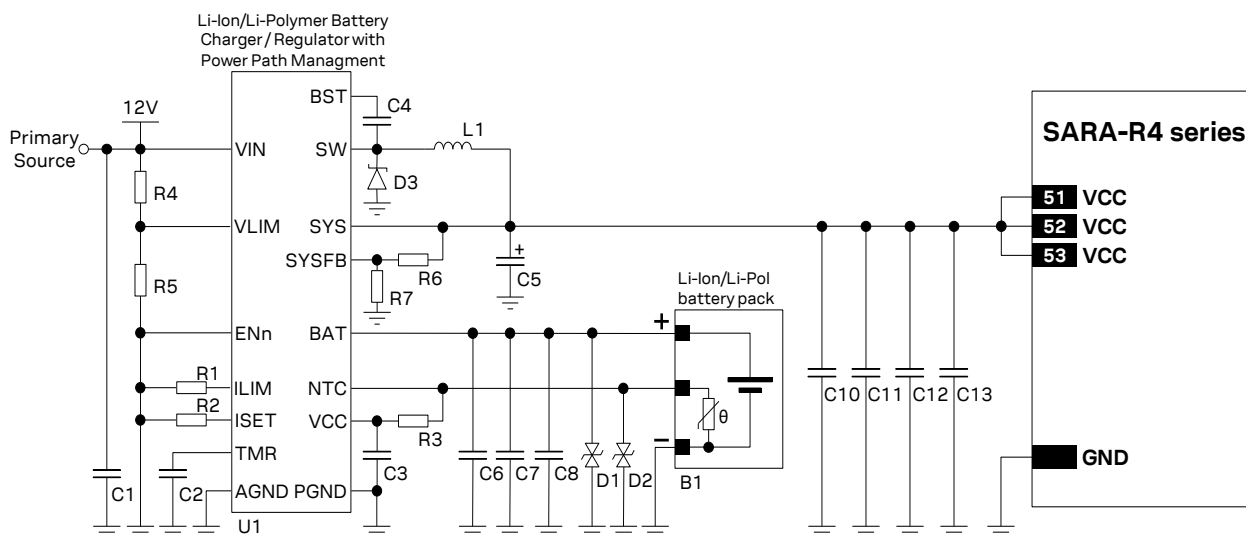
Additionally, the power path control allows an internal connection from battery to the module with a low series internal ON resistance (40 mΩ typical), in order to supplement additional power to the module when the current demand increases over the external main primary source or when this external source is removed.

Battery charging is managed in three phases:

- **Pre-charge constant current** (active when the battery is deeply discharged): the battery is charged with a low current, set to 10% of the fast-charge current
- **Fast-charge constant current**: the battery is charged with the maximum current, configured by the value of an external resistor to a value suitable for the application
- **Constant voltage**: when the battery voltage reaches the regulated output voltage (4.2 V), the current is progressively reduced until the charge termination is done. The charging process ends when the charging current reaches the 10% of the fast-charge current or when the charging timer reaches the value configured by an external capacitor

Using a battery pack with an internal NTC resistor, the MP2617H can monitor the battery temperature to protect the battery from operating under unsafe thermal conditions.

Several parameters as the charging current, the charging timings, the input current limit, the input voltage limit, the system output voltage can be easily set according to the specific application requirements, as the actual electrical characteristics of the battery and the external supply / charging source: suitable resistors or capacitors must be accordingly connected to the related pins of the IC.



**Figure 30: Li-Ion (or Li-Polymer) battery charging and power path management application circuit**

| Reference      | Description  | Part Number - Manufacturer               |
|----------------|--|--|
| B1             | Li-Ion (or Li-Polymer) battery pack with 10 kΩ NTC   | Various manufacturer                     |
| C1, C6         | 22 μF Capacitor Ceramic X5R 1210 10% 25 V  | GRM32ER61E226KE15 - Murata               |
| C2, C4, C10    | 100 nF Capacitor Ceramic X7R 0402 10% 16 V   | GRM155R61A104KA01 - Murata               |
| C3             | 1 μF Capacitor Ceramic X7R 0603 10% 25 V   | GRM188R71E105KA12 - Murata               |
| C5             | 330 μF Capacitor Tantalum D_SIZE 6.3 V 45 mΩ   | T520D337M006ATE045 - KEMET               |
| C7, C12        | 68 pF Capacitor Ceramic C0G 0402 5% 50 V   | GRM1555C1H680JA01 - Murata               |
| C8, C13        | 15 pF Capacitor Ceramic C0G 0402 5% 25 V   | GRM1555C1E150JA01 - Murata               |
| C11            | 10 nF Capacitor Ceramic X7R 0402 10% 16 V  | GRM155R71C103KA01 - Murata               |
| D1, D2         | Low Capacitance ESD Protection   | CG0402MLE-18G - Bourns                   |
| D3             | Schottky Diode 40 V 3 A  | MBRA340T3G - ON Semiconductor            |
| R1, R3, R5, R7 | 10 kΩ Resistor 0402 1% 1/16 W  | Generic manufacturer                     |
| R2             | 1.05 kΩ Resistor 0402 1% 0.1 W   | Generic manufacturer                     |
| R4             | 22 kΩ Resistor 0402 1% 1/16 W  | Generic manufacturer                     |
| R6             | 26.5 kΩ Resistor 0402 1% 1/16 W  | Generic manufacturer                     |
| L1             | 2.2 μH Inductor 7.4 A 13 mΩ 20%  | SRN8040-2R2Y - Bourns                    |
| U1             | Li-Ion/Li-Polymer Battery DC/DC Charger / Regulator with integrated Power Path Management function | MP2617H - Monolithic Power Systems (MPS) |

**Table 18: Suggested components for battery charging and power path management application circuit**



See the section 2.2.1.10, and in particular Figure 33 / Table 21, for the parts recommended to be provided if the application device integrates an internal antenna.

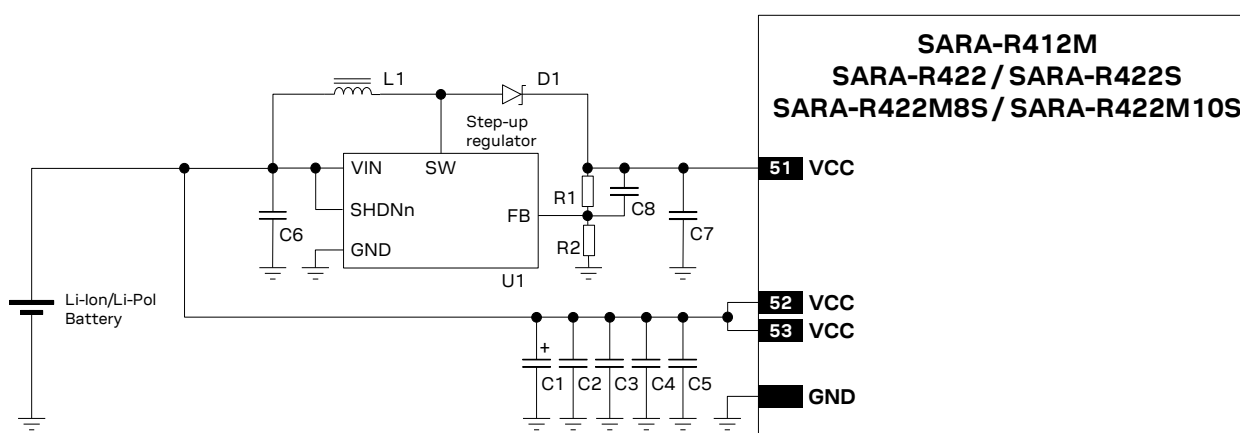


### 2.2.1.8 Guidelines for particular VCC supply circuit design for SARA-R4x2

SARA-R412M, SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules, supporting 2G radio access technology, have separate supply inputs over the **VCC** pins (see [Figure 8](#)):

- **VCC** pins #52 and #53: supply input for the internal RF Power Amplifier, demanding most of the total current drawn of the module when RF transmission is enabled during a call
- **VCC** pin #51: supply input for the internal power management unit, baseband and transceiver parts, demanding minor current

Generally, all the **VCC** pins are intended to be connected to the same external power supply circuit, but separate supply sources can be implemented for specific (e.g. battery-powered) applications. The voltage at the VCC pins #52 and #53 can drop to a value lower than the one at the VCC pin #51, keeping the module still switched-on and functional. [Figure 31](#) illustrates a possible application circuit.



**Figure 31: VCC circuit example with separate supply for SARA-R412M and SARA-R42 series modules**

| Reference | Description                                    | Part Number - Manufacturer          |
|-----------|--|-------------------------------------|
| C1        | 100 µF Capacitor Tantalum B_SIZE 20% 6.3V 15mΩ | T520B107M006ATE015 – Kemet          |
| C2        | 100 nF Capacitor Ceramic X7R 0402 10% 16 V     | GRM155R61A104KA01 - Murata          |
| C3        | 10 nF Capacitor Ceramic X7R 0402 10% 16 V      | GRM155R71C103KA01 - Murata          |
| C4        | 56 pF Capacitor Ceramic C0G 0402 5% 25 V       | GRM1555C1E560JA01 - Murata          |
| C5        | 15 pF Capacitor Ceramic C0G 0402 5% 25 V       | GRM1555C1E150JA01 - Murata          |
| C6        | 10 µF Capacitor Ceramic X5R 0603 20% 6.3 V     | GRM188R60J106ME47 - Murata          |
| C7        | 22 µF Capacitor Ceramic X5R 1210 10% 25 V      | GRM32ER61E226KE15 - Murata          |
| C8        | 10 pF Capacitor Ceramic C0G 0402 5% 25 V       | GRM1555C1E100JA01 - Murata          |
| D1        | Schottky Diode 40 V 1 A                        | SS14 - Vishay General Semiconductor |
| L1        | 10 µH Inductor 20% 1 A 276 mΩ                  | SRN3015-100M - Bourns Inc.          |
| R1        | 1 MΩ Resistor 0402 5% 0.063 W                  | Generic manufacturer                |
| R2        | 412 kΩ Resistor 0402 5% 0.063 W                | Generic manufacturer                |
| U1        | Step-up Regulator 350 mA                       | AP3015 - Diodes Incorporated        |

**Table 19: Examples of parts for the VCC circuit with separate supply for SARA-R412M and SARA-R42 series modules**

See the section [2.2.1.10](#), and in particular [Figure 33](#) / [Table 21](#), for the parts recommended to be provided if the application device integrates an internal antenna.



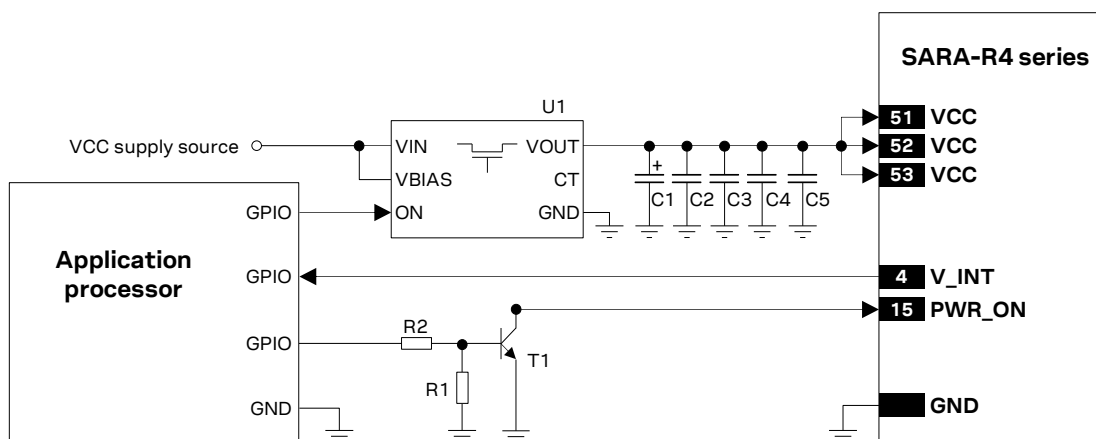
### 2.2.1.9 Guidelines for removing VCC supply

Removing the **VCC** power can be useful to minimize the current consumption when the SARA-R4 series modules are switched off or when the modules are in deep sleep Power Saving Mode.

In applications in which the module is paired to a host application processor equipped with a RTC, the module can execute standard PSM procedures, store NAS protocol context in non-volatile memory, and rely on the host application processor to run its RTC and to trigger wake-up upon need. The application processor can disconnect the **VCC** supply source from the module and zero out the module's PSM current.

The **VCC** supply source can be removed using an appropriate low-leakage load switch or p-channel MOSFET controlled by the application processor as shown in [Figure 32](#), given that the external switch has provide:

- Ultra low leakage current (for example, less than 1  $\mu\text{A}$ ), to minimize the current consumption
- Very low  $R_{\text{DS(ON)}}$  series resistance (for example, less than 50 m $\Omega$ ), to minimize voltage drops
- Adequate maximum drain current (see the SARA-R4 series data sheet [\[1\]](#) for module current consumption figures)



**Figure 32: Example of application circuit for VCC supply removal**

| Reference | Description   | Part Number - Manufacturer      |
|-----------|---|---------------------------------|
| C1        | 100 $\mu\text{F}$ Capacitor Tantalum B_SIZE 20% 6.3V 15m $\Omega$ | T520B107M006ATE015 – Kemet      |
| C2        | 10 nF Capacitor Ceramic X7R 0402 10% 16 V                         | GRM155R71C103KA01 - Murata      |
| C3        | 100 nF Capacitor Ceramic X7R 0402 10% 16 V                        | GRM155R61A104KA01 - Murata      |
| C4        | 68 pF Capacitor Ceramic C0G 0402 5% 50 V                          | GRM1555C1H680JA01 - Murata      |
| C5        | 15 pF Capacitor Ceramic C0G 0402 5% 25 V                          | GRM1555C1E150JA01 - Murata      |
| R1, R3    | 47 k $\Omega$ Resistor 0402 5% 0.1 W                              | RC0402JR-0747KL - Yageo Phycomp |
| R2        | 10 k $\Omega$ Resistor 0402 5% 0.1 W                              | RC0402JR-0710KL - Yageo Phycomp |
| T1        | NPN BJT Transistor  | BC847 - Infineon                |
| U1        | Ultra-Low Resistance Load Switch                                  | TPS22967 - Texas Instruments    |

**Table 20: Components for VCC supply removal application circuit**

- ✍ It is highly recommended to avoid an abrupt removal of the **VCC** supply during SARA-R4 series normal operations: the **VCC** supply can be removed only after **V\_INT** goes low, indicating that the module has entered Deep-Sleep Power Saving Mode or Power-Off Mode.
- ✍ See the section [2.2.1.10](#), and in particular [Figure 33](#) / [Table 21](#), for the parts recommended to be provided if the application device integrates an internal antenna.

### 2.2.1.10 Additional guidelines for VCC supply circuit design

To reduce voltage drops, use a low impedance power source. The series resistance of the supply lines (connected to the modules' **VCC** and **GND** pins) on the application board and battery pack should also be considered and minimized: cabling and routing must be as short as possible to minimize losses.

Three pins are allocated to **VCC** supply connection. Several pins are designated for **GND** connection. It is recommended to correctly connect all of them to supply the module minimizing series resistance.

To reduce voltage ripple and noise, improving RF performance especially if the application device integrates an internal antenna, place the following bypass capacitors near the **VCC** pins:

- 68 pF capacitor with Self-Resonant Frequency in the 800/900 MHz range (e.g. Murata GRM1555C1H680J), to filter EMI in the low cellular frequency bands
- 15 pF capacitor with Self-Resonant Frequency in the 1800/1900 MHz range (as Murata GRM1555C1H150J), to filter EMI in the high cellular frequency bands
- 10 nF capacitor (e.g. Murata GRM155R71C103K), to filter digital logic noise from clocks and data
- 100 nF capacitor (e.g. Murata GRM155R61C104K), to filter digital logic noise from clocks and data

An additional capacitor is recommended to avoid undershoot and overshoot at the start and at the end of RF transmission:

- 100  $\mu$ F low ESR capacitor (e.g. Kemet T520B107M006ATE015), for SARA-R412M supporting 2G
- 10  $\mu$ F capacitor (or greater), for the other SARA-R4 series modules that do not support 2G

An additional series ferrite bead is recommended for additional RF noise filtering, in particular if the application device integrates an internal antenna:

- Ferrite bead specifically designed for EMI suppression in GHz band (e.g. Murata BLM18EG221SN1), placed as close as possible to the **VCC** pins of the module, implementing the circuit described in [Figure 33](#), to filter out EMI in all the cellular bands

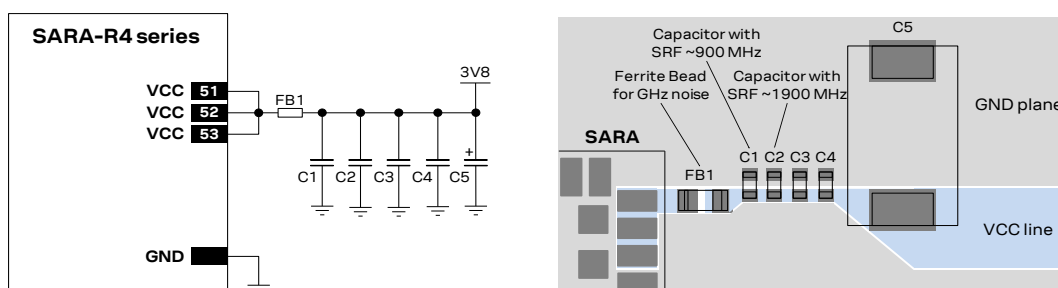



Figure 33: Suggested design to reduce ripple / noise on VCC, highly recommended when using an integrated antenna

| Reference | Description  | Part Number - Manufacturer |
|-----------|--|----------------------------|
| C1        | 68 pF Capacitor Ceramic COG 0402 5% 50 V   | GRM1555C1H680JA01 - Murata |
| C2        | 15 pF Capacitor Ceramic COG 0402 5% 50 V   | GRM1555C1H150JA01 - Murata |
| C3        | 10 nF Capacitor Ceramic X7R 0402 10% 16 V  | GRM155R71C103KA01 - Murata |
| C4        | 100 nF Capacitor Ceramic X7R 0402 10% 16 V   | GRM155R71C104KA01 - Murata |
| C5        | 100 $\mu$ F Capacitor Tantalum B_SIZE 20% 6.3V 15m $\Omega$  | T520B107M006ATE015 - Kemet |
|           | 10 $\mu$ F Capacitor Ceramic X5R 0603 20% 6.3 V  | GRM188R60J106ME47 - Murata |
| FB1       | Chip Ferrite Bead EMI Filter for GHz Band Noise<br>220 $\Omega$ at 100 MHz, 260 $\Omega$ at 1 GHz, 2000 mA | BLM18EG221SN1 - Murata     |

Table 21: Suggested components to reduce ripple / noise on VCC

The necessity of each part depends on the specific design, but it is recommended to provide all the parts described in [Figure 33](#) / [Table 21](#) if the application device integrates an internal antenna.

 ESD sensitivity rating of the **VCC** supply pins is 1 kV (HBM according to JESD22-A114). Higher protection level can be required if the line is externally accessible on the application board, e.g. if accessible battery connector is directly connected to the supply pins. Higher protection level can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG varistor) close to accessible point.

### 2.2.1.11 Guidelines for VCC supply layout design

Good connection of the module **VCC** pins with DC supply source is required for correct RF performance. Guidelines are summarized in the following list:

- All the available **VCC** pins must be connected to the DC source
- **VCC** connection must be as wide as possible and as short as possible
- Any series component with Equivalent Series Resistance (ESR) greater than few milliohms must be avoided
- **VCC** connection must be routed through a PCB area separated from RF lines / parts, sensitive analog signals and sensitive functional units: it is good practice to interpose at least one layer of PCB ground between the **VCC** track and other signal routing
- **VCC** connection must be routed as far as possible from the antenna, in particular if embedded in the application device: see [Figure 34](#)
- Coupling between **VCC** and digital lines, especially USB, must be avoided.
- The tank bypass capacitor with low ESR for current spikes smoothing described in section [2.2.1.10](#) should be placed close to the **VCC** pins. If the main DC source is a switching DC-DC converter, place the large capacitor close to the DC-DC output and minimize **VCC** track length. Otherwise consider using separate capacitors for DC-DC converter and module tank capacitor
- The bypass capacitors in the pF range described in [Figure 33](#) and [Table 21](#) should be placed as close as possible to the **VCC** pins, where the **VCC** line narrows close to the module input pins, improving the RF noise rejection in the band centered on the Self-Resonant Frequency of the pF capacitors. This is highly recommended if the application device integrates an internal antenna
- Since **VCC** input provide the supply to RF Power Amplifiers, voltage ripple at high frequency may result in unwanted spurious modulation of transmitter RF signal. This is more likely to happen with switching DC-DC converters, in which case it is better to select the highest operating frequency for the switcher and add a large L-C filter before connecting to the SARA-R4 series modules in the worst case
- Shielding of switching DC-DC converter circuit, or at least the use of shielded inductors for the switching DC-DC converter, may be considered since all switching power supplies may potentially generate interfering signals as a result of high-frequency high-power switching.
- If **VCC** is protected by transient voltage suppressor to ensure that the voltage maximum ratings are not exceeded, place the protecting device along the path from the DC source toward the module, preferably closer to the DC source (otherwise protection function may be compromised)

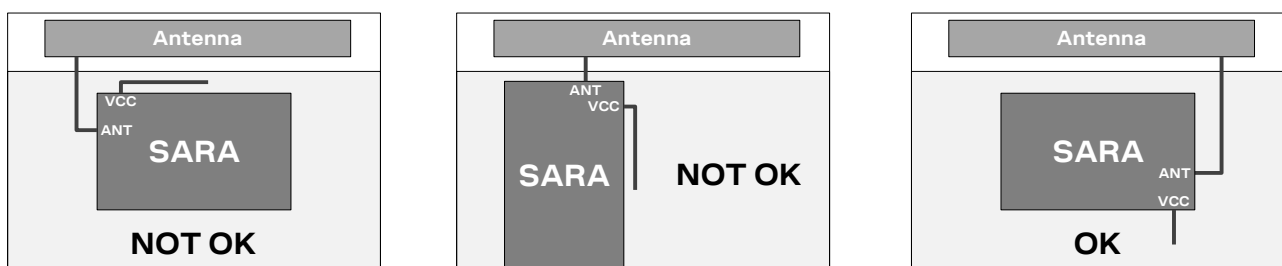


Figure 34: VCC line routing guideline for designs integrating an embedded antenna

### 2.2.1.12 Guidelines for grounding layout design

Good connection of the module **GND** pins with application board solid ground layer is required for correct RF performance. It significantly reduces EMC issues and provides a thermal heat sink for the module.


- Connect each **GND** pin with application board solid GND layer. It is strongly recommended that each **GND** pad surrounding **VCC** pins have one or more dedicated via down to the application board solid ground layer
- The **VCC** supply current flows back to main DC source through GND as ground current: provide adequate return path with suitable uninterrupted ground plane to main DC source
- It is recommended to implement one layer of the application board as ground plane as wide as possible
- If the application board is a multilayer PCB, then all the board layers should be filled with GND plane as much as possible and each GND area should be connected together with complete via stack down to the main ground layer of the board. Use as many vias as possible to connect the ground planes
- Provide a dense line of vias at the edges of each ground area, in particular along RF and high speed lines
- If the whole application device is composed by more than one PCB, then it is required to provide a good and solid ground connection between the GND areas of all the different PCBs
- Good grounding of **GND** pads also ensures thermal heat sink. This is critical during connection, when the real network commands the module to transmit at maximum power: correct grounding helps prevent module overheating.


## 2.2.2 Generic digital interfaces supply output (V\_INT)


### 2.2.2.1 Guidelines for V\_INT circuit design


SARA-R4 series modules provide the **V\_INT** generic digital interfaces 1.8 V supply output, which can be mainly used to:


- Indicate when the module is switched on and it is not in the deep sleep power saving mode (as described in sections [1.6.1](#), [1.6.2](#))
- Pull-up SIM detection signal (see section [2.5](#) for more details)
- Supply voltage translators to connect 1.8 V module generic digital interfaces to 3.0 V devices (e.g. see [2.6.1](#))
- Enable external voltage regulators providing supply for external devices

 Do not apply loads which might exceed the maximum available current from **V\_INT** supply (see SARA-R4 series data sheet [\[1\]](#)) as this can cause malfunctions in internal circuitry.

 **V\_INT** can only be used as an output: do not connect any external supply source on **V\_INT**.

 ESD sensitivity rating of the **V\_INT** supply pin is 1 kV (HBM according to JESD22-A114). Higher protection level could be required if the line is externally accessible and it can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG) close to accessible point.

 It is recommended to monitor the **V\_INT** pin to sense the end of the internal switch-off sequence of SARA-R4 series modules: **VCC** supply can be removed only after **V\_INT** goes low.

 It is highly recommended to provide direct access to the **V\_INT** pin on the application board by means of an accessible test point directly connected to the **V\_INT** pin, for firmware upgrade and/or for diagnostic purposes.


## 2.3 System functions interfaces

### 2.3.1 Module PWR\_ON / PWR\_CTRL input

#### 2.3.1.1 Guidelines for PWR\_ON / PWR\_CTRL circuit design

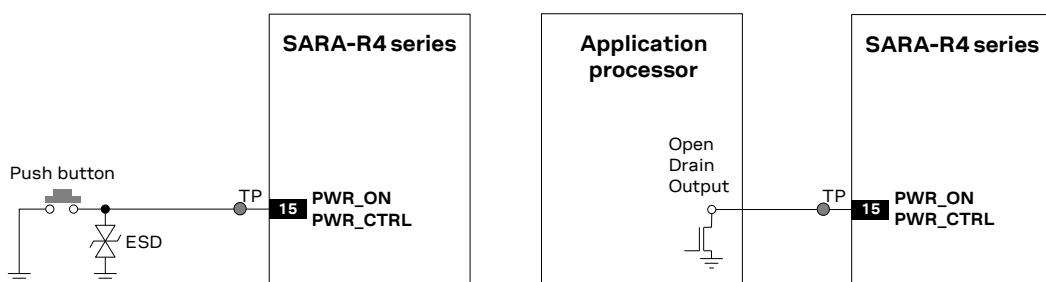
SARA-R4 series **PWR\_ON / PWR\_CTRL** input is equipped with an internal active pull-up resistor; an external pull-up resistor is not required and should not be provided.

If connecting the **PWR\_ON / PWR\_CTRL** input to a push button, the pin will be externally accessible on the application device. According to EMC/ESD requirements of the application, an additional ESD protection should be provided close to the accessible point, as described in [Figure 35](#) and [Table 22](#).

 ESD sensitivity rating of the **PWR\_ON / PWR\_CTRL** pin is 1 kV (HBM according to JESD22-A114). Higher protection level can be required if the line is externally accessible on the application board, e.g. if an accessible push button is directly connected to the pin, and it can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG varistor) close to the accessible point.

An open drain or open collector output is suitable to drive the **PWR\_ON / PWR\_CTRL** input from an application processor, as described in [Figure 35](#).


 **PWR\_ON / PWR\_CTRL** input line should not be driven high, as it may cause start up issues.



**Figure 35: PWR\_ON / PWR\_CTRL application circuits using a push button and an open drain output of an external processor**

| Reference | Description           | Remarks                           |
|-----------|-----------------------|-----------------------------------|
| ESD       | CT0402S14AHSG - EPCOS | Varistor array for ESD protection |

**Table 22: Example ESD protection component for the PWR\_ON / PWR\_CTRL application circuit**

 It is highly recommended to provide direct access to the **PWR\_ON / PWR\_CTRL** pin on the application board by means of an accessible test point directly connected to the **PWR\_ON / PWR\_CTRL** pin, for firmware upgrade and/or for diagnostic purposes

#### 2.3.1.2 Guidelines for PWR\_ON / PWR\_CTRL layout design

The **PWR\_ON / PWR\_CTRL** circuit requires careful layout since it is the sensitive input available to switch on and switch off the SARA-R4 series modules. It is required to ensure that the voltage level is well defined during operation and no transient noise is coupled on this line, otherwise the module might detect a spurious power-on request.

## 2.3.2 Module RESET\_N input

### 2.3.2.1 Guidelines for RESET\_N circuit design

The **RESET\_N** input line of the SARA-R410M and SARA-R412M modules is equipped with an internal pull-up; an external pull-up resistor is not required.

If connecting the **RESET\_N** input to a push button, the pin will be externally accessible on the application device. According to EMC/ESD requirements of the application, an additional ESD protection device (e.g. the EPCOS CA05P4S14THSG varistor) should be provided close to accessible point on the line connected to this pin, as described in [Figure 36](#) and [Table 23](#).

- ESD sensitivity rating of the **RESET\_N** pin is 1 kV (HBM according to JESD22-A114). Higher protection level can be required if the line is externally accessible on the application board, e.g. if an accessible push button is directly connected to the **RESET\_N** pin, and it can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG varistor) close to accessible point.

An open drain output or open collector output is suitable to drive the **RESET\_N** input from an application processor, as described in [Figure 36](#).

- RESET\_N** input pin should not be driven high by an external device, as it may cause start up issues.

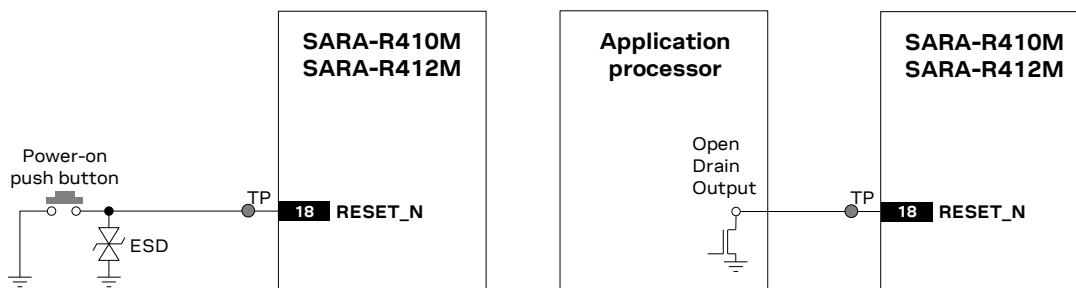


Figure 36: RESET\_N application circuits using a push button and an open drain output of an application processor

| Reference | Description           | Remarks                           |
|-----------|-----------------------|-----------------------------------|
| ESD       | CT0402S14AHSG - EPCOS | Varistor array for ESD protection |

Table 23: Example of ESD protection component for the RESET\_N application circuits

- If the external reset function is not required by the customer application, the **RESET\_N** input pin can be left unconnected to external components, but it is recommended providing direct access on the application board by means of an accessible test point directly connected to the **RESET\_N** pin for diagnostic purpose.

### 2.3.2.2 Guidelines for RESET\_N layout design

The **RESET\_N** circuit require careful layout due to the pin function: ensure that the voltage level is well defined during operation and no transient noise is coupled on this line, otherwise the module might detect a spurious reset request. It is recommended to keep the connection line to **RESET\_N** pin as short as possible.

## 2.4 Antenna interfaces

SARA-R4 series modules provide an RF interface for connecting the external antenna: the **ANT** pin represents the RF input/output for RF signals transmission and reception.

SARA-R422M8S and SARA-R422M10S modules provide also a GNSS RF interface for connecting the external GNSS antenna: the **ANT\_GNSS** pin represents the RF input for GNSS signals reception.

The **ANT** and **ANT\_GNSS** pins have a nominal characteristic impedance of  $50\ \Omega$  and must be connected to the related external antenna system through a  $50\ \Omega$  transmission line to allow clean transmission / reception of RF signals.

### 2.4.1 General guidelines for antenna interfaces

#### 2.4.1.1 Guidelines for ANT and ANT\_GNSS pins RF connection design

 GNSS antenna RF interface is supported by SARA-R422M8S / SARA-R422M10S modules only.

A clean transition between the **ANT** and **ANT\_GNSS** pads and the application board PCB must be provided, implementing the following design-in guidelines for the layout of the application PCB close to the **ANT** and **ANT\_GNSS** pads:

- On a multilayer board, the whole layer stack below the RF connections should be free of digital lines
- Increase GND keep-out (i.e. clearance, a void area) around the **ANT** and **ANT\_GNSS** pads, on the top layer of the application PCB, to at least  $250\ \mu\text{m}$  up to adjacent pads metal definition and up to  $400\ \mu\text{m}$  on the area below the module, to reduce parasitic capacitance to ground, as described in the left picture in [Figure 37](#)
- Add GND keep-out (i.e. clearance, a void area) on the buried metal layer below the **ANT** and **ANT\_GNSS** pads if the top-layer to buried layer dielectric thickness is below  $200\ \mu\text{m}$ , to reduce parasitic capacitance to ground, as described in the right picture in [Figure 37](#)

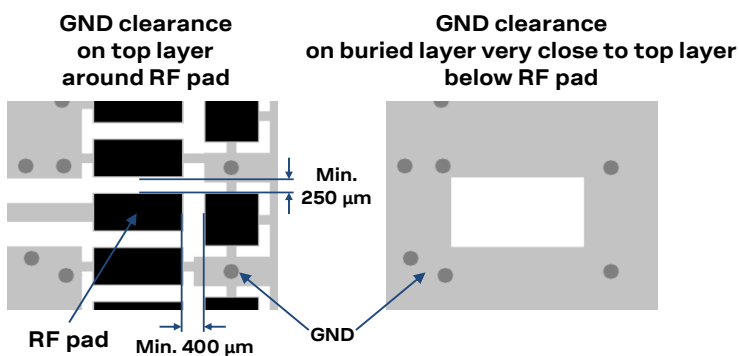


Figure 37: GND keep-out area on top layer around RF pad and on very close buried layer below RF pad (ANT / ANT\_GNSS)



### 2.4.1.2 Guidelines for RF transmission lines design

GNSS antenna RF interface is supported by SARA-R422M8S / SARA-R422M10S modules only.

Any RF transmission line, such as the ones from the **ANT** and **ANT\_GNSS** pads up to the related antenna connector or up to the related internal antenna pad, must be designed so that the characteristic impedance is as close as possible to 50  $\Omega$ .

RF transmission lines can be designed as a micro strip (consists of a conducting strip separated from a ground plane by a dielectric material) or a strip line (consists of a flat strip of metal which is sandwiched between two parallel ground planes within a dielectric material). The micro strip, implemented as a coplanar waveguide, is the most common configuration for printed circuit board.

Figure 38 and Figure 39 provide two examples of suitable 50  $\Omega$  coplanar waveguide designs. The first example of RF transmission line can be implemented in case of 4-layer PCB stack-up herein described, and the second example of RF transmission line can be implemented in case of 2-layer PCB stack-up herein described.

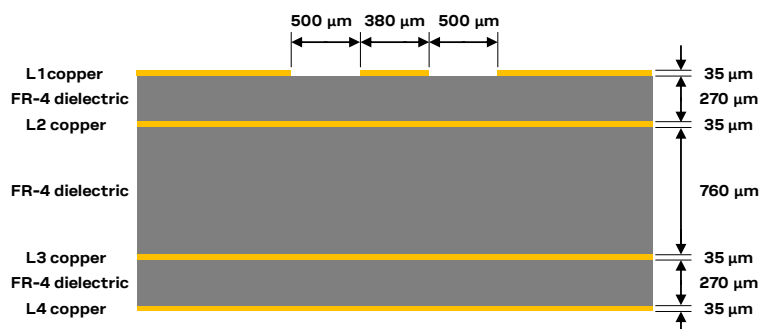


Figure 38: Example of 50  $\Omega$  coplanar waveguide transmission line design for the described 4-layer board layup

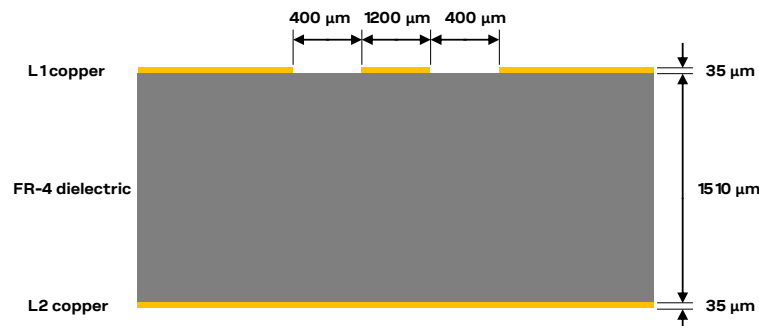


Figure 39: Example of 50  $\Omega$  coplanar waveguide transmission line design for the described 2-layer board layup

If the two examples do not match the application PCB stack-up, then the 50  $\Omega$  characteristic impedance calculation can be made using the HFSS commercial finite element method solver for electromagnetic structures from Ansys Corporation, or using freeware tools like Avago / Broadcom AppCAD (<https://www.broadcom.com/appcad>) taking care of the approximation formulas used by the tools for the impedance computation.

To achieve a 50  $\Omega$  characteristic impedance, the transmission line width must be chosen due to:

- the thickness of the transmission line itself (e.g. 35  $\mu\text{m}$  in the example of Figure 38 and Figure 39)
- the thickness of the dielectric material between the top layer (where the line is routed) and the inner closer layer implementing the ground plane (e.g. 270  $\mu\text{m}$  in Figure 38 and Figure 39)
- the dielectric constant of the dielectric material (e.g. dielectric constant of the FR-4 dielectric material in Figure 38 and Figure 39)
- the gap from the transmission line to the adjacent ground plane on the same layer of the transmission line (e.g. 500  $\mu\text{m}$  in Figure 38 and 400  $\mu\text{m}$  in Figure 39)



If the distance between the transmission line and the adjacent GND area (on the same layer) does not exceed 5 times the width of the line, use the “Coplanar Waveguide” model for the 50  $\Omega$  calculation.

Additionally to the 50  $\Omega$  impedance, the following guidelines are recommended for transmission lines:

- Minimize the transmission line length: the insertion loss should be minimized as much as possible, in the order of a few tenths of a dB,
- Add GND keep-out (i.e. clearance, a void area) on buried metal layers below any pad of component present on the RF transmission lines, if top-layer to buried layer dielectric thickness is below 200  $\mu\text{m}$ , to reduce parasitic capacitance to ground,
- The transmission lines width and spacing to GND must be uniform and routed as smoothly as possible: avoid abrupt changes of width and spacing to GND,
- Add GND stitching vias around transmission lines, as described in [Figure 40](#),
- Ensure solid metal connection of the adjacent metal layer on the PCB stack-up to main ground layer, providing enough vias on the adjacent metal layer, as described in [Figure 40](#),
- Route RF transmission lines far from any noise source (as switching supplies and digital lines) and from any sensitive circuit (as USB),
- Avoid stubs on the transmission lines,
- Avoid signal routing in parallel to transmission lines or crossing the transmission lines on buried metal layer,
- Do not route microstrip lines below discrete component or other mechanics placed on top layer

Two examples of a suitable RF circuit design for **ANT** pin are illustrated in [Figure 40](#), where the cellular antenna detection circuit is not implemented (if the cellular antenna detection function is required by the application, follow the guidelines for circuit and layout implementation detailed in [section 2.4.5](#)):

- In the first example shown on the left, the **ANT** pin is directly connected to an SMA connector by means of a suitable 50  $\Omega$  transmission line, designed with the appropriate layout.
- In the second example shown on the right, the **ANT** pin is connected to an SMA connector by means of a suitable 50  $\Omega$  transmission line, designed with the appropriate layout, with an additional high pass filter to improve the ESD immunity at the antenna port. (The filter consists of a suitable series capacitor and shunt inductor, for example the Murata GRM1555C1H150JB01 15 pF capacitor and the Murata LQG15HN39NJ02 39 nH inductor with SRF  $\sim$ 1 GHz.).

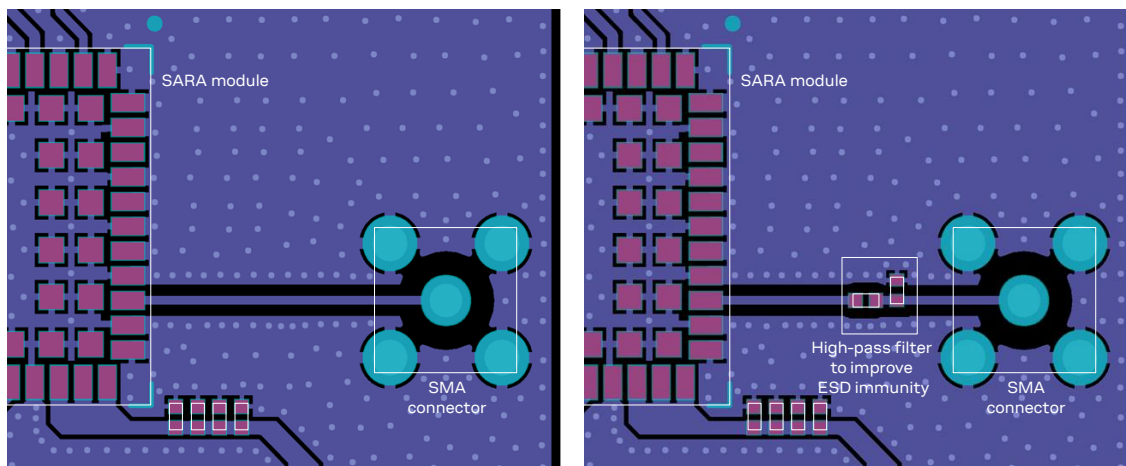


Figure 40: Example of circuit and layout for ANT RF circuits on the application board

### 2.4.1.3 Guidelines for RF termination design

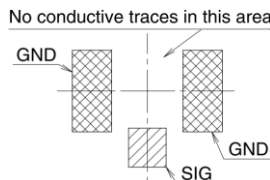
GNSS antenna RF interface is supported by SARA-R422M8S / SARA-R422M10S modules only.

The RF termination must provide a characteristic impedance of  $50\ \Omega$  as well as the RF transmission line up to the RF termination, to match the characteristic impedance of **ANT** and **ANT\_GNSS** ports.

However, real antennas do not have a perfect  $50\ \Omega$  load on all the supported frequency bands. So to reduce as much as possible any performance degradation due to antenna mismatching, the RF termination must provide optimal return loss (or VSWR) figures over all the operating frequencies, as summarized in [Table 7](#) and [Table 8](#).

If an external antenna is used, the antenna connector represents the RF termination on the PCB:

- Use a suitable  $50\ \Omega$  connector providing a clean PCB-to-RF-cable transition.
- Strictly follow the connector manufacturer's recommended layout, for example:
  - SMA Pin-Through-Hole connectors require a GND keep-out (i.e. clearance, a void area) on all the layers around the central pin up to the annular pads of the four GND posts (see [Figure 40](#))
  - U.FL surface mounted connectors require no conductive traces (i.e. clearance, a void area) in the area below the connector between the GND land pads, as illustrated in [Figure 41](#)



**Figure 41: U.FL surface mounted connector mounting pattern layout**

- Cut out the GND layer under the RF connector and close to any buried vias, to remove stray capacitance and thus keep the RF line at  $50\ \Omega$ , e.g. the active pad of U.FL connector needs to have a GND keep-out (i.e. clearance, a void area) at least on the first inner layer to reduce parasitic capacitance to ground.

If an integrated antenna is used, the integrated antenna represents the RF terminations. The following guidelines should be followed:

- Use an antenna designed by an antenna manufacturer providing the best possible return loss.
- Provide a ground plane large enough according to the relative integrated antenna requirements. The ground plane of the application PCB can be reduced down to a minimum size that must be similar to one quarter of wavelength of the minimum frequency that needs to be radiated. As numerical example,  
Frequency = 617 MHz  $\rightarrow$  Wavelength  $\cong$  48 cm  $\rightarrow$  Minimum GND plane size  $\cong$  12 cm
- It is highly recommended to strictly follow the detailed and specific guidelines provided by the antenna manufacturer regarding correct installation and deployment of the antenna system, including the PCB layout and matching circuitry.
- Further to the custom PCB and product restrictions, the antenna may require a tuning to comply with all the applicable required certification schemes. It is recommended to consult the antenna manufacturer for antenna matching design-in guidelines relative to the custom application.

Additionally, these recommendations regarding the antenna system placement must be followed:

- Do not place the antennas within a closed metal case.
- Do not place the cellular antenna in close vicinity to the end user since the emitted radiation in human tissue is restricted by regulatory requirements.
- Place the antennas as far as possible from VCC supply line and related parts (see also [Figure 34](#)), from high speed digital lines (as USB) and from any possible noise source.

- Place the antenna far from sensitive analog systems or employ countermeasures to reduce EMC or EMI issues.
- Be aware of interaction between co-located RF systems since the LTE transmitted power may interact or affect the performance of companion systems as a GNSS receiver (see section [2.4.4](#) for further details and design-in guidelines regarding Cellular / GNSS RF coexistence).

## 2.4.2 Cellular antenna RF interface (ANT)

### 2.4.2.1 General guidelines for antenna selection and design

The antenna is the most critical component to be evaluated. Designers must take care of the antenna from all perspective at the very start of the design phase when the physical dimensions of the application board are under analysis/decision, since the RF compliance of the device integrating SARA-R4 series modules with all the applicable required certification schemes depends on antenna's radiating performance.

Cellular antennas are typically available as:

- External antennas (e.g. linear monopole):
  - External antennas basically do not imply physical restriction to the design of the PCB where the SARA-R4 series module is mounted.
  - The radiation performance mainly depends on the antennas. It is required to select antennas with optimal radiating performance in the operating bands.
  - RF cables should be carefully selected to have minimum insertion losses. Additional insertion loss will be introduced by low quality or long cable. Large insertion loss reduces both transmit and receive radiation performance.
  - A high quality 50  $\Omega$  RF connector provides a clean PCB-to-RF-cable transition. It is recommended to strictly follow the layout and cable termination guidelines provided by the connector manufacturer.
- Integrated antennas (e.g. PCB antennas such as patches or ceramic SMT elements):
  - Internal integrated antennas imply physical restriction to the design of the PCB: Integrated antenna excites RF currents on its counterpoise, typically the PCB ground plane of the device that becomes part of the antenna: its dimension defines the minimum frequency that can be radiated. Therefore, the ground plane can be reduced down to a minimum size that should be similar to the quarter of the wavelength of the minimum frequency that needs to be radiated, given that the orientation of the ground plane relative to the antenna element must be considered. As numerical example, the physical restriction to the PCB design can be considered as following:  
Frequency = 750 MHz  $\rightarrow$  Wavelength = 40 cm  $\rightarrow$  Minimum GND plane size = 10 cm
  - Radiation performance depends on the whole PCB and antenna system design, including product mechanical design and usage. Antennas should be selected with optimal radiating performance in the operating bands according to the mechanical specifications of the PCB and the whole product.
  - It is recommended to select a custom antenna designed by an antennas' manufacturer if the required ground plane dimensions are very small (e.g. less than 6.5 cm long and 4 cm wide). The antenna design process should begin at the start of the whole product design process
  - It is highly recommended to strictly follow the detailed and specific guidelines provided by the antenna manufacturer regarding correct installation and deployment of the antenna system, including PCB layout and matching circuitry
  - Further to the custom PCB and product restrictions, antennas may require tuning to obtain the required performance for compliance with all the applicable required certification schemes. It is recommended to consult the antenna manufacturer for the design-in guidelines for antenna matching relative to the custom application

In both of cases, selecting external or internal antennas, these recommendations should be observed:

- Select an antenna providing optimal return loss / VSWR / efficiency figure over all the operating cellular frequencies.
- Select an antenna providing the worst possible return loss / VSWR / efficiency figure in the GNSS frequency band, to optimize the RF coexistence between the cellular and the GNSS systems (see section 2.4.4 for further details and guidelines regarding Cellular / GNSS RF coexistence).
- Select an antenna providing appropriate gain figure (i.e. combined antenna directivity and efficiency figure) so that the electromagnetic field radiation intensity do not exceed the regulatory limits specified in some countries, such as FCC United States (see section 4.2.2), ISED Canada (see section 4.3.1), RED Europe (see section 4.4), GITEKI Japan (see section 4.9), etc.

## 2.4.2.2 Examples of cellular antennas

Table 24 lists some examples of possible internal on-board surface-mount antennas.

| Manufacturer       | Part number          | Product name | Description  |
|--------------------|----------------------|--------------|--|
| Taoglas            | PA.710.A             | Warrior      | GSM / WCDMA / LTE SMD antenna<br>698..960 MHz, 1710..2170 MHz, 2300..2400 MHz,<br>2490..2690 MHz<br>40.0 x 6.0 x 5.0 mm  |
| Taoglas            | PCS.26.A             | Havok        | LTE SMD dielectric antenna<br>617..960 MHz, 1710..2690 MHz<br>54.6 x 13.0 x 3.0 mm                                       |
| Taoglas            | PCS.06.A             | Reach        | Low-profile 4G/3G/2G SMD antenna<br>698..960 MHz, 1710..2690 MHz<br>42.0 x 10.0 x 3.0 mm                                 |
| Taoglas            | PCS.86.A             | Reach        | Wideband cellular SMD antenna<br>791..6000 MHz<br>32.0 x 16.0 x 1.6 mm   |
| Antenova           | SR4L002              | Lucida       | GSM / WCDMA / LTE SMD antenna<br>698..960 MHz, 1710..2170 MHz, 2300..2400 MHz,<br>2490..2690 MHz<br>35.0 x 8.5 x 3.2 mm  |
| AVX / Ethertronics | 1004795 /<br>1004796 |              | Cellular SMD antenna<br>617..960 MHz, 1710..2200 MHz, 2490..2700 MHz<br>36.0 x 9.0 x 3.2 mm                              |
| AVX / Ethertronics | P822601 /<br>P822602 |              | GSM / WCDMA / LTE SMD antenna<br>698..960 MHz, 1710..2170 MHz, 2490..2700 MHz<br>50.0 x 8.0 x 3.2 mm                     |
| AVX / Ethertronics | 1002436              |              | GSM / WCDMA / LTE vertical mount antenna<br>698..960 MHz, 1710..2700 MHz<br>50.6 x 19.6 x 1.6 mm                         |
| Fractus            | NN03-310             | TRIO mXTEND™ | GSM / WCDMA / LTE SMD antenna<br>698..8000 MHz<br>30.0 x 3.0 x 1.0 mm  |
| Pulse              | W3796                | Domino       | GSM / WCDMA / LTE SMD antenna<br>698..960 MHz, 1427..1661 MHz, 1695..2200 MHz,<br>2300..2700 MHz<br>42.0 x 10.0 x 3.0 mm |
| TE Connectivity    | 2118310-1            |              | GSM / WCDMA / LTE vertical mount antenna<br>698..960 MHz, 1710..2170 MHz, 2300..2700 MHz<br>74.0 x 10.6 x 1.6 mm         |

| Manufacturer | Part number | Product name | Description  |
|--------------|-------------|--------------|--|
| Molex        | 1462000001  |              | GSM / WCDMA / LTE SMD antenna<br>698..960 MHz, 1700..2700 MHz<br>40.0 x 5.0 x 5.0 mm |
| Cirocomm     | DSAN0001    |              | Ceramic LTE SMD antenna<br>698..960 MHz, 1710..2170 MHz<br>40.0 x 6.0 x 5.0 mm       |
| Amotech      | AMMAL025    |              | Vertical global LTE SMD antenna<br>699...2690 MHz<br>50.6 x 19.8 x 1.6 mm            |

**Table 24: Examples of internal surface-mount antennas**

Table 25 lists some examples of possible internal off-board PCB-type antennas with cable and connector.

| Manufacturer            | Part number        | Product name | Description  |
|-------------------------|--------------------|--------------|--|
| PulseLarsen<br>Antennas | W3929B0100         |              | LTE FPC antenna with coax feed<br>617..960 MHz, 1710..2690 MHz, 3400..3900 MHz<br>115.8 x 30.4 mm  |
| Taoglas                 | FXUB63             |              | GSM / WCDMA / LTE PCB antenna with cable and U.FL<br>698..960 MHz, 1575.42 MHz, 1710..2170 MHz, 2400..2690 MHz<br>96.0 x 21.0 mm                 |
| Taoglas                 | FXUB64             | Cyclone      | LTE wideband flex antenna<br>617..960 MHz, 1710..2690 MHz<br>130.0 x 30.0 mm   |
| Taoglas                 | FXUB65 /<br>FXUB68 | Minima       | Flexible wideband antenna<br>700..2700 MHz<br>67.0 x 58.0 x 0.2 mm   |
| Laird Tech.             | EFF692SA3S         | Revie Flex   | Flexible LTE antenna<br>689..875 MHz, 1710..2500 MHz<br>90.0 x 20.0 mm   |
| Antenova                | SRFL026            | Mitis        | GSM / WCDMA / LTE antenna on flexible PCB with cable and U.FL<br>689..960 MHz, 1710..2170 MHz, 2300..2400 MHz, 2500..2690 MHz<br>110.0 x 20.0 mm |
| AVX / Ethertronics      | 1002289            |              | GSM / WCDMA / LTE antenna on flexible PCB with cable and U.FL<br>698..960 MHz, 1710..2700 MHz<br>140.0 x 75.0 mm                                 |
| EAD                     | FSQS35241-UF-10    | SQ7          | GSM / WCDMA / LTE PCB antenna with cable and U.FL<br>690..960 MHz, 1710..2170 MHz, 2500..2700 MHz<br>110.0 x 21.0 mm                             |
| Amotech                 | AMMAL024           |              | FPCB antenna with cable<br>617..5000 MHz<br>120.0 x 30.0 mm  |

**Table 25: Examples of internal antennas with cable and connector**



Table 26 lists some examples of possible external antennas.

| Manufacturer       | Part number | Description  |
|--------------------|-------------|--|
| AVX / Ethertronics | 1003657     | Cellular antenna with RG178 coax cable and MMCX connector<br>698..960 MHz, 1710..2700 MHz<br>104 x 22 x 4.2 mm |

| Manufacturer       | Part number                                      | Description   |
|--------------------|--|---|
| AVX / Ethertronics | 1004112-A001 /<br>1004112-B002 /<br>1004112-C003 | Broadband External LTE / Cellular Antenna<br>698..960 MHz, 1710..2700 MHz<br>218.2 x 27.2 x 13.8 mm   |
| AVX / Ethertronics | X1005246-4GA1SA10A1                              | Adhesive-mount LTE external antenna<br>698..960 MHz, 1710..2170 MHz, 2300..2690 MHz,<br>105.1 x 30.1 x 6.7 mm   |
| Taoglas            | TG.35.8113                                       | Wideband LTE dipole terminal antenna hinged SMA(M)<br>617..1200 MHz, 1710..2700 MHz, 4900..5900 MHz<br>224 x 58 x 13 mm   |
| Taoglas            | MA241.BI.001                                     | GSM / WCDMA / LTE MIMO 2in1 adhesive-mount combination antenna<br>waterproof IP67 rated with cable and SMA(M)<br>698..960 MHz, 1710..2170 MHz, 2400..2700 MHz<br>205.8 x 58 x 12.4 mm |
| Taoglas            | GSA.8827.A.101111                                | Wideband I-Bar adhesive mount IP65 antenna with cable and SMA(M)<br>698..960 MHz, 1575.42 MHz, 1710..2700 MHz<br>105 x 30 x 7.7 mm  |
| Taoglas            | GSA.8835.A.101111                                | Wideband I-Bar adhesive mount IP67 antenna with cable and SMA(M)<br>698..960 MHz, 1575.42 MHz, 1710..2700 MHz<br>105 x 30 x 7.7 mm  |
| Laird Tech.        | CMS69273   | GSM / WCDMA / LTE ceiling-mount antenna with cable and N-type(F)<br>698..960 MHz, 1575.42 MHz, 1710..2700 MHz<br>86 x Ø 199 mm  |
| Laird Tech.        | OC69271-FNM                                      | GSM / WCDMA / LTE pole-mount antenna with N-type(M)<br>698..960 MHz, 1710..2690 MHz<br>248 x Ø 24.5 mm  |
| Pulse Electronics  | SPDA24617/3900                                   | Multiband swivel dipole antenna with SMA(M)<br>617..960 MHz, 1400..2700 MHz, 3200..3900 MHz<br>223.24 x 56.13 x 10.97 mm  |
| Amotech            | ACA556022-S0-A1                                  | LTE + Sub6G External Antenna<br>699..3800 MHz<br>80.0 x 60.0 x 22.5 mm  |

**Table 26: Examples of external antennas**

### 2.4.3 GNSS antenna RF interface (ANT\_GNSS)

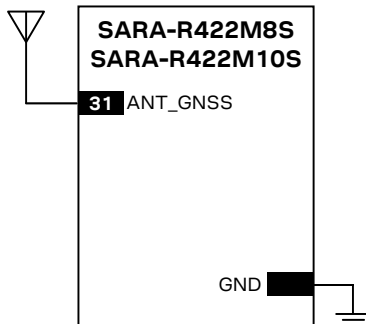
-  GNSS antenna RF interface is supported by SARA-R422M8S / SARA-R422M10S modules only.
-  For additional information and guidelines regarding the GNSS design, see the u-blox SARA-R4 / SARA-R5 positioning implementation application note [\[21\]](#).

The antenna and its placement are critical system factors for accurate GNSS reception. Use of a ground plane will minimize the effects of ground reflections and enhance the antenna efficiency. A good allowance for ground plane size is typically in the area of 50 x 50 to 70 x 70 mm<sup>2</sup>. The smaller the electrical size of the plane, the narrower the reachable bandwidth and the lower the radiation efficiency. Exercise care with rover vehicles that emit RF energy from motors etc. as interference may extend into the GNSS band and couple into the GNSS antenna suppressing the wanted signal. For more details about GNSS antennas, see also the u-blox GNSS antennas application note [\[22\]](#).

Since SARA-R422M8S and SARA-R422M10S modules already include an internal SAW filter followed by an additional LNA before the u-blox GNSS chipset (as illustrated in [Figure 6](#)), they are optimized to work with passive or active antennas without requiring additional external circuitry.


### 2.4.3.1 Guidelines for applications with a passive antenna

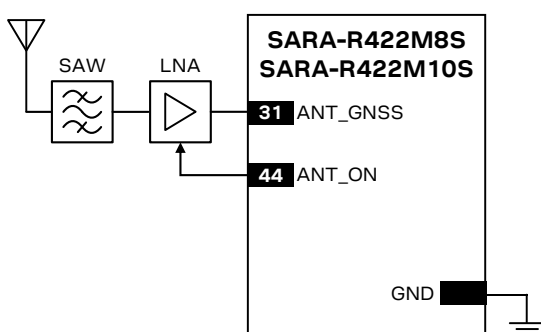
If a GNSS passive antenna with high gain and good sky view is used, together with a short 50  $\Omega$  line between antenna and receiver, and no jamming sources affect the GNSS passive antenna, the circuit illustrated in [Figure 42](#) can be used. This provides the minimum BoM cost and minimum board space.



**Figure 42: Minimum circuit with GNSS passive antenna**

If the connection between the module and antenna incurs additional losses (e.g. antenna placed far away from the module, small ground plane for a patch antenna) or improved jamming immunity is needed due to strong out-of-band jammers close to the GNSS antenna (e.g. the cellular antenna is close to the GNSS antenna), consider adding an external SAW filter (see [Table 27](#) for possible suitable examples) close to the GNSS passive antenna, followed by an external LNA (see [Table 28](#) for possible suitable examples), as illustrated in [Figure 43](#), provided that SARA-R422M8S / SARA-R422M10S modules already include dedicated internal SAW filter followed by an LNA before the u-blox GNSS chipset (as illustrated in [Figure 6](#)), so that additional external SAW and LNA are not required for most of the applications (see section 2.4.4 for further details and design-in guidelines regarding Cellular / GNSS RF coexistence).

 An external LNA with related external SAW filter are only required if the GNSS antenna is far away (more than 10 cm) from the GNSS RF input of the module. In that case, the SAW and the LNA must be placed close to the passive antenna.



**Figure 43: Typical circuit for best performance and improved jamming immunity with GNSS passive antenna**

The external LNA can be selected to deliver the performance needed by the application in terms of:

- Noise figure (sensitivity)
- Selectivity and linearity (robustness against jamming)
- Robustness against RF power

Depending on the characteristics of the supply source (DC/DC regulator, linear LDO regulator or other) used to supply the external LNA, make sure some good filtering is in place for the external LNA supply because of the noise on the external LNA supply line can affect the performance of the LNA itself:



consider adding a proper series ferrite bead (see [Table 29](#) for possible suitable examples) and a proper decoupling capacitor to ground with Self-Resonant Frequency in the GNSS frequency range (as for example the 27 pF 0402 capacitor Murata GCM1555C1H270JA16) at the input of the external LNA supply line.

It should be noted anyway that the insertion loss of the filter directly affects the system noise figure and hence the system performance. The selected SAW filter has to provide very low loss (no more than 1.5 dB) in the GNSS pass-band, beside providing very large attenuation (more than 40 to 60 dB) in the out-of-band jammers' cellular frequency bands (see [Table 27](#) for possible suitable examples).

SARA-R422M8S and SARA-R422M10S modules already provides an integrated SAW filter and LNA (as illustrated in [Figure 6](#)). The addition of such external components should be carefully evaluated, especially in case the application power consumption should be minimized, since the LNA alone requires an additional supply current of typically 5 to 20 mA.

Moreover, the first LNA of the input chain will dominate the receiver noise performance, therefore its noise figure should be less than 2 dB. If the antenna is close to the receiver, then a good passive antenna (see [Table 30](#)) can be directly connected to the receiver with a short (a few cm) 50  $\Omega$  line. From a noise point of view, this design choice offers comparable performance as an active antenna with a long (~3 to 5m) cable attached to the application board by means of an SMA connector without the increased power consumption and BOM cost. If the goal is to protect the GNSS receiver in a noisy environment, then an additional external SAW filter may be required. If a degradation in the C/No of 2 to 3 dB (depending on the choice of the filter) is not acceptable for the application, then, to compensate for the filter losses and restore an adequate C/No level, an external LNA with good gain and low noise figure (see [Table 28](#)) is to be considered.

[Table 27](#) lists examples of SAW filters suitable for the GNSS RF input of the modules.

| Manufacturer | Part number     | Description   |
|--------------|-----------------|---|
| Murata       | SAFFB1G56AC0F0A | GPS / SBAS / QZSS / GLONASS / Galileo / BeiDou RF band-pass SAW filter with high attenuation in Cellular frequency ranges |
| Murata       | SAFFB1G56AC0F7F | GPS / SBAS / QZSS / GLONASS / Galileo / BeiDou RF band-pass SAW filter with high attenuation in Cellular frequency ranges |

**Table 27: Examples of GNSS band-pass SAW filters**

[Table 28](#) lists examples of LNA suitable for the GNSS RF input of the modules.

| Manufacturer        | Part number | Comments   |
|---------------------|-------------|--|
| Maxim               | MAX2659ELT+ | Low noise figure, up to 10 dBm RF input power      |
| JRC New Japan Radio | NJG1143UA2  | Low noise figure, up to 15 dBm RF input power      |
| NXP                 | BGU8006     | Low noise figure, very small package size (WL-CSP) |
| Infineon            | BGA524N6    | Low noise figure, small package size               |

**Table 28: Examples of GNSS Low Noise Amplifiers**

[Table 29](#) lists examples of ferrite beads suitable for the supply line of an external GNSS LNA.

| Manufacturer | Part number   | Comments                    |
|--------------|---------------|-----------------------------|
| Murata       | BLM15HD102SN1 | High impedance at 1.575 GHz |
| Murata       | BLM15HD182SN1 | High impedance at 1.575 GHz |
| TDK          | MMZ1005F121E  | High impedance at 1.575 GHz |
| TDK          | MMZ1005A121E  | High impedance at 1.575 GHz |

**Table 29: Examples of ferrite beads for the supply line of external GNSS Low Noise Amplifiers**



Table 30 lists examples of passive antennas suitable for the GNSS RF input of the modules.

| Manufacturer | Part number       | Product name | Description   |
|--------------|-------------------|--------------|---|
| Tallysman    | TW3400P           |              | Passive antenna<br>GPS / SBAS / QZSS / GLONASS                                    |
| Tallysman    | TW3710P           |              | Passive antenna<br>GPS / SBAS / QZSS / GLONASS / Galileo / BeiDou                 |
| Taoglas      | CGGBP.35.3.A.02   |              | Ceramic patch antenna<br>GPS / SBAS / QZSS / GLONASS / Galileo / BeiDou           |
| Taoglas      | CGGBP.18.4.A.02   |              | Embedded patch antenna<br>GPS / SBAS / QZSS / GLONASS / Galileo / BeiDou          |
| Inpaq        | PA1590MF6G        |              | Patch antenna<br>GPS / SBAS / QZSS / GLONASS                                      |
| Yageo        | ANT2525B00BT1516S |              | Ceramic patch antenna<br>GPS / SBAS / QZSS / GLONASS                              |
| Antenova     | SR4G008           | Sinica       | Ultra-low profile patch antenna<br>GPS / SBAS / QZSS / GLONASS / Galileo / BeiDou |
| Amotech      | A18-4T            |              | Ceramic patch antenna<br>GPS / SBAS / QZSS / GLONASS / BeiDou                     |
| Amotech      | A25-4T            |              | Ceramic patch antenna<br>GPS / SBAS / QZSS / BeiDou                               |

**Table 30: Examples of GNSS passive antennas**

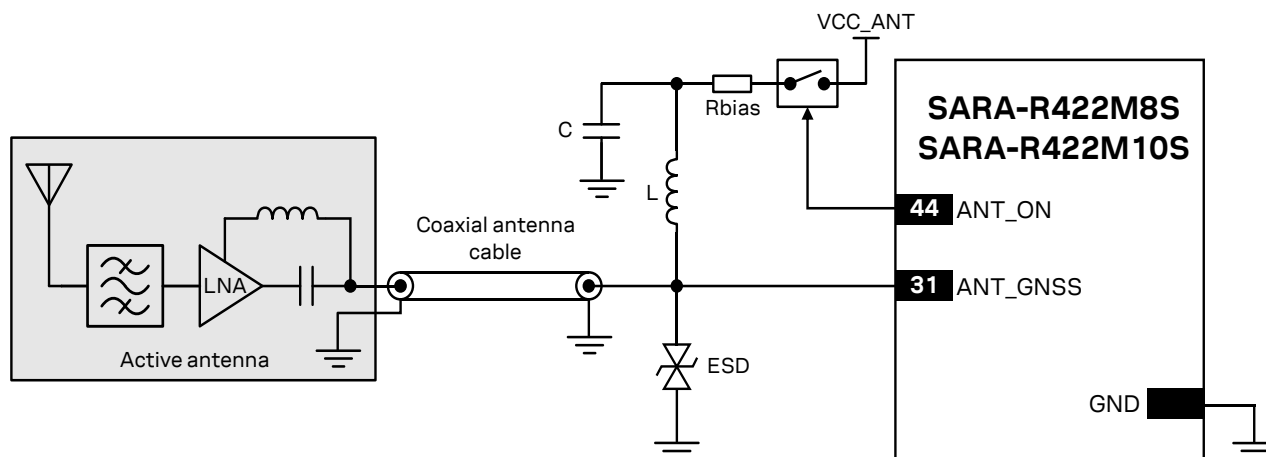
### 2.4.3.2 Guidelines for applications with an active antenna

Active antennas offer higher gain and better overall performance compared with passive antennas (without additional external SAW filter and LNA). However, the integrated low-noise amplifier contributes an additional current of typically 5 to 20 mA to the system's power consumption budget.

Active antennas for GNSS applications are usually powered through a DC bias on the RF cable. A simple bias-T, as shown in Figure 44, can be used to add this DC current to the RF signal line. The inductance L is responsible for isolating the RF path from the DC path. It should be selected to offer high impedance ( $> 500 \Omega$ ) at L-band frequencies. A series current limiting resistor is required to prevent short circuits destroying the bias-T inductor.

To avoid damaging the bias-T series inductor in the case of a short circuit at the antenna connector, it is recommended to implement a proper over-current protection circuit, which may consist in a series resistor as in the example illustrated in Figure 44. Component values are calculated according to the characteristics of the active antenna and the related supply circuit in use: the value of  $R_{bias}$  is calculated such that the maximum current capacity of the inductor L is never exceeded. Moreover,  $R_{bias}$  and C form a low pass filter to remove high frequency noise from the DC supply. Assuming  $VCC\_ANT=3.3\text{ V}$ , Table 31 reports suggested components for the circuit in Figure 44.

The recommended bias-T inductor (Murata LQW15ANR12J00) has a maximum current capacity of 110 mA. Hence the current is limited to 100 mA by way of a  $33 \Omega$  bias resistor. This resistor power rating must be chosen to ensure reliability in the chosen circuit design.



**Figure 44:** Typical circuit with active antenna connected to GNSS RF interface, using an external supply

| Reference | Description                                  | Part number - Manufacturer |
|-----------|--|----------------------------|
| L         | 120 nH wire-wound RF Inductor 0402 5% 110 mA | LQW15ANR12J00 - Murata     |
| C         | 100 nF capacitor ceramic X7R 0402 10% 16 V   | GCM155R71C104KA55 - Murata |
| Rbias     | 33 ohm resistor 0.5W                         | Various manufacturers      |

**Table 31:** Example component values for active antenna biasing

- Refer to the antenna datasheet and/or manufacturer for proper values of the supply voltage VCC\_ANT, inductance L and capacitance C.
- ESD sensitivity rating of the **ANT\_GNSS** RF input pin is 1 kV (HBM according to JESD22-A114). Higher protection level can be required if the line is externally accessible on the application board. Higher protection level can be achieved by mounting an ultra low capacitance (i.e. < 1 pF) ESD protection (see [Table 32](#)) close to accessible point.

[Table 32](#) lists examples of ESD protection suitable for the GNSS RF input of the modules.

| Manufacturer     | Part number    | Description   |
|------------------|----------------|---|
| ON Semiconductor | ESD9R3.3ST5G   | ESD protection diode with ultra-low capacitance (0.5 pF)  |
| Infineon         | ESD5V3U1U-02LS | ESD protection diode with ultra-low capacitance (0.4 pF)  |
| Littelfuse       | PESD0402-140   | ESD protection diode with ultra-low capacitance (0.25 pF) |

**Table 32:** Examples of ultra-low capacitance ESD protections

[Table 33](#) lists examples of GNSS active antennas to be used with the modules.

| Manufacturer | Part number                    | Product name | Description  |
|--------------|--------------------------------|--------------|--|
| Tallysman    | TW3400 – TW3402                |              | Active antenna– 2.5 - 16 V<br>GPS / SBAS / QZSS / GLONASS  |
| Tallysman    | TW3710 – TW3712                |              | Active antenna, 2.5 – 16 V<br>GPS / SBAS / QZSS / GLONASS / Galileo / BeiDou                           |
| Taoglas      | AA.162.301111                  | Ulysses      | Ultra-Low profile miniature antenna, 1.8 – 5.5V<br>GPS / SBAS / QZSS / GLONASS / Galileo               |
| Taoglas      | MA310.A.LB.001                 |              | Magnet mount antenna, 1.8 – 5.5 V<br>GPS / SBAS / QZSS / GLONASS                                       |
| Taoglas      | ASGGB254.A -<br>ASGGB184.A     |              | Active GNSS surface-mount patch antenna, 1.8 – 5.5 V<br>GPS / SBAS / QZSS / GLONASS / BeiDou / Galileo |
| Taoglas      | AGGBP.SL.25A –<br>AGGBP.SL.18A |              | Active GNSS surface-mount patch antenna, 1.8 – 5.5 V<br>GPS / SBAS / QZSS / GLONASS / BeiDou / Galileo |

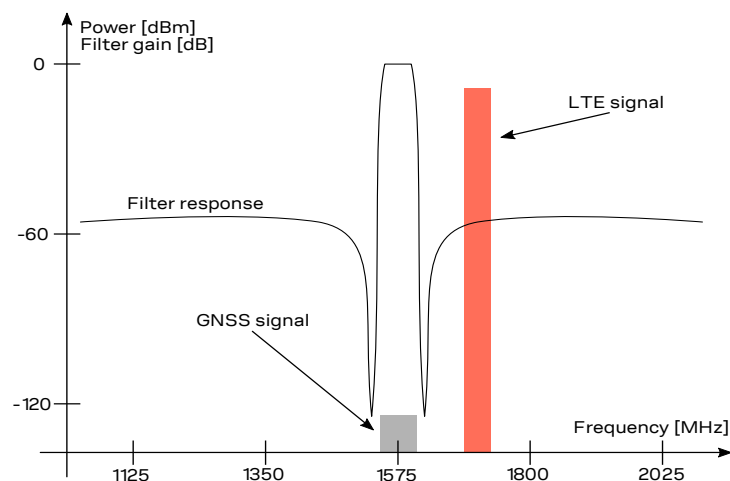
| Manufacturer    | Part number     | Product name | Description  |
|-----------------|-----------------|--------------|--|
| Abracon LLC     | APAMP-110       |              | Module RF antenna 5dBic SMA adhesive, 2.5 – 3.5 V<br>GPS / SBAS / QZSS   |
| TE Connectivity | 2195768-1       |              | Active antenna, 3.0 V typical<br>GPS / SBAS / QZSS                       |
| Amotech         | AGA151502-S0    |              | Active antenna, 3.0 V typical<br>GPS / SBAS / QZSS / GLONASS             |
| Amotech         | AGA393914-S0-A6 |              | Active antenna, IP66, 5V typical<br>GPS / SBAS / QZSS / GLONASS / BeiDou |

**Table 33: Examples of GNSS active antennas**

## 2.4.4 Cellular and GNSS RF coexistence

### Overview

Desensitization or receiver blocking is a form of electromagnetic interference where a radio receiver is unable to detect a weak signal that it might otherwise be able to receive when there is no interference (see [Figure 45](#)). Good blocking performance is particularly important in the scenarios where several radios of various forms are used in close proximity to each other.



**Figure 45: Interference due to transmission in LTE B3, B4 and B66 low channels (1710 MHz) adjacent to GNSS frequency range (1561 to 1605 MHz). Harmonics due to transmission in LTE B13 high channels (787 MHz) may fall into the GNSS bands**

Jamming signals may come from in-band and out-of-band frequency sources. In-band jamming is caused by signals with frequencies falling within the GNSS frequency range, while the out-of-band jamming is caused by very strong signals adjacent to the GNSS frequency range so that part of the strong signal power may leak at the input of the GNSS receiver and/or block GNSS reception.

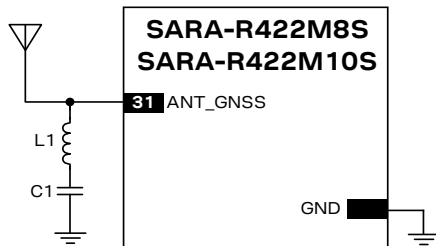
If not properly taken into consideration, in-band and out-of-band jamming signals may cause a reduction in the carrier-to-noise power density ratio (C/No) of the GNSS satellites.

### In-band interference

In-band interference signals are typically caused by harmonics from displays, switching converters, micro-controllers and bus systems. Moreover, considering for example the LTE band 13 high channel transmission frequency (787 MHz) and the GPS operating band ( $1575.42 \text{ MHz} \pm 1.023 \text{ MHz}$ ), the second harmonic of the cellular signal is exactly within the GPS operating band. Therefore, depending on the board layout and the transmit power, the highest channel of LTE band 13 is the channel that has the greatest impact on the C/No reduction.

Countermeasures against in-band interference include:

- maintaining a good grounding concept in the design
- ensuring proper shielding of the different RF paths
- ensuring proper impedance matching of RF traces
- placing the GNSS antenna away from noise sources
- add a notch filter along the GNSS RF path, just after the antenna, at the frequency of the jammer (as for example illustrated in [Figure 46](#))



**Figure 46: Simple notch filter for improved in-band jamming immunity against a single jamming frequency**

With reference to [Figure 46](#), a simple notch filter can be realized by the series connection of an inductor and capacitor. Capacitor C1 and inductor L1 values are calculated according to the formula:

$$f = \frac{1}{2\pi\sqrt{C \cdot L}}$$

For example, a notch filter at ~787 MHz improves the GNSS immunity to LTE band 13 high channel. Suitable component nominal values are C1 = 3.3 pF and L1 = 12 nH, with tolerance less than or equal to 2 % to ensure adequate notch frequency accuracy.

## Out-of-band interference

Out-of-band interference is caused by signal frequencies that are different from the GNSS, the main sources being cellular, Wi-Fi, bluetooth transmitters, etc. For example, the lowest channels in LTE band 3, 4 and 66 can compromise the good reception of the GLONASS satellites. Again, the effect can be explained by comparing the LTE frequencies (low channel transmission frequency is 1710 MHz) with the GLONASS operating band (1602 MHz ± 8 MHz). In this case the LTE signal is outside the useful GNSS band, but provided that the power received by the GNSS subsystem at 1710 MHz is high enough, blocking and leakage effects may appear reducing once again the C/No.

Countermeasures against out-of-band interference include:

- maintaining a good grounding concept in the design
- keeping the GNSS and cellular antennas more than the quarter-wavelength (of the minimum Tx frequency) away from each other. If for layout or size reasons this requirement cannot be met, then the antennas should be placed orthogonally to each other and/or on different side of the PCB.
- selecting a cellular antenna providing the worst possible return loss / VSWR / efficiency figure in the GNSS frequency band: the lower is the cellular antenna efficiency between 1575 MHz and 1610 MHz, the higher is the isolation between the cellular and the GNSS systems
- ensuring at least 15 – 20 dB isolation between antennas in the GNSS band by implementing the most suitable placement for the antennas, considering in particular the related radiation diagrams of the antennas: better isolation results from antenna patterns with radiation lobes in different directions considering the GNSS frequency band.
- adding a GNSS pass-band SAW filter along the GNSS RF line, providing very large attenuation in the cellular frequency bands (see [Table 27](#) for possible suitable examples). It has to be noted that, as shown in [Figure 6](#), a SAW filter and an LNA are already integrated in the GNSS RF path of the module: the addition of an external filter along the GNSS RF line has to be considered only if the conditions above cannot be met.

## Additional countermeasures

In case all the aforementioned countermeasures cannot be implemented, adding a GNSS stop-band SAW filter along the cellular RF line may be considered. The filter shall provide very low attenuation in the cellular frequency bands (see [Table 34](#) for possible suitable examples). It has to be noted that the addition of an external filter along the cellular RF line has to be carefully evaluated, considering that the additional insertion loss of such filter may affect the cellular TRP and/or TIS RF figures.

[Table 34](#) lists examples of GNSS band-stop SAW filters that may be considered for the cellular RF input/output in case enough isolation between the cellular and the GNSS RF systems cannot be provided by proper selection and placement of the antennas beside other proper RF design solutions.

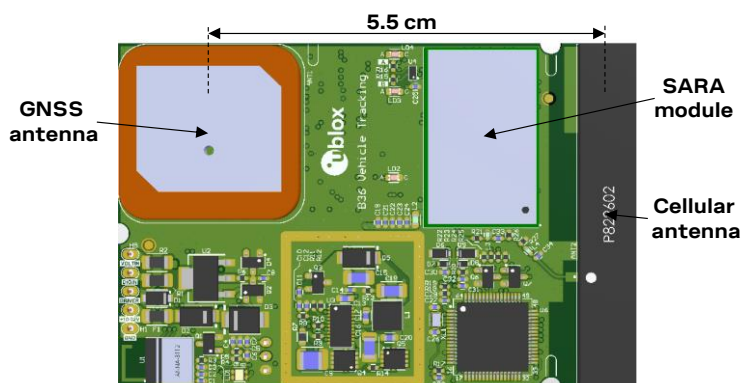
| Manufacturer | Part number | Description  |
|--------------|-------------|--|
| Qualcomm     | B8636       | GPS / SBAS / QZSS / GLONASS / Galileo / BeiDou RF band-stop SAW filter with low attenuation in Cellular frequency ranges |
| Qualcomm     | B8666       | GPS / SBAS / QZSS / GLONASS / Galileo / BeiDou RF band-stop SAW filter with low attenuation in Cellular frequency ranges |

**Table 34: Examples of GNSS band-stop SAW filters**

## Additional considerations

As far as the RF Tx power is involved in the cellular / GNSS RF coexistence, it has to be noted that high-power transmission occurs very infrequently: typical values are in the range of -3 to 0 dBm (see Figure 1 in the GSMA official document TS.09 [\[12\]](#)). Therefore, depending on the application, careful PCB layout, antenna selection and placement should be sufficient to ensure accurate GNSS reception.

For an example of vehicle tracking application in a small form factor featuring cellular and short-range connectivity alongside a multi-constellation GNSS receiver, with successful RF coexistence between the systems, refer to the u-blox B36 vehicle tracking blueprint [\[23\]](#). The distance between the cellular and GNSS antennas for the u-blox B36 blueprint is annotated in [Figure 47](#).



**Figure 47: PCB top rendering for the u-blox B36 blueprint with annotated distance between cellular and GNSS antennas**

## 2.4.5 Antenna detection interface (ANT\_DET)

### 2.4.5.1 Guidelines for ANT\_DET circuit design

Figure 48 and Table 35 describe the recommended schematic / components for the antenna detection circuit that must be provided on the application board and for the diagnostic circuit that must be provided on the antenna's assembly to achieve antenna detection functionality.

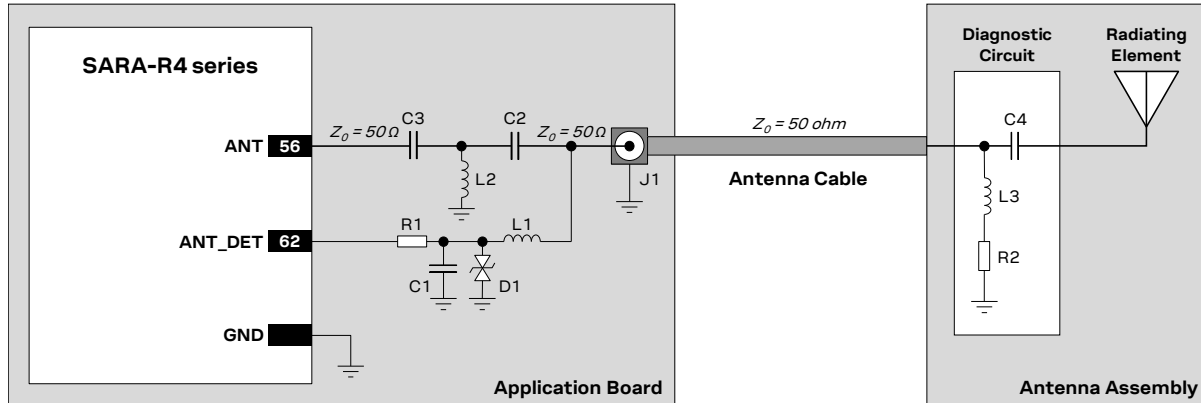


Figure 48: Suggested schematic for antenna detection circuit on application PCB and diagnostic circuit on antenna assembly

| Reference | Description                                 | Part Number - Manufacturer      |
|-----------|---|---------------------------------|
| C1        | 27 pF Capacitor Ceramic C0G 0402 5% 50 V    | GRM1555C1H270J - Murata         |
| C2        | 33 pF Capacitor Ceramic C0G 0402 5% 50 V    | GRM1555C1H330J - Murata         |
| D1        | Very Low Capacitance ESD Protection         | PESD0402-140 - Tyco Electronics |
| L1        | 68 nH Multilayer Inductor 0402 (SRF ~1 GHz) | LQG15HS68NJ02 - Murata          |
| R1        | 10 kΩ Resistor 0402 1% 0.063 W              | RK73H1ETTP1002F - KOA Speer     |
| J1        | SMA Connector 50 Ω Through Hole Jack        | SMA6251A1-3GT50G-50 - Amphenol  |
| C3        | 15 pF Capacitor Ceramic C0G 0402 5% 50 V    | GRM1555C1H150J - Murata         |
| L2        | 39 nH Multilayer Inductor 0402 (SRF ~1 GHz) | LQG15HN39NJ02 - Murata          |
| C4        | 22 pF Capacitor Ceramic C0G 0402 5% 25 V    | GRM1555C1H220J - Murata         |
| L3        | 68 nH Multilayer Inductor 0402 (SRF ~1 GHz) | LQG15HS68NJ02 - Murata          |
| R2        | 15 kΩ Resistor for Diagnostics              | Various Manufacturers           |


Table 35: Suggested parts for antenna detection circuit on application PCB and diagnostic circuit on antennas assembly

The antenna detection circuit and diagnostic circuit suggested in Figure 48 and Table 35 are here explained:

- When antenna detection is forced by the +UANTR AT command, the **ANT\_DET** pin generates a DC current measuring the resistance (R2) from the antenna connector (J1) provided on the application board to GND.
- DC blocking capacitors are needed at the **ANT** pin (C2) and at the antenna radiating element (C4) to decouple the DC current generated by the **ANT\_DET** pin.
- Choke inductors with a Self-Resonance Frequency (SRF) in the range of 1 GHz are needed in series at the **ANT\_DET** pin (L1) and in series at the diagnostic resistor (L3), to avoid a reduction of the RF performance of the system, improving the RF isolation of the load resistor.
- Resistor on the **ANT\_DET** path (R1) is needed for accurate measurements through the +UANTR AT command. It also acts as an ESD protection.
- Additional components (C1 and D1 in Figure 48) are provided as **ANT\_DET** pin as ESD protection.
- Additional high pass filter (C3 and L2 in Figure 48) is provided as ESD immunity improvement
- The **ANT** pin must be connected to the antenna connector by means of a transmission line with nominal characteristics impedance as close as possible to 50 Ω.

The DC impedance at RF port for some antennas may be a DC open (e.g. linear monopole) or a DC short to reference GND (e.g. PIFA antenna). For those antennas, without the diagnostic circuit of [Figure 48](#), the measured DC resistance is always at the limits of the measurement range (respectively open or short), and there is no mean to distinguish between a defect on antenna path with similar characteristics (respectively: removal of linear antenna or RF cable shorted to GND for PIFA antenna).


Furthermore, any other DC signal injected to the RF connection from ANT connector to radiating element will alter the measurement and produce invalid results for antenna detection.

 It is recommended to use an antenna with a built-in diagnostic resistor in the range from 5 k $\Omega$  to 30 k $\Omega$  to assure good antenna detection functionality and avoid a reduction of module RF performance. The choke inductor should exhibit a parallel Self Resonance Frequency (SRF) in the range of 1 GHz to improve the RF isolation of load resistor.

For example:

Consider an antenna with built-in DC load resistor of 15 k $\Omega$ . Using the +UANTR AT command, the module reports the resistance value evaluated from the antenna connector provided on the application board to GND:

- Reported values close to the used diagnostic resistor nominal value (i.e. values from 13 k $\Omega$  to 17 k $\Omega$  if a 15 k $\Omega$  diagnostic resistor is used) indicate that the antenna is correctly connected.
- Values close to the measurement range maximum limit (approximately 50 k $\Omega$ ) or an open-circuit “over range” report (see the SARA-R4 series AT commands manual [\[2\]](#)) means that the antenna is not connected or the RF cable is broken.
- Reported values below the measurement range minimum limit (1 k $\Omega$ ) highlights a short to GND at antenna or along the RF cable.
- Measurement inside the valid measurement range and outside the expected range may indicate an unclear connection, a damaged antenna or incorrect value of the antenna load resistor for diagnostics.
- Reported value could differ from the real resistance value of the diagnostic resistor mounted inside the antenna assembly due to antenna cable length, antenna cable capacity and the used measurement method.

 If the antenna detection function is not required by the customer application, the **ANT\_DET** pin can be left not connected and the **ANT** pin can be directly connected to the antenna connector by means of a 50  $\Omega$  transmission line as described in [Figure 40](#).



### 2.4.5.2 Guidelines for ANT\_DET layout design

Figure 49 describes the recommended layout for the antenna detection circuit to be provided on the application board to achieve antenna detection functionality, implementing the recommended schematic described in the previous Figure 48 and Table 35:

- The **ANT** pin must be connected to the antenna connector by means of a 50  $\Omega$  transmission line, implementing the design guidelines described in section 2.4.2 and the recommendations of the SMA connector manufacturer.
- DC blocking capacitor at **ANT** pin (C2) must be be placed in series to the 50  $\Omega$  RF line.
- The **ANT\_DET** pin must be connected to the 50  $\Omega$  transmission line by means of a sense line.
- Choke inductor in series at the **ANT\_DET** pin (L1) must be placed so that one pad is on the 50  $\Omega$  transmission line and the other pad represents the start of the sense line to the **ANT\_DET** pin.
- The additional components (R1, C1 and D1) are provided as **ANT\_DET** ESD protection.
- The additional high pass filter (C3 and L2) is provided as ESD immunity improvement.

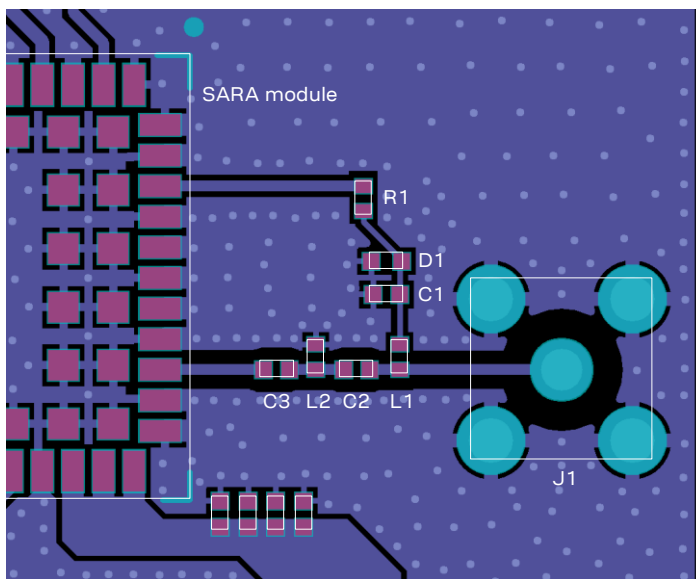


Figure 49: Suggested layout for antenna detection circuit on application board

### 2.4.6 Cellular antenna dynamic tuner interface

The cellular antenna dynamic tuner interface is not supported by SARA-R410M, SARA-R412M, SARA-R422-00B, SARA-R422S-00B and SARA-R422M8S-00B modules product versions.

SARA-R422-01B, SARA-R422S-01B and SARA-R422M10S modules product versions includes two output pins (named **I2S\_TXD** and **I2S\_WA**) that can be configured, as optional feature, to change their output value dynamically according to the specific actual cellular band in use by the module. These pins, paired with an external antenna tuner IC or RF switch, can be used to:

- tune antenna impedance to reduce power losses due to mismatch
- tune antenna aperture to improve total antenna efficiency
- select the optimal antenna for each operating band

Figure 50 shows the example application circuits implementing impedance tuning and aperture tuning. The module controls an RF switch which is responsible for selecting the appropriate matching element for the operating band. Table 36 reports suggested components implementing the SP4T RF switch functionality.



In [Figure 50\(a\)](#), tuning the antenna impedance optimizes the power delivered into the antenna by dynamically adjusting the RF impedance seen by **ANT** pin of SARA-R4 series module. By creating a tuned matching network for each operating band, the total radiated power (TRP) and the total isotropic sensitivity (TIS) metrics are improved.

In [Figure 50\(b\)](#), antenna aperture tuning enables higher antenna efficiency over a wide frequency range. The dynamically tunable components are added to the antenna structure itself, thereby modifying the effective electrical length of the radiating element. Thus, the resonant frequency of the antenna is shifted into the module's operating frequency band. Aperture tuning optimizes radiation efficiency, insertion loss, isolation, and rejection levels of the antenna.

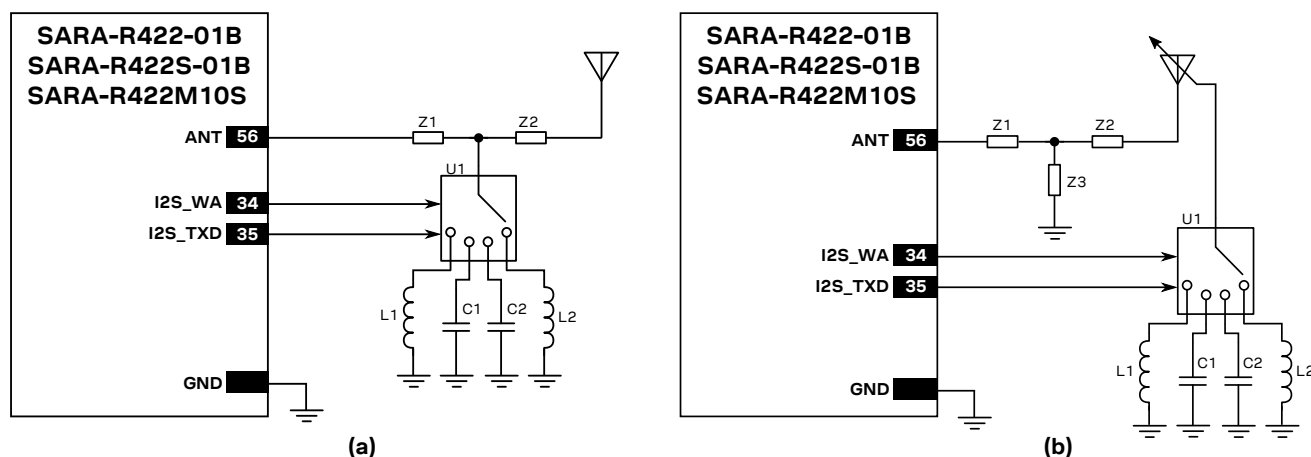


Figure 50: Examples of schematics for cellular antenna dynamic impedance tuning (a) and aperture tuning (b).

Refer to the antenna datasheet and/or manufacturer for proper values of matching components Z1, Z2, Z3, L1, L2, C1, C2. These components should have low losses to avoid degrading the radiating efficiency of the antenna, thereby hindering the positive effects of dynamic tuning.

| Manufacturer            | Part number    | Description  |
|-------------------------|----------------|--|
| Peregrine Semiconductor | PE42442        | 30..6000 MHz UltraCMOS SP4T RF switch                  |
| Peregrine Semiconductor | PE613050       | 5..3000 MHz UltraCMOS SP4T RF switch                   |
| Peregrine Semiconductor | PE42440        | 50..3000 MHz UltraCMOS SP4T RF switch                  |
| Skyworks Solutions      | SKY13626-685LF | 400..3800 MHz SP4T high-power RF switch                |
| Skyworks Solutions      | SKY13380-350LF | 20..3000 MHz SP4T high-power RF switch                 |
| AVX / Ethertronics      | EC646          | 100..3000 MHz ultra-small SP4T RF switch               |
| AVX / Ethertronics      | EC686-3        | 100..3000 MHz ultra-low R <sub>ON</sub> SP4T RF switch |
| Qorvo                   | RF1654A        | 100..2700 MHz SP4T RF switch                           |

Table 36: Examples of RF switches for cellular antenna dynamic tuning

## 2.5 SIM interface

### 2.5.1 Guidelines for SIM circuit design

#### 2.5.1.1 Guidelines for SIM cards, SIM connectors and SIM chips selection

The ISO/IEC 7816, the ETSI TS 102 221 and the ETSI TS 102 671 specifications define the physical, electrical and functional characteristics of Universal Integrated Circuit Cards (UICC), which contains the Subscriber Identification Module (SIM) integrated circuit that securely stores all the information needed to identify and authenticate subscribers over the LTE network.

Removable UICC / SIM card contacts mapping is defined by ISO/IEC 7816 and ETSI TS 102 221 as follows:

- |   |  |
|---|--|
| • Contact C1 = VCC (Supply)             | → It must be connected to <b>VSIM</b>    |
| • Contact C2 = RST (Reset)              | → It must be connected to <b>SIM_RST</b> |
| • Contact C3 = CLK (Clock)              | → It must be connected to <b>SIM_CLK</b> |
| • Contact C4 = AUX1 (Auxiliary contact) | → It must be left not connected          |
| • Contact C5 = GND (Ground)             | → It must be connected to <b>GND</b>     |
| • Contact C6 = VPP/SWP (Other function) | → It can be left not connected           |
| • Contact C7 = I/O (Data input/output)  | → It must be connected to <b>SIM_IO</b>  |
| • Contact C8 = AUX2 (Auxiliary contact) | → It must be left not connected          |

A removable SIM card can have 6 contacts (C1, C2, C3, C5, C6, C7) or 8 contacts, also including the auxiliary contacts C4 and C8. Only 6 contacts are required and must be connected to the module SIM interface.

Removable SIM cards are suitable for applications requiring a change of SIM card during the product lifetime.

A SIM card holder can have 6 or 8 positions if a mechanical card presence detector is not provided, or it can have 6+2 or 8+2 positions if two additional pins relative to the normally-open mechanical switch integrated in the SIM connector for the mechanical card presence detection are provided. Select a SIM connector providing 6+2 or 8+2 positions if the optional SIM detection feature is required by the custom application, otherwise a connector without integrated mechanical presence switch can be selected.

Surface-Mounted UICC / SIM chip contact mapping (M2M UICC Form Factor) is defined by the ETSI TS 102 671 as:

- |  |  |
|--|--|
| • Case pin 8 = UICC contact C1 = VCC (Supply)        | → It must be connected to <b>VSIM</b>    |
| • Case pin 7 = UICC contact C2 = RST (Reset)         | → It must be connected to <b>SIM_RST</b> |
| • Case pin 6 = UICC contact C3 = CLK (Clock)         | → It must be connected to <b>SIM_CLK</b> |
| • Case pin 5 = UICC contact C4 = AUX1 (Aux.contact)  | → It must be left not connected          |
| • Case pin 1 = UICC contact C5 = GND (Ground)        | → It must be connected to <b>GND</b>     |
| • Case pin 2 = UICC contact C6 = VPP/SWP (Other)     | → It can be left not connected           |
| • Case pin 3 = UICC contact C7 = I/O (Data I/O)      | → It must be connected to <b>SIM_IO</b>  |
| • Case pin 4 = UICC contact C8 = AUX2 (Aux. contact) | → It must be left not connected          |

A Surface-Mounted SIM chip has 8 contacts and can also include the auxiliary contacts C4 and C8 for other uses, but only 6 contacts are required and must be connected to the module SIM card interface as described above.

Surface-Mounted SIM chips are suitable for M2M applications where it is not required to change the SIM once installed.

### 2.5.1.2 Guidelines for single SIM card connection without detection

A removable SIM card placed in a SIM card holder must be connected to the SIM card interface of SARA-R4 series modules as described in Figure 51, where the optional SIM detection feature is not implemented.

Follow these guidelines to connect the module to a SIM connector without SIM presence detection:

- Connect the UICC / SIM contacts C1 (VCC) to the **VSIM** pin of the module.
- Connect the UICC / SIM contact C7 (I/O) to the **SIM\_IO** pin of the module.
- Connect the UICC / SIM contact C3 (CLK) to the **SIM\_CLK** pin of the module.
- Connect the UICC / SIM contact C2 (RST) to the **SIM\_RST** pin of the module.
- Connect the UICC / SIM contact C5 (GND) to ground.
- Provide a 100 nF bypass capacitor (e.g. Murata GRM155R71C104K) on SIM supply line, close to the relative pad of the SIM connector, to prevent digital noise.
- Provide a bypass capacitor of about 22 pF to 47 pF (e.g. Murata GRM1555C1H470J) on each SIM line, very close to each related pad of the SIM connector, to prevent RF coupling especially in case the RF antenna is placed closer than 10 - 30 cm from the SIM card holder.
- Provide a very low capacitance (i.e. less than 10 pF) ESD protection (e.g. Tyco PESD0402-140) on each externally accessible SIM line, close to each relative pad of the SIM connector. ESD sensitivity rating of the SIM interface pins is 1 kV (HBM). So that, according to EMC/ESD requirements of the custom application, higher protection level can be required if the lines are externally accessible on the application device.
- Limit capacitance and series resistance on each SIM signal to match the SIM requirements (50 ns is the maximum allowed rise time on clock line, 1.0  $\mu$ s is the maximum allowed rise time on data and reset lines).

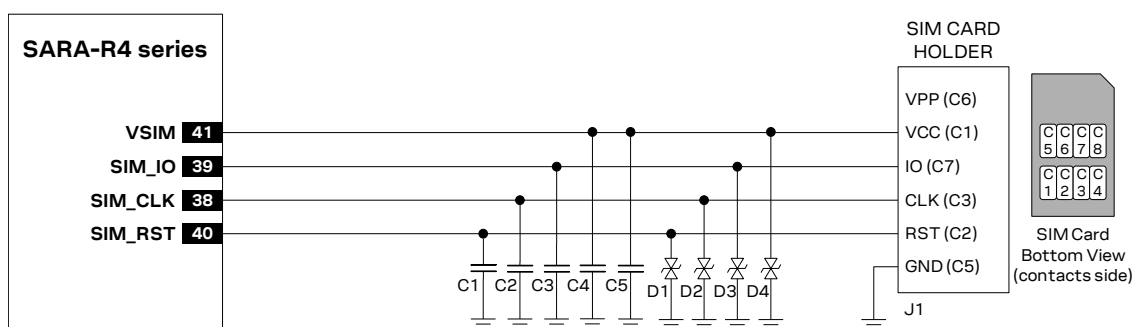


Figure 51: Application circuits for the connection to a single removable SIM card, with SIM detection not implemented

| Reference      | Description  | Part Number - Manufacturer                             |
|----------------|--|--|
| C1, C2, C3, C4 | 47 pF Capacitor Ceramic C0G 0402 5% 50 V           | GRM1555C1H470JA01 - Murata                             |
| C5             | 100 nF Capacitor Ceramic X7R 0402 10% 16 V         | GRM155R71C104KA01 - Murata                             |
| D1, D2, D3, D4 | Very Low Capacitance ESD Protection                | PESD0402-140 - Tyco Electronics                        |
| J1             | SIM Card Holder, 6 p, without card presence switch | Various manufacturers, as C707 10M006 136 2 - Amphenol |

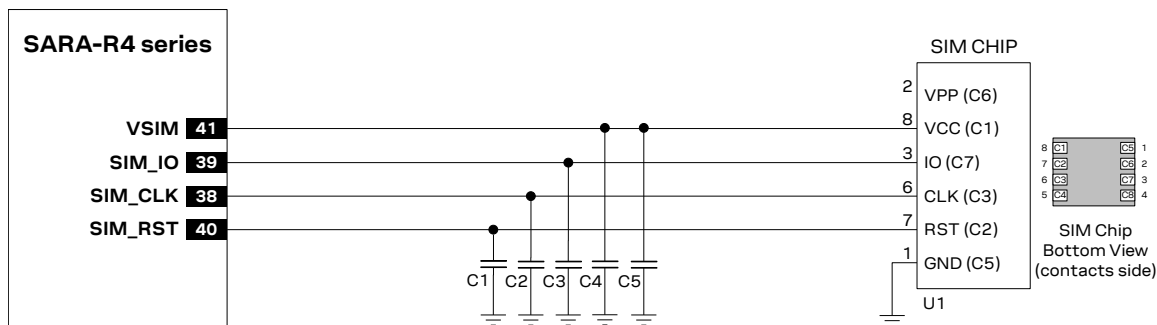
Table 37: Example of components for the connection to a single removable SIM card, with SIM detection not implemented

### 2.5.1.3 Guidelines for single SIM chip connection

A Surface-Mounted SIM chip (M2M UICC Form Factor) must be connected the SIM card interface of the SARA-R4 series modules as described in [Figure 52](#).

Follow these guidelines to connect the module to a Surface-Mounted SIM chip without SIM presence detection:

- Connect the UICC / SIM contacts C1 (VCC) to the **VSIM** pin of the module.
- Connect the UICC / SIM contact C7 (I/O) to the **SIM\_IO** pin of the module.
- Connect the UICC / SIM contact C3 (CLK) to the **SIM\_CLK** pin of the module.
- Connect the UICC / SIM contact C2 (RST) to the **SIM\_RST** pin of the module.
- Connect the UICC / SIM contact C5 (GND) to ground.
- Provide a 100 nF bypass capacitor (e.g. Murata GRM155R71C104K) at the SIM supply line close to the relative pad of the SIM chip, to prevent digital noise.
- Provide a bypass capacitor of about 22 pF to 47 pF (e.g. Murata GRM1555C1H470J) on each SIM line, to prevent RF coupling especially in case the RF antenna is placed closer than 10 - 30 cm from the SIM lines.
- Limit capacitance and series resistance on each SIM signal to match the SIM requirements (50 ns is the maximum allowed rise time on clock line, 1.0  $\mu$ s is the maximum allowed rise time on data and reset lines).



**Figure 52: Application circuits for the connection to a single Surface-Mounted SIM chip, with SIM detection not implemented**

| Reference      | Description                                | Part Number - Manufacturer |
|----------------|--|----------------------------|
| C1, C2, C3, C4 | 47 pF Capacitor Ceramic COG 0402 5% 50 V   | GRM1555C1H470JA01 - Murata |
| C5             | 100 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R71C104KA01 - Murata |
| U1             | SIM chip (M2M UICC Form Factor)            | Various Manufacturers      |

**Table 38: Example of components for the connection to a single solderable SIM chip, with SIM detection not implemented**

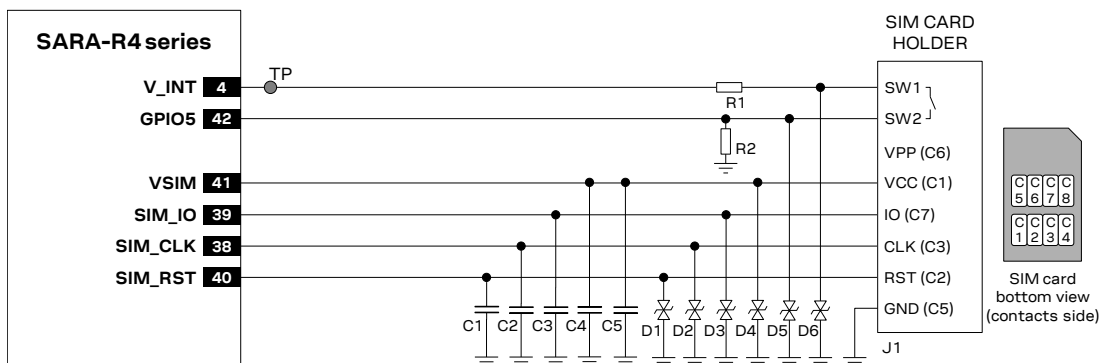
### 2.5.1.4 Guidelines for single SIM card connection with detection

An application circuit for the connection to a single removable SIM card placed in a SIM card holder is described in [Figure 53](#), where the optional SIM card detection feature is implemented.

Follow these guidelines connecting the module to a SIM connector implementing SIM presence detection:

- Connect the UICC / SIM contacts C1 (VCC) to the **VSIM** pin of the module.
- Connect the UICC / SIM contact C7 (I/O) to the **SIM\_IO** pin of the module.
- Connect the UICC / SIM contact C3 (CLK) to the **SIM\_CLK** pin of the module.
- Connect the UICC / SIM contact C2 (RST) to the **SIM\_RST** pin of the module.
- Connect the UICC / SIM contact C5 (GND) to ground.

- Connect one pin of the normally-open mechanical switch integrated in the SIM connector (as the SW2 pin in Figure 53) to the **GPIO5** input pin, providing a weak pull-down resistor (e.g. 470 kΩ, as R2 in Figure 53).
- Connect the other pin of the normally-open mechanical switch integrated in the SIM connector (SW1 pin in Figure 53) to **V\_INT** 1.8 V supply output by means of a strong pull-up resistor (e.g. 1 kΩ, as R1 in Figure 53)
- Provide a 100 nF bypass capacitor (e.g. Murata GRM155R71C104K) at the SIM supply line (**VSIM**), close to the related pad of the SIM connector, to prevent digital noise.
- Provide a bypass capacitor of about 22 pF to 47 pF (e.g. Murata GRM1555C1H470J) on each SIM line (**VSIM**, **SIM\_CLK**, **SIM\_IO**, **SIM\_RST**), very close to each related pad of the SIM connector, to prevent RF coupling especially in case the RF antenna is placed closer than 10 - 30 cm from the SIM card holder.
- Provide a low capacitance (i.e. less than 10 pF) ESD protection (e.g. Tyco Electronics PESD0402-140) on each externally accessible SIM line, close to each related pad of the SIM connector. The ESD sensitivity rating of SIM interface pins is 1 kV (HBM according to JESD22-A114), so that, according to the EMC/ESD requirements of the custom application, higher protection level can be required if the lines are externally accessible.
- Limit capacitance and series resistance on each SIM signal to match the requirements for the SIM interface (50 ns = maximum rise time on **SIM\_CLK**, 1.0 μs = maximum rise time on **SIM\_IO** and **SIM\_RST**).



**Figure 53: Application circuit for the connection to a single removable SIM card, with SIM detection implemented**

| Reference      | Description   | Part Number - Manufacturer                                    |
|----------------|---|---|
| C1, C2, C3, C4 | 47 pF Capacitor Ceramic COG 0402 5% 50 V                      | GRM1555C1H470JA01 - Murata                                    |
| C5             | 100 nF Capacitor Ceramic X7R 0402 10% 16 V                    | GRM155R71C104KA01 - Murata                                    |
| D1 – D6        | Very Low Capacitance ESD Protection                           | PESD0402-140 - Tyco Electronics                               |
| R1             | 1 kΩ Resistor 0402 5% 0.1 W                                   | RC0402JR-071KL - Yageo Phycomp                                |
| R2             | 470 kΩ Resistor 0402 5% 0.1 W                                 | RC0402JR-07470KL - Yageo Phycomp                              |
| J1             | SIM Card Holder<br>6 + 2 positions, with card presence switch | Various Manufacturers,<br>CCM03-3013LFT R102 - C&K Components |

**Table 39: Example of components for the connection to a single removable SIM card, with SIM detection implemented**

## 2.5.2 Guidelines for SIM layout design

The layout of the SIM card interface lines (**VSIM**, **SIM\_CLK**, **SIM\_IO**, **SIM\_RST**) may be critical if the SIM card is placed far away from the SARA-R4 series modules or in close proximity to the RF antenna: these two cases should be avoided or at least mitigated as described below.

In the first case, the long connection can cause the radiation of some harmonics of the digital data frequency as any other digital interface. It is recommended to keep the traces short and avoid coupling with RF line or sensitive analog inputs.

In the second case, the same harmonics can be picked up and create self-interference that can reduce the sensitivity of LTE receiver channels whose carrier frequency is coincidental with harmonic frequencies. It is strongly recommended to place the RF bypass capacitors suggested in [Figure 51](#) near the SIM connector.

In addition, since the SIM card is typically accessed by the end user, it can be subjected to ESD discharges. Add adequate ESD protection as suggested to protect module SIM pins near the SIM connector.

Limit capacitance and series resistance on each SIM signal to match the SIM specifications. The connections should always be kept as short as possible.

Avoid coupling with any sensitive analog circuit, since the SIM signals can cause the radiation of some harmonics of the digital data frequency.

## 2.6 Data communication interfaces

### 2.6.1 UART interface

#### 2.6.1.1 Guidelines for UART circuit design

##### Providing the full RS-232 functionality (using the complete V.24 link)<sup>37</sup>

If RS-232 compatible signal levels are needed, two different external voltage translators can be used to provide full RS-232 (9 lines) functionality: e.g. using the Texas Instruments SN74AVC8T245PW for the translation from 1.8 V to 3.3 V, and the Maxim MAX3237E for the translation from 3.3 V to RS-232 compatible signal level.

If a 1.8 V Application Processor (DTE) is used and complete RS-232 functionality is required, then the complete 1.8 V UART of the module (DCE) should be connected to a 1.8 V DTE, as in [Figure 54](#).

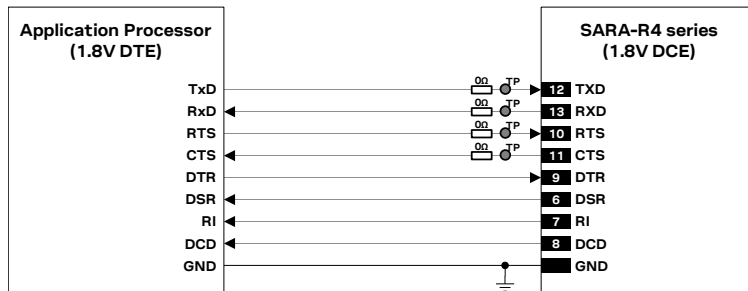


Figure 54: UART interface application circuit with complete V.24 link in DTE/DCE serial communication (1.8V DTE)

If a 3.0 V Application Processor (DTE) is used, then it is recommended to connect the 1.8 V UART of the module (DCE) by means of appropriate unidirectional voltage translators using the module V\_INT output as 1.8 V supply for the voltage translators on the module side, as described in [Figure 55](#).

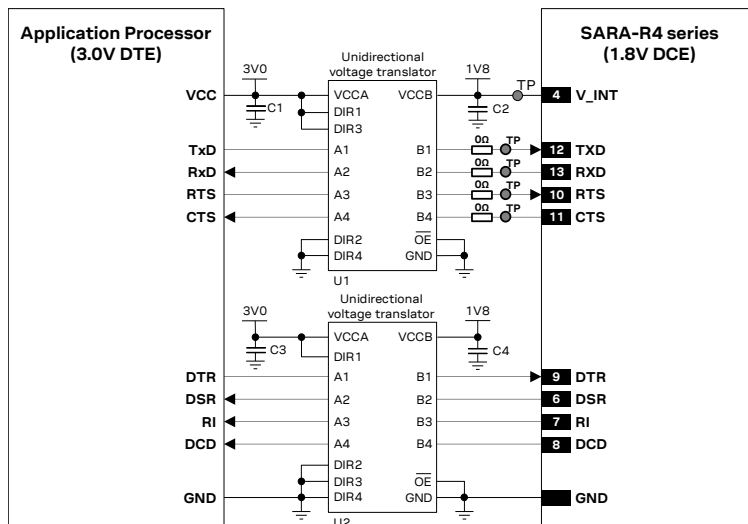


Figure 55: UART interface application circuit with complete V.24 link in DTE/DCE serial communication (3.0 V DTE)

| Reference      | Description                                | Part Number - Manufacturer                     |
|----------------|--|--|
| C1, C2, C3, C4 | 100 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R61A104KA01 - Murata                     |
| U1, U2         | Unidirectional Voltage Translator          | SN74AVC4T774 <sup>38</sup> - Texas Instruments |

Table 40: Component for UART application circuit with complete V.24 link in DTE/DCE serial communication (3.0 V DTE)

<sup>37</sup> Flow control is not supported by SARA-R410M-01B and SARA-R410M-02B-00 product versions. The **RTS** input must be set low to communicate over UART on SARA-R410M-01B product version. The **DTR** input must be set low to have URCs presented over UART on SARA-R410M-01B and SARA-R41xM-x2B product versions.

<sup>38</sup> Voltage translator providing partial power down feature so that the DTE 3 V supply can be also ramped up before V\_INT 1.8 V supply

## Providing the TXD, RXD, RTS, CTS and DTR lines only <sup>39</sup>

If the functionality of the **DSR**, **DCD** and **RI** lines is not required, or the lines are not available:

- Leave **DSR**, **DCD** and **RI** lines of the module floating

If RS-232 compatible signal levels are needed, two different external voltage translators (e.g. Maxim MAX3237E and Texas Instruments SN74AVC4T774) can be used. The Texas Instruments chips provide the translation from 1.8 V to 3.3 V, while the Maxim chip provides the translation from 3.3 V to RS-232 compatible signal level.

Figure 56 describes the circuit that should be implemented as if a 1.8 V Application Processor (DTE) is used, given that the DTE will behave correctly regardless of the **DSR** input setting.

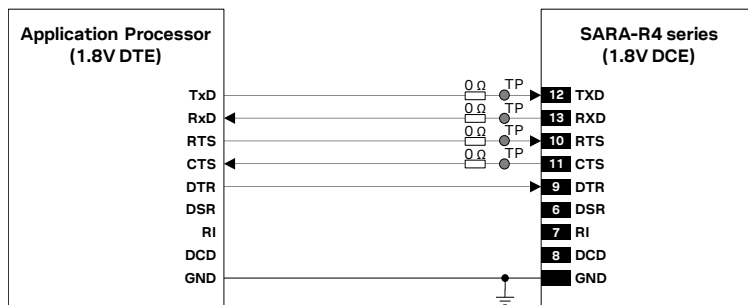


Figure 56: UART interface application circuit with partial V.24 link (6-wire) in the DTE/DCE serial communication (1.8 V DTE)

If a 3.0 V Application Processor (DTE) is used, then it is recommended to connect the 1.8 V UART interface of the module (DCE) by means of appropriate unidirectional voltage translators using the module V\_INT output as 1.8 V supply for the voltage translators on the module side, as described in Figure 57, given that the DTE will behave correctly regardless of the **DSR** input setting.

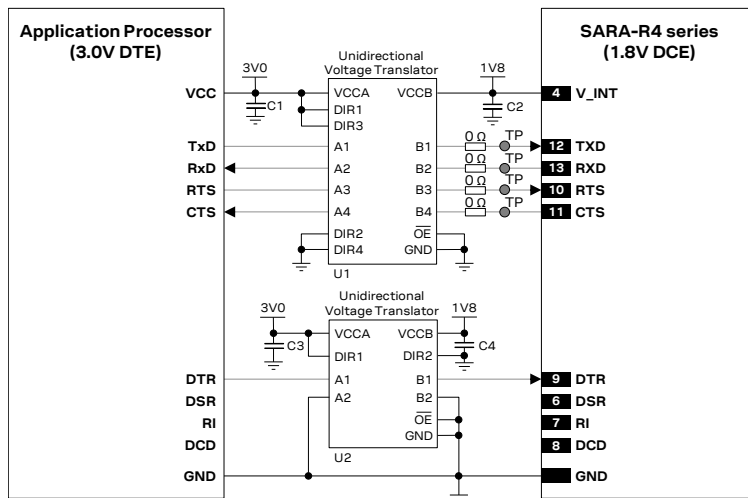


Figure 57: UART interface application circuit with partial V.24 link (6-wire) in DTE/DCE serial communication (3.0 V DTE)

| Reference      | Description                                | Part Number - Manufacturer                     |
|----------------|--|--|
| C1, C2, C3, C4 | 100 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R61A104KA01 - Murata                     |
| U1             | Unidirectional Voltage Translator          | SN74AVC4T774 <sup>40</sup> - Texas Instruments |
| U2             | Unidirectional Voltage Translator          | SN74AVC2T245 <sup>40</sup> - Texas Instruments |

Table 41: UART application circuit components with partial V.24 link (6-wire) in DTE/DCE serial communication (3.0 V DTE)

<sup>39</sup> Flow control is not supported by SARA-R410M-01B and SARA-R410M-02B-00 product versions. The **RTS** input must be set low to communicate over UART on SARA-R410M-01B product version. The **DTR** input must be set low to have URCs presented over UART on SARA-R410M-01B and SARA-R41xM-x2B product versions.

<sup>40</sup> Voltage translator providing partial power down feature so that the DTE 3 V supply can be also ramped up before V\_INT 1.8 V supply



## Providing the TXD, RXD, RTS and CTS lines only <sup>41</sup>

If the functionality of the **DSR**, **DCD**, **RI** and **DTR** lines is not required, or the lines are not available:

- Connect the module **DTR** input to GND using a 0  $\Omega$  series resistor, since it may be useful to set **DTR** active if not specifically handled, in particular to have URCs presented over the UART interface (see the SARA-R4 series AT commands manual [2] for the &D, S0, +CNMI AT commands)
- Leave **DSR**, **DCD** and **RI** lines of the module floating

If RS-232 compatible signal levels are needed, the Maxim MAX13234E voltage level translator can be used. This chip translates voltage levels from 1.8 V (module side) to the RS-232 standard. If a 1.8 V Application Processor is used, the circuit should be implemented as described in Figure 58.

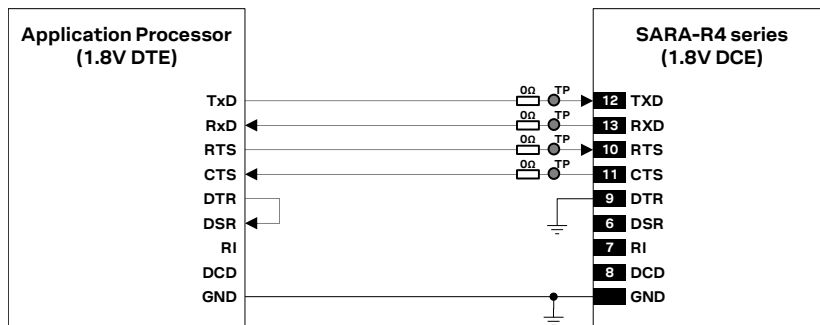


Figure 58: UART interface application circuit with partial V.24 link (5-wire) in the DTE/DCE serial communication (1.8V DTE)

If a 3.0 V Application Processor (DTE) is used, then it is recommended to connect the 1.8 V UART interface of the module (DCE) by means of appropriate unidirectional voltage translators using the module **V\_INT** output as 1.8 V supply for the voltage translators on the module side, as in Figure 59.

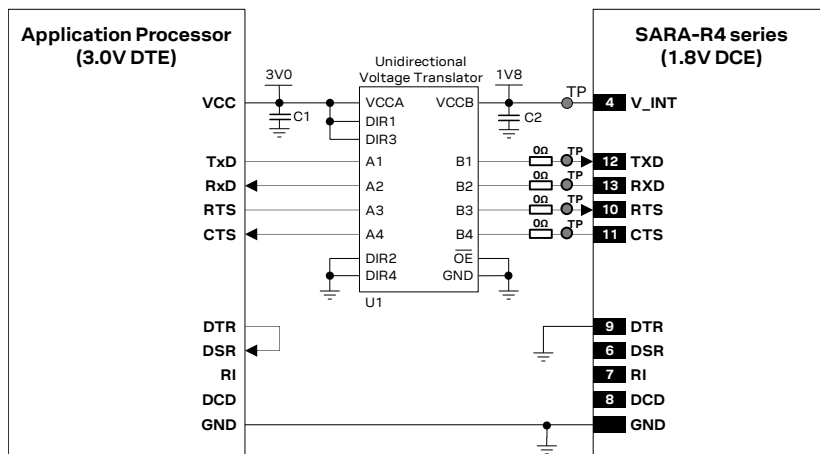


Figure 59: UART interface application circuit with a partial V.24 link (5-wire) in DTE/DCE serial communication (3.0 V DTE)

| Reference | Description                                | Part Number - Manufacturer                     |
|-----------|--|--|
| C1, C2    | 100 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R61A104KA01 - Murata                     |
| U1        | Unidirectional Voltage Translator          | SN74AVC4T774 <sup>42</sup> - Texas Instruments |

Table 42: UART application circuit components with a partial V.24 link (5-wire) in DTE/DCE serial communication (3.0 V DTE)

<sup>41</sup> Flow control is not supported by SARA-R410M-01B and SARA-R410M-02B-00 product versions. The **RTS** input must be set low to communicate over UART on SARA-R410M-01B product version. The **DTR** input must be set low to have URCs presented over UART on SARA-R410M-01B and SARA-R41xM-x2B product versions.

<sup>42</sup> Voltage translator providing partial power down feature so that the DTE 3 V supply can be also ramped up before **V\_INT** 1.8 V supply

## Providing the TXD and RXD lines only <sup>43</sup>

Providing the **TXD** and **RXD** lines only is not recommended if the multiplexer functionality is used in the application: providing also at least the HW flow control (**RTS** and **CTS** lines) is recommended, and it is in particular necessary if the low power mode is enabled by +UPSV AT command.

If functionality of the **CTS**, **RTS**, **DSR**, **DCD**, **RI** and **DTR** lines is not required in the application, then:

- Connect the **RTS** input line to GND or to the **CTS** output line of the module, since the module requires **RTS** active (low electrical level) if HW flow-control is enabled (AT&K3, default setting)
- Connect the **DTR** input line to GND using a 0  $\Omega$  series resistor, because it is useful to set **DTR** active if not specifically handled, in particular to have URCs presented over the UART interface (see SARA-R4 series AT commands manual [2], &D, S0, +CNMI AT commands)
- Leave **DSR**, **DCD** and **RI** lines of the module floating

If RS-232 compatible signal levels are needed, the Maxim MAX13234E voltage level translator can be used. This chip translates voltage levels from 1.8 V (module side) to the RS-232 standard.

If a 1.8 V Application Processor (DTE) is used, the circuit that should be implemented as in Figure 60.

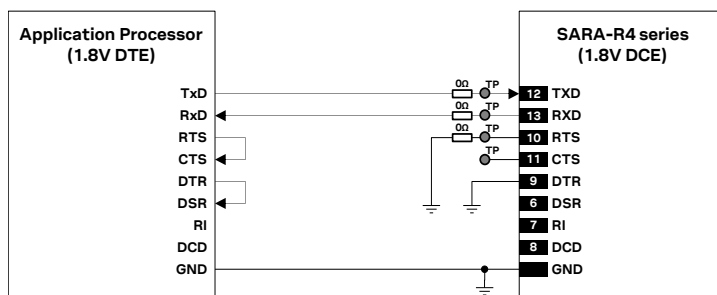


Figure 60: UART interface application circuit with a 3-wire link in the DTE/DCE serial communication (1.8V DTE)

If a 3.0 V Application Processor (DTE) is used, then it is recommended to connect the 1.8 V UART interface of the module (DCE) by means of appropriate unidirectional voltage translators using the module **V\_INT** output as 1.8 V supply for the voltage translators on the module side, as in Figure 61.

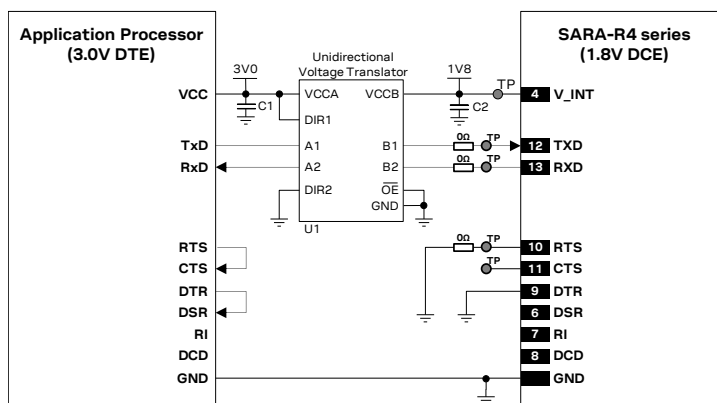


Figure 61: UART interface application circuit with a partial V.24 link (3-wire) in DTE/DCE serial communication (3.0 V DTE)

| Reference | Description                                | Part Number - Manufacturer                     |
|-----------|--|--|
| C1, C2    | 100 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R61A104KA01 - Murata                     |
| U1        | Unidirectional Voltage Translator          | SN74AVC2T245 <sup>44</sup> - Texas Instruments |

Table 43: UART application circuit components with partial V.24 link (3-wire) in DTE/DCE serial communication (3.0 V DTE)




<sup>43</sup> Flow control is not supported by SARA-R410M-01B and SARA-R410M-02B-00 product versions. The **RTS** input must be set low to communicate over UART on SARA-R410M-01B product version. The **DTR** input must be set low to have URCs presented over UART on SARA-R410M-01B and SARA-R41xM-x2B product versions.

<sup>44</sup> Voltage translator providing partial power down feature so that the DTE 3 V supply can be also ramped up before **V\_INT** 1.8 V supply

## Additional considerations

If a 3.0 V Application Processor (DTE) is used, the voltage scaling from any 3.0 V output of the DTE to the corresponding 1.8 V input of the module (DCE) can be implemented as an alternative low-cost solution, by means of an appropriate voltage divider. Consider the value of the pull-down / pull-up integrated at the input of the module (DCE) for the correct selection of the voltage divider resistance values. Make sure that any DTE signal connected to the module is tri-stated or set low when the module is in power-down mode and during the module power-on sequence (at least until the activation of the **V\_INT** supply output of the module), to avoid latch-up of circuits and allow a clean boot of the module (see the remark below).

Moreover, the voltage scaling from any 1.8 V output of the cellular module (DCE) to the corresponding 3.0 V input of the Application Processor (DTE) can be implemented by means of an appropriate low-cost non-inverting buffer with open drain output. The non-inverting buffer should be supplied by the **V\_INT** supply output of the cellular module. Consider the value of the pull-up integrated at each input of the DTE (if any) and the baud rate required by the application for the appropriate selection of the resistance value for the external pull-up biased by the application processor supply rail.

-  The **TXD** data input line of the module has an internal active pull-down enabled on the “00B” and on the SARA-R410M-02B product versions, and it has an internal active pull-up enabled on the other product versions of SARA-R4 series modules.
-  Do not apply voltage to any UART interface pin before the switch-on of the UART supply source (**V\_INT**), to avoid latch-up of circuits and allow a clean boot of the module. If the external signals connected to the cellular module cannot be tri-stated or set low, insert a multi-channel digital switch (e.g. TI SN74CB3Q16244, TS5A3159, or TS5A63157) between the two-circuit connections and set to high impedance before **V\_INT** switch-on.
-  ESD sensitivity rating of the UART interface pins is 1 kV (HBM according to JESD22-A114). Higher protection levels could be required if the lines are externally accessible and it can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG varistor array) close to the accessible points.

### 2.6.1.2 Guidelines for UART layout design

The UART serial interface requires the same consideration regarding electro-magnetic interference as any other digital interface. Keep the traces short and avoid coupling with RF line or sensitive analog inputs, since the signals can cause the radiation of some harmonics of the digital data frequency.

## 2.6.2 USB interface


### 2.6.2.1 Guidelines for USB circuit design

The **USB\_D+** and **USB\_D-** lines carry the USB serial data and signaling. The lines are used in single-ended mode for full speed signaling handshake, as well as in differential mode for high speed signaling and data transfer.

USB pull-up or pull-down resistors and external series resistors on **USB\_D+** and **USB\_D-** lines as required by the USB 2.0 specification [6] are part of the module USB pins driver and do not need to be externally provided.

The USB interface of SARA-R410M and SARA-R412M modules is enabled only if a valid voltage is detected by the **VUSB\_DET** input (see the SARA-R4 series data sheet [1]). Neither the USB interface nor the whole module is supplied by the **VUSB\_DET** input: the **VUSB\_DET** senses the USB supply voltage and absorbs few microamperes.

Routing the USB pins to a connector, they will be externally accessible on the application device. According to EMC/ESD requirements of the application, an additional ESD protection device with very low capacitance should be provided close to accessible point on the line connected to this pin, as described in Figure 62 and Table 44.

 USB interface pins ESD sensitivity rating is 1 kV (HBM according to JESD22-A114F). Higher protection level could be required if the lines are externally accessible and it can be achieved by mounting an ultra low capacitance (i.e. < 1 pF) ESD protection (e.g. Littelfuse PESD0402-140 ESD protection device) on the lines connected to these pins, close to accessible points.

The USB pins of SARA-R410M and SARA-R412M modules can be directly connected to the USB host application processor without additional ESD protections if they are not externally accessible or according to EMC/ESD requirements.

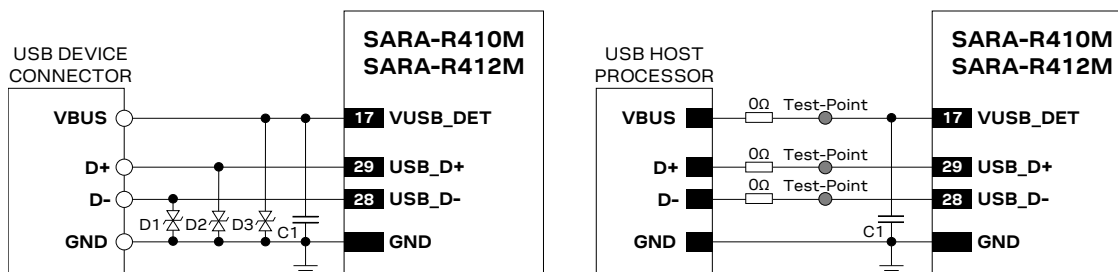




Figure 62: USB Interface application circuits for SARA-R410M and SARA-R412M modules

| Reference  | Description                                | Part Number - Manufacturer      |
|------------|--|---------------------------------|
| C1         | 100 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R61A104KA01 - Murata      |
| D1, D2, D3 | Very Low Capacitance ESD Protection        | PESD0402-140 - Tyco Electronics |

Table 44: Components for USB application circuits for SARA-R410M and SARA-R412M modules

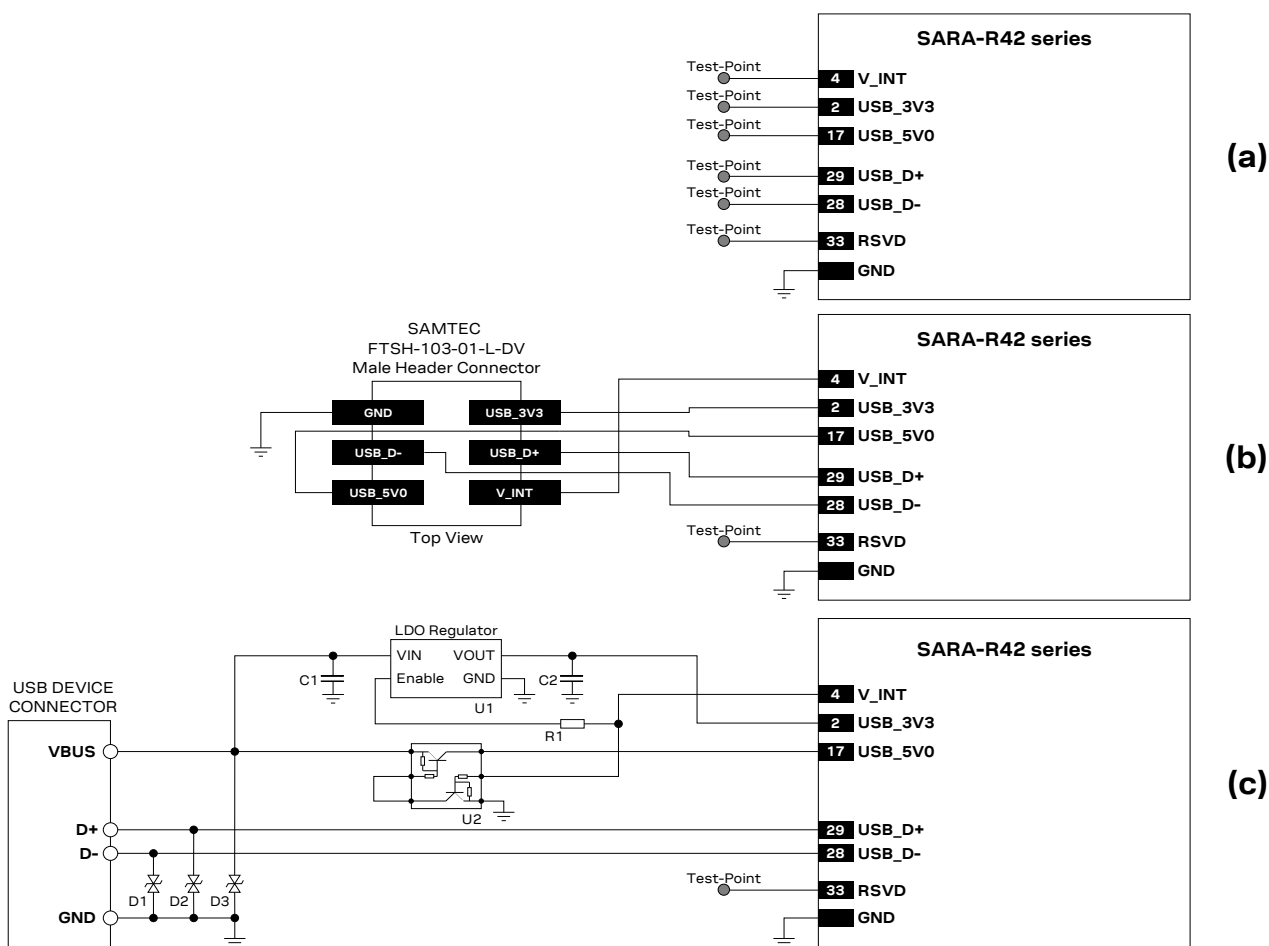
 If the USB interface is enabled, the module does not enter the low power deep sleep mode: the external USB VBUS supply voltage needs to be removed from the **VUSB\_DET** input of the module to let it enter the Power Saving Mode defined in 3GPP Rel.13.

 If the USB interface is not used with SARA-R410M and SARA-R412M modules, the USB interface pins can be left unconnected on the application board, but it is strongly recommended to provide accessible test points directly connected to the **VUSB\_DET**, **USB\_D+**, and **USB\_D-** pins for FW upgrade and/or for diagnostic purpose.

The SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules do not support AT command / data communication over USB interface: the USB interface is available on these modules product versions for FW upgrade by means of the dedicated u-blox EasyFlash tool and for diagnostic purposes only. Therefore, the USB interface of these modules product versions is not designed to be connected to an external host processor mounted on the application board.

It is highly recommended to provide access to **V\_INT**, **PWR\_CTRL**, **USB\_5V0**, **USB\_3V3**, **USB\_D+**, **USB\_D-**, and **RSVD #33** pins of SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules for FW upgrade and/or for diagnostic purpose, making available:

- accessible test points, directly connected to the related pins of the module, as illustrated in the application circuit example (a) of [Figure 63](#), or
- the specific SAMTEC FTSH-103-01-L-DV male header connector, directly connected to the related pins of the module, as shown in the application circuit example (b) of [Figure 63](#), or
- a generic USB device connector, connected to the related pins of the module through the specific circuit illustrated in the application circuit example (c) of [Figure 63](#) and [Table 45](#).



**Figure 63: USB Interface application circuits for SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules**

| Reference  | Description                               | Part Number - Manufacturer        |
|------------|---|-----------------------------------|
| C1, C2     | 1 $\mu$ F Capacitor Ceramic X7R 16 V      | Generic manufacturer              |
| D1, D2, D3 | Very Low Capacitance ESD Protection       | PESD0402-140 - Littelfuse         |
| R1         | 10 k $\Omega$ Resistor 0402 5% 0.1 W      | Various manufacturers             |
| U1         | LDO Linear Regulator 3.3 V 150 mA         | NCP600SN330T1G - ON Semiconductor |
| U2         | NPN/PNP 10k/47k Biased Silicon Transistor | BCR35PN - Infineon Technologies   |

**Table 45: Components for USB application circuits for SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S**

### 2.6.2.2 Guidelines for USB layout design

The **USB\_D+** / **USB\_D-** lines require accurate layout design to achieve reliable signaling at the high speed data rate (up to 480 Mb/s) supported by the USB serial interface.

The characteristic impedance of **USB\_D+** / **USB\_D-** lines is specified by the USB 2.0 specification [6]. The most important parameter is the differential characteristic impedance applicable for the odd-mode electromagnetic field, which should be as close as possible to 90  $\Omega$  differential. Signal integrity may be degraded if PCB layout is not optimal, especially when the USB signaling lines are very long.

Use the following general routing guidelines to minimize signal quality problems:

- Route **USB\_D+** / **USB\_D-** lines as a differential pair
- Route **USB\_D+** / **USB\_D-** lines as short as possible
- Ensure the differential characteristic impedance ( $Z_0$ ) is as close as possible to 90  $\Omega$
- Ensure the common mode characteristic impedance ( $Z_{CM}$ ) is as close as possible to 30  $\Omega$
- Use design rules for **USB\_D+** / **USB\_D-** as RF transmission lines, being them coupled differential micro-strip or buried stripline: avoid stubs, abrupt change of layout, and route on clear PCB area

Figure 64 and Figure 65 provide two examples of coplanar waveguide designs with differential characteristic impedance close to 90  $\Omega$  and common mode characteristic impedance close to 30  $\Omega$ . The first transmission line can be implemented in case of 4-layer PCB stack-up herein described, the second transmission line can be implemented in case of 2-layer PCB stack-up herein described.

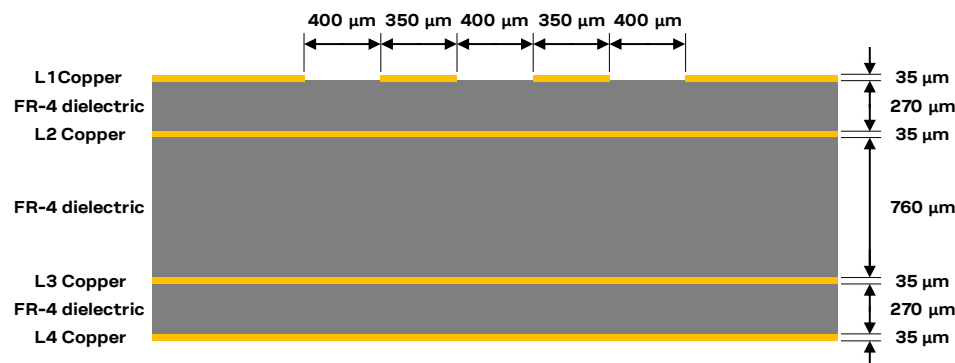


Figure 64: Example of USB line design, with  $Z_0$  close to 90  $\Omega$  and  $Z_{CM}$  close to 30  $\Omega$ , for the described 4-layer board layout

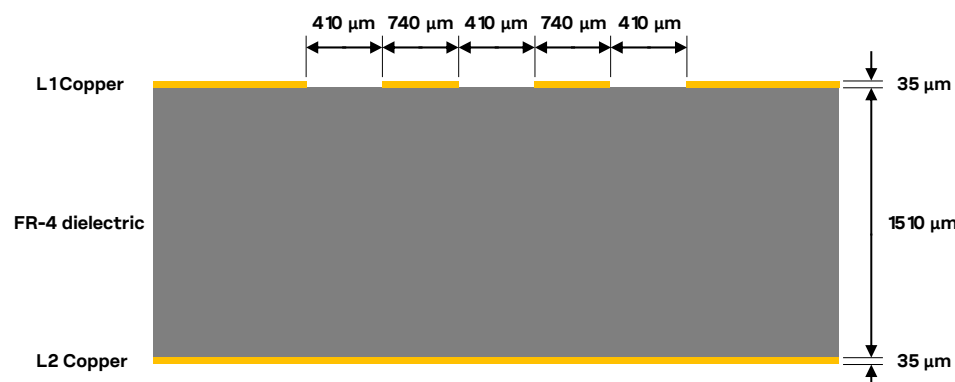



Figure 65: Example of USB line design, with  $Z_0$  close to 90  $\Omega$  and  $Z_{CM}$  close to 30  $\Omega$ , for the described 2-layer board layout


## 2.6.3 SPI interface

### 2.6.3.1 Guidelines for SPI circuit design

-  SPI interface is not available on SARA-R422, SARA-R422S, SARA-R422M8S or SARA-R422M10S modules, and it is not supported by current product versions of SARA-R410M or SARA-R412M modules: the SPI interface pins should not be driven by any external device.


## 2.6.4 SDIO interface

### 2.6.4.1 Guidelines for SDIO circuit design

-  SDIO interface is not available on SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules, and it is not supported by current product versions of SARA-R410M or SARA-R412M modules: the SDIO interface pins should not be driven by any external device.




## 2.6.5 DDC (I2C) interface

### 2.6.5.1 Guidelines for DDC (I2C) circuit design

-  DDC (I2C) interface is not supported by the SARA-R410M-01B product version: the DDC (I2C) interface pins should not be driven by any external device.

The DDC I2C-bus host interface can be used to communicate with u-blox GNSS receivers and other external I2C-bus devices as an audio codec.

The **SDA** and **SCL** pins of the module are open drain output as per I2C bus specifications [11], and they have internal pull-up resistors to the **V\_INT** 1.8 V supply rail of the module, so there is no need of additional pull-up resistors on the external application board.

-  Capacitance and series resistance must be limited on the bus to match the I2C specifications (maximum proper rise time for **SCL** / **SDA** lines is 1.0  $\mu$ s): route connections as short as possible.
-  ESD sensitivity rating of the DDC (I2C) pins is 1 kV (HBM according to JESD22-A114). Higher protection level could be required if the lines are externally accessible and it can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG varistor) close to accessible points.
-  If the pins are not used as DDC bus interface, they can be left unconnected.

## Connection with u-blox 1.8 V GNSS receivers

Dedicated AT commands for external u-blox GNSS receiver communication and control are not supported by SARA-R422, SARA-R422M8S or SARA-R422M10S product versions.

Figure 66 shows an application circuit for connecting the cellular module to an external u-blox 1.8 V GNSS receiver:

- The **SDA** and **SCL** pins of the cellular module are directly connected to the related pins of the u-blox 1.8 V GNSS receiver. External pull-up resistors are not needed, as they are already integrated in the cellular module.
- The **GPIO2** pin is connected to the active-high enable pin of the voltage regulator that supplies the u-blox 1.8 V GNSS receiver providing the “GNSS supply enable” function. A pull-down resistor is provided to avoid a switch on of the positioning receiver when the cellular module is switched off or in the reset state.
- The **GPIO3** pin is connected to the **TXD1** pin of the u-blox 1.8 V GNSS receiver providing the additional “GNSS Tx data ready” function.

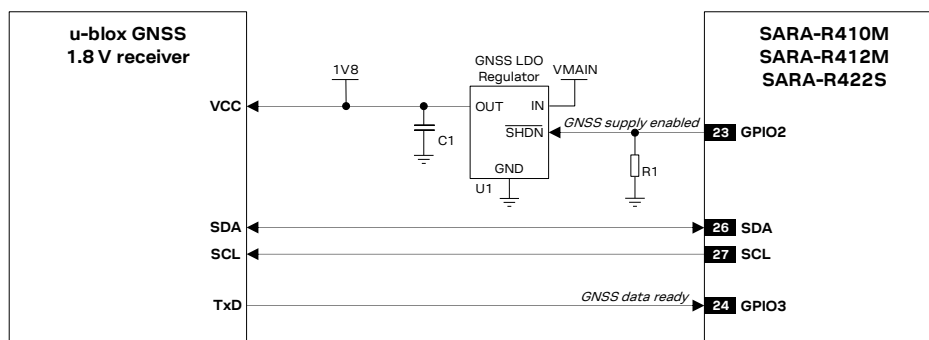


Figure 66: Application circuit for connecting SARA-R4 series modules to u-blox 1.8 V GNSS receivers

| Reference | Description                         | Part Number - Manufacturer                    |
|-----------|-------------------------------------|---|
| R1        | 47 kΩ Resistor 0402 5% 0.1 W        | RC0402JR-0747KL - Yageo Phycomp               |
| U1        | Voltage Regulator for GNSS receiver | See GNSS receiver hardware integration manual |

Table 46: Components for connecting SARA-R4 series modules to u-blox 1.8 V GNSS receivers

For additional guidelines regarding the design of applications with u-blox 1.8 V GNSS receivers, see the hardware integration manual of the u-blox GNSS receivers.

For additional guidelines regarding cellular and GNSS RF coexistence, see section [2.4.4](#)



## Connection with u-blox 3.0 V GNSS receivers

Dedicated AT commands for external u-blox GNSS receiver communication and control are not supported by SARA-R422, SARA-R422M8S or SARA-R422M10S product versions.

Figure 67 shows an application circuit for connecting the cellular module to an external u-blox 3.0 V GNSS receiver:

- As the **SDA** and **SCL** pins of the cellular module are not tolerant up to 3.0 V, the connection to the related I2C pins of the u-blox 3.0 V GNSS receiver must be provided using a suitable I2C-bus Bidirectional Voltage Translator (e.g. TI TCA9406, which additionally provides the partial power down feature so that the GNSS 3.0 V supply can be ramped up before the **V\_INT** 1.8 V cellular supply). External pull-up resistors are not needed on the cellular module side, as they are already integrated in the cellular module.
- The **GPIO2** is connected to the active-high enable pin of the voltage regulator that supplies the u-blox 3.0 V GNSS receiver providing the “GNSS supply enable” function. A pull-down resistor is provided to avoid a switch on of the positioning receiver when the cellular module is switched off or in the reset state.
- The **GPIO3** pin is connected to the **TXD1** pin of the u-blox 3.0 V GNSS receiver providing the additional “GNSS Tx data ready” function, using a suitable Unidirectional General Purpose Voltage Translator (e.g. TI SN74AVC2T245, which additionally provides the partial power down feature so that the 3.0 V GNSS supply can be also ramped up before the **V\_INT** 1.8 V cellular supply).

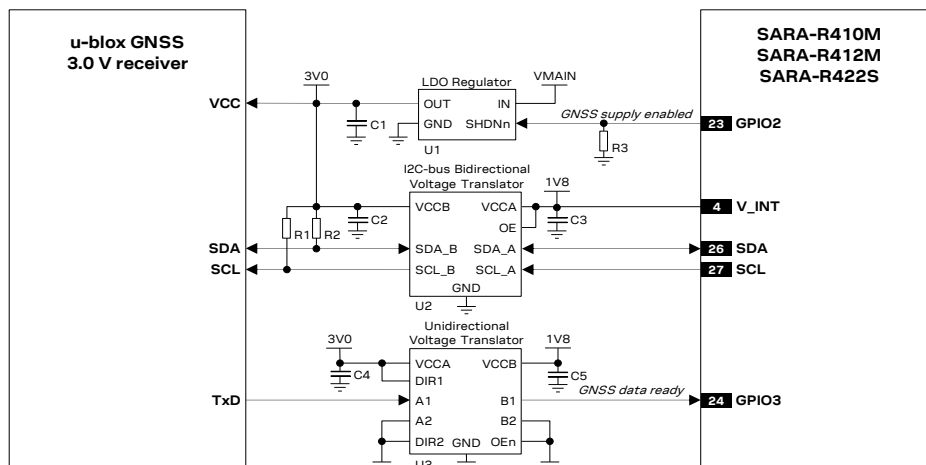


Figure 67: Application circuit for connecting SARA-R4 series modules to u-blox 3.0 V GNSS receivers

| Reference      | Description   | Part Number - Manufacturer                    |
|----------------|---|---|
| R1, R2         | 4.7 kΩ Resistor 0402 5% 0.1 W   | RC0402JR-074K7L - Yageo Phycomp               |
| R3             | 47 kΩ Resistor 0402 5% 0.1 W  | RC0402JR-0747KL - Yageo Phycomp               |
| C2, C3, C4, C5 | 100 nF Capacitor Ceramic X5R 0402 10% 10V                               | GRM155R71C104KA01 - Murata                    |
| U1, C1         | Voltage Regulator for GNSS receiver and related output bypass capacitor | See GNSS receiver hardware integration manual |
| U2             | I2C-bus Bidirectional Voltage Translator                                | TCA9406DCUR - Texas Instruments               |
| U3             | Generic Unidirectional Voltage Translator                               | SN74AVC2T245 - Texas Instruments              |

Table 47: Components for connecting SARA-R4 series modules to u-blox 3.0 V GNSS receivers

For additional guidelines regarding the design of applications with u-blox 1.8 V GNSS receivers, see the hardware integration manual of the u-blox GNSS receivers.

For additional guidelines regarding Cellular and GNSS RF coexistence, see section [2.4.4](#)

## 2.6.5.2 Guidelines for DDC (I2C) layout design

The DDC (I2C) serial interface requires the same consideration regarding electro-magnetic interference as any other digital interface. Keep the traces short and avoid coupling with RF line or sensitive analog inputs, since the signals can cause the radiation of some harmonics of the digital data frequency.

## 2.7 Audio

### 2.7.1 Guidelines for Audio circuit design

Audio is not supported by current product versions: the I2S digital audio interface pins should not be driven by any external device.

## 2.8 General Purpose Input/Output

### 2.8.1 Guidelines for GPIO circuit design

A typical usage of SARA-R4 series modules' GPIOs can be the following:

- Network indication provided over **GPIO1** pin (see [Figure 68](#) / [Table 48](#) below)
- GNSS supply enable function provided by the **GPIO2** pin (see [section 2.6.5](#))
- GNSS Tx data ready function provided by the **GPIO3** pin (see [section 2.6.5](#))
- Module operating status indication provided by a **GPIO** pin (see [section 1.6.1](#))
- SIM card detection provided over **GPIO5** pin (see [Figure 53](#) / [Table 39](#) in [section 2.5](#))

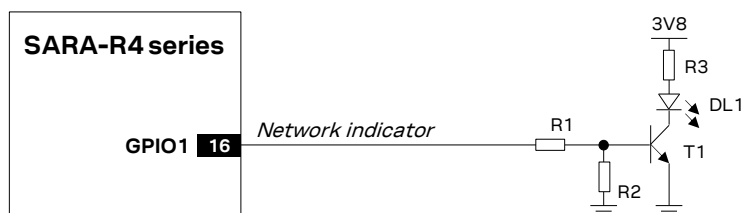




Figure 68: Application circuit for network indication provided over GPIO1

| Reference | Description                  | Part Number - Manufacturer                     |
|-----------|------------------------------|--|
| R1        | 10 kΩ Resistor 0402 5% 0.1 W | Various manufacturers                          |
| R2        | 47 kΩ Resistor 0402 5% 0.1 W | Various manufacturers                          |
| R3        | 820 Ω Resistor 0402 5% 0.1 W | Various manufacturers                          |
| DL1       | LED Red SMT 0603             | LTST-C190KRKT - Lite-on Technology Corporation |
| T1        | NPN BJT Transistor           | BC847 - Infineon                               |

Table 48: Components for network indication application circuit

- Use transistors with at least an integrated resistor in the base pin or otherwise put a 10 kΩ resistor on the board in series to the GPIO of SARA-R4 series modules.
- Do not apply voltage to any GPIO of the module before the switch-on of the GPIOs supply (**V\_INT**), to avoid latch-up of circuits and allow a clean module boot. If the external signals connected to the module cannot be tri-stated or set low, insert a multi-channel digital switch (e.g. TI SN74CB3Q16244, TS5A3159, TS5A63157) between the two-circuit connections and set to high impedance before **V\_INT** switch-on.

-  ESD sensitivity rating of the GPIO pins is 1 kV (HBM according to JESD22-A114). Higher protection level could be required if the lines are externally accessible and it can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG varistor) close to accessible points.
-  If the GPIO pins are not used, they can be left unconnected on the application board.

## 2.8.2 Guidelines for general purpose input/output layout design

The general purpose inputs / outputs pins are generally not critical for layout.

## 2.9 GNSS peripheral input output

-  GNSS peripheral input output pins are supported by SARA-R422M8SS / SARA-R422M10S only.

### 2.9.1 Guidelines for GNSS peripheral input output circuit design

SARA-R422M8S and SARA-R422M10S modules provides the following 1.8 V peripheral input output pins directly connected to the internal u-blox M8 GNSS chipset, as illustrated in [Figure 3](#):

- The **TXD\_GNSS** pin consisting in the UART data output of the internal u-blox GNSS chipset: the line can be connected to a UART data input pin of the application processor (see [Figure 69](#)).
- The **EXTINT** external interrupt pin that can be used for control of the GNSS receiver or for aiding: the line can be connected to a digital output pin of the application processor (see [Figure 69](#)).
- The **TIMEPULSE** output pin that can generate synchronized pulse trains with configurable intervals / frequency: the line can be connected to a digital input pin of the application processor (see [Figure 71](#)), or it can be connected to a circuit driving an LED (see [Figure 69](#)).
- The **ANT\_ON** output pin that can provide optional control for switching off power to an external active GNSS antenna or an external separate LNA (see [Figure 44](#) and [Figure 43](#)).

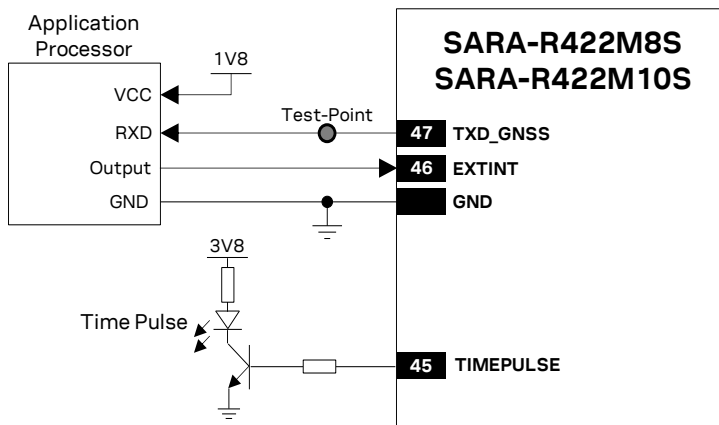



Figure 69: Application circuit for GNSS peripheral input output


-  It is recommended to provide accessible test point directly connected to the **TXD\_GNSS** pin for diagnostic purpose.

### 2.9.2 Guidelines for GNSS peripheral input output layout design

The GNSS peripheral input output pins are generally not critical for layout.

## 2.10 Reserved pins (RSVD)

SARA-R4 series modules have pins reserved for future use, marked as **RSVD**, which can all be left unconnected on the application board, except for the **RSVD** pin number **33** that can be externally connected to ground by 0  $\Omega$  series jumper, making available an accessible Test-Point to this pin for the SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules.

 It is highly recommended to provide accessible test point directly connected to the **RSVD #33** pin for diagnostic purposes (see [Figure 63](#)). It is also highly recommended to provide access to the **V\_INT**, **PWR\_ON** / **PWR\_CTRL**, **VUSB\_DET** / **USB\_5V0**, **USB\_3V3**, **USB\_D+**, **USB\_D-** pins for FW update and/or for diagnostic purposes, making available accessible dedicated Test-Points directly connected to each of these pins, or making available a dedicated connector / circuit.

## 2.11 Module placement


An optimized placement allows a minimum RF line's length and closer path from DC source for **VCC**.

Make sure that the module, analog parts and RF circuits are clearly separated from any possible source of radiated energy. In particular, digital circuits can radiate digital frequency harmonics, which can produce Electro-Magnetic Interference that affects the module, analog parts and RF circuits' performance. Implement suitable countermeasures to avoid any possible Electro-Magnetic Compatibility issue.

Make sure that the module, RF and analog parts / circuits, and high speed digital circuits are clearly separated from any sensitive part / circuit which may be affected by Electro-Magnetic Interference, or employ countermeasures to avoid any possible Electro-Magnetic Compatibility issue.

Make sure that the module is placed in order to keep the antenna as far as possible from VCC supply line and related parts (refer to [Figure 34](#)), from high speed digital lines (as USB) and from any possible noise source.

Provide enough clearance between the module and any external part: clearance of at least 0.4 mm per side is recommended to let suitable mounting of the parts.

 The heat dissipation during continuous transmission at maximum power can significantly raise the temperature of the application base-board below the SARA-R4 series modules: avoid placing temperature sensitive devices close to the module.

## 2.12 Module footprint and paste mask

Figure 70 and Table 49 describe the suggested footprint (i.e. copper mask) and paste mask layout for SARA modules: the proposed land pattern layout reflects the modules' pins layout, while the proposed stencil apertures layout is slightly different (see the F'', H'', I'', J'', O'' parameters compared to the F', H', I', J', O' ones).

The Non Solder resist Mask Defined (NSMD) pad type is recommended over the Solder resist Mask Defined (SMD) pad type, as it implements the solder resist mask opening 50  $\mu\text{m}$  larger per side than the corresponding copper pad.

The recommended thickness of the stencil for the soldering paste is 150  $\mu\text{m}$ , according to application production process requirements.

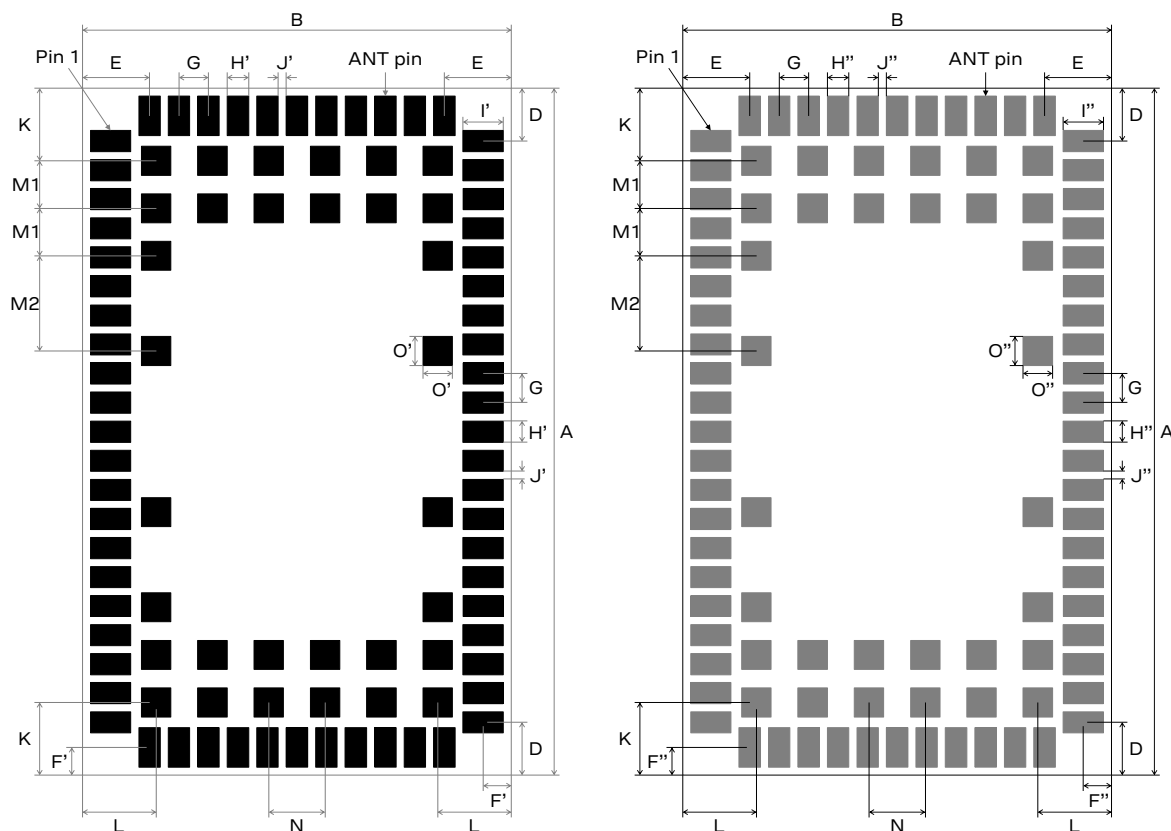


Figure 70: SARA-R4 series modules suggested footprint and paste mask (application board top view)

| Parameter | Value   | Parameter | Value   | Parameter | Value   |
|-----------|---------|-----------|---------|-----------|---------|
| A         | 26.0 mm | G         | 1.10 mm | K         | 2.75 mm |
| B         | 16.0 mm | H'        | 0.80 mm | L         | 2.75 mm |
| C         | 3.00 mm | H''       | 0.75 mm | M1        | 1.80 mm |
| D         | 2.00 mm | I'        | 1.50 mm | M2        | 3.60 mm |
| E         | 2.50 mm | I''       | 1.55 mm | N         | 2.10 mm |
| F'        | 1.05 mm | J'        | 0.30 mm | O'        | 1.10 mm |
| F''       | 1.00 mm | J''       | 0.35 mm | O''       | 1.05 mm |

Table 49: SARA-R4 series modules suggested footprint and paste mask dimensions

These are recommendations only and not specifications. The exact copper, solder and paste mask geometries, distances, stencil thicknesses and solder paste volumes must be adapted to the specific production processes (e.g. soldering etc.) implemented.

## 2.13 Thermal guidelines



The module operating temperature range is specified in the SARA-R4 series data sheet [1].

The most critical condition concerning module thermal performance is the uplink transmission at maximum power (data upload in connected mode), when the baseband processor runs at full speed, radio circuits are all active and the RF power amplifier is driven to higher output RF power. This scenario is not often encountered in real networks (for example, see the Terminal Tx Power distribution for WCDMA, taken from operation on a live network, described in the GSMA TS.09 battery life measurement and current consumption technique [12]); however the application should be correctly designed to cope with it.

During transmission at maximum RF power the SARA-R4 series modules generate thermal power that may exceed 0.5 W: this is an indicative value since the exact generated power strictly depends on operating condition such as the actual antenna return loss, the transmitting frequency band, etc. The generated thermal power must be adequately dissipated through the thermal and mechanical design of the application.

The spreading of the Module-to-Ambient thermal resistance ( $R_{th,M-A}$ ) depends on the module operating condition. The overall temperature distribution is influenced by the configuration of the active components during the specific mode of operation and their different thermal resistance toward the case interface.



The Module-to-Ambient thermal resistance value and the relative increase of module temperature will differ according to the specific mechanical deployments of the module, e.g. application PCB with different dimensions and characteristics, mechanical shells enclosure, or forced air flow.

The increase of the thermal dissipation, i.e. the reduction of the Module-to-Ambient thermal resistance, will decrease the temperature of the modules' internal circuitry for a given operating ambient temperature. This improves the device long-term reliability in particular for applications operating at high ambient temperature.

Recommended hardware techniques to be used to improve heat dissipation in the application:

- Connect each **GND** pin with solid ground layer of the application PCB and connect each ground area of the multilayer application PCB with complete thermal via stacked down to main ground layer.
- Provide a ground plane as wide as possible on the application board.
- Optimize antenna return loss, to optimize overall electrical performance of the module including a decrease of module thermal power.
- Optimize the thermal design of any high-power components included in the application, such as linear regulators and amplifiers, to optimize overall temperature distribution in the application.
- Select the material, the thickness and the surface of the box (i.e. the mechanical enclosure) of the application device that integrates the module so that it provides good thermal dissipation.

Beside the reduction of the Module-to-Ambient thermal resistance implemented by correct application hardware design, the increase of module temperature can be moderated by a correspondingly correct application software implementation:

- Enable power saving configuration using the +CPSMS AT command
- Enable module connected mode for a given time period and then disable it for a time period long enough to adequately mitigate the temperature increase.

## 2.14 Schematic for SARA-R4 series module integration

### 2.14.1 Schematic for SARA-R4 series modules

Figure 71 is an example of a schematic diagram where a SARA-R4 series module is integrated into an application board using almost all available interfaces and functions.

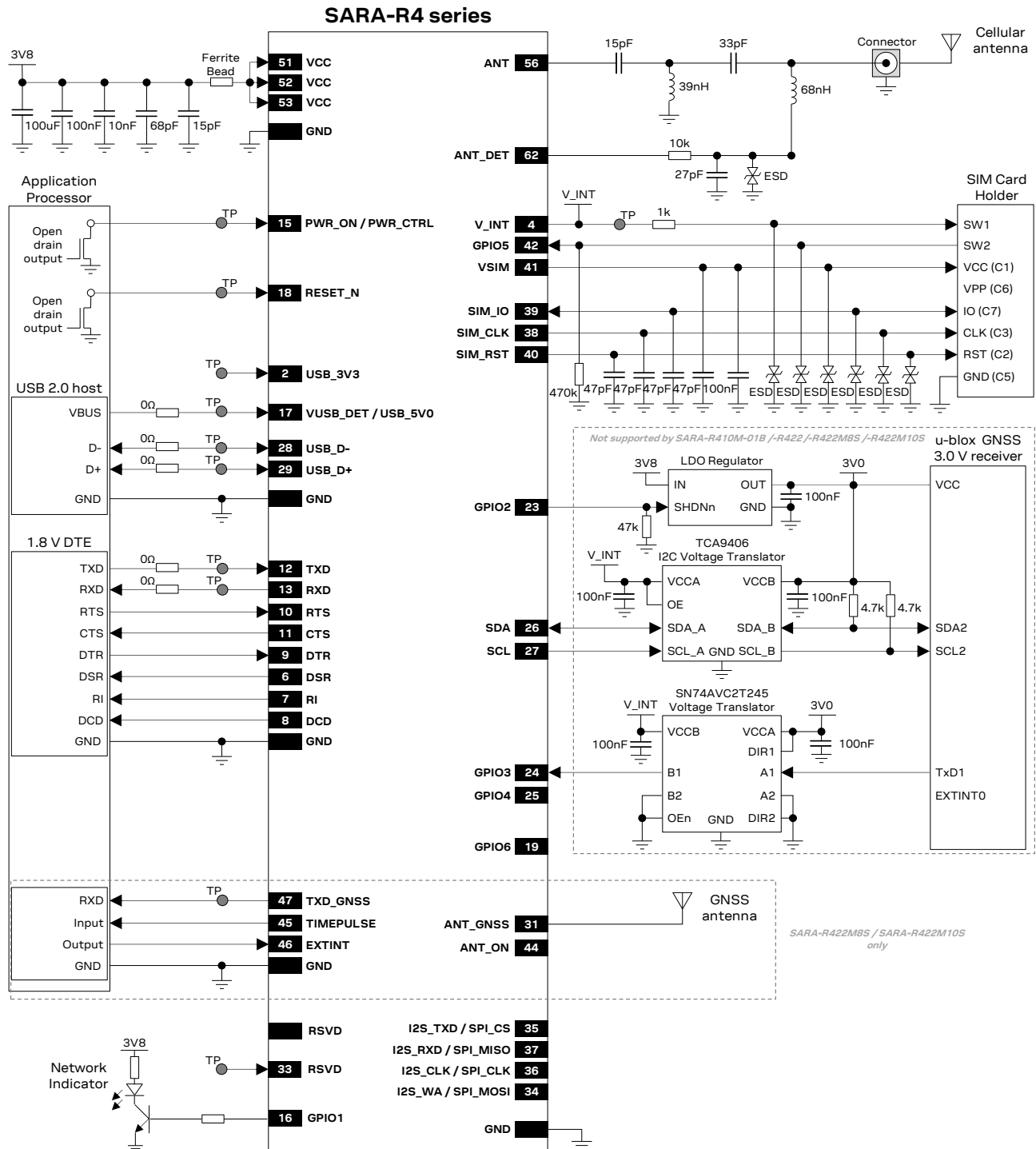


Figure 71: Example of schematic diagram to integrate a SARA-R4 series module using all available interfaces<sup>45</sup>

<sup>45</sup> Flow control is not supported by SARA-R410M-01B and SARA-R410M-02B-00 product versions. The **RTS** input must be set low to communicate over UART on SARA-R410M-01B product version. The **DTR** input must be set low to have URCs presented over UART on SARA-R410M-01B and SARA-R41xM-x2B product versions.

## 2.15 Design-in checklist

This section provides a design-in checklist.

### 2.15.1 Schematic checklist

The following are the most important points for a simple schematic check:

- ✓ DC supply must provide a nominal voltage at **VCC** pin within the operating range limits.
- ✓ DC supply must be capable of supporting the highest peak / pulse current consumption values and the maximum averaged current consumption values in connected mode, as specified in the SARA-R4 series data sheet [1].
- ✓ **VCC** voltage supply should be clean, with very low ripple/noise: provide the suggested bypass capacitors, in particular if the application device integrates an internal antenna.
- ✓ Do not apply loads which might exceed the limit for maximum available current from **V\_INT** supply.
- ✓ Check that voltage level of any connected pin does not exceed the relative operating range.
- ✓ Provide accessible test points directly connected to the **RESET\_N** pin for diagnostic purposes.
- ✓ Capacitance and series resistance must be limited on each SIM signal to match the SIM specifications.
- ✓ Insert the suggested pF capacitors on each SIM signal and low capacitance ESD protections if accessible.
- ✓ Check UART signals direction, as the modules' signal names follow the ITU-T V.24 recommendation [7].
- ✓ Capacitance and series resistance must be limited on each high speed line of the USB interface.
- ✓ It is strongly recommended to provide accessible test points directly connected to the **V\_INT**, **PWR\_ON** / **PWR\_CTRL**, **VUSB\_DET** / **USB\_5V0**, **USB\_3V3**, **USB\_D+**, **USB\_D-**, and **RSVD #33** pins for diagnostic and/or FW update purposes.
- ✓ Use transistors with at least an integrated resistor in the base pin or otherwise put a 10 kΩ resistor on the board in series to the GPIO when those are used to drive LEDs.
- ✓ Provide adequate precautions for EMC / ESD immunity as required on the application board.
- ✓ Do not apply voltage to any generic digital interface pin of SARA-R4 series modules before the switch-on of the generic digital interface supply source (**V\_INT**).
- ✓ All unused pins can be left unconnected.

### 2.15.2 Layout checklist

The following are the most important points for a simple layout check:

- ✓ Check 50 Ω nominal characteristic impedance of the RF transmission line connected to the **ANT** port (antenna RF interface).
- ✓ Ensure no coupling occurs between the RF interface and noisy or sensitive signals (SIM signals, high-speed digital lines such as USB, and other data lines).
- ✓ Optimize placement for minimum length of RF line.
- ✓ Check the footprint and paste mask designed for SARA-R4 series module as illustrated in section 2.12.
- ✓ **VCC** line should be enough wide and as short as possible.
- ✓ Route **VCC** supply line away from RF line / part (refer to Figure 34) and other sensitive analog lines / parts.



- ☑ The **VCC** bypass capacitors in the picoFarad range should be placed as close as possible to the **VCC** pins, in particular if the application device integrates an internal antenna.
- ☑ Ensure an optimal grounding connecting each **GND** pin with application board solid ground layer.
- ☑ Use as many vias as possible to connect the ground planes on multilayer application board, providing a dense line of vias at the edges of each ground area, in particular along RF and high speed lines.
- ☑ Keep routing short and minimize parasitic capacitance on the SIM lines to preserve signal integrity.
- ☑ **USB\_D+** / **USB\_D-** traces should meet the characteristic impedance requirement (90  $\Omega$  differential and 30  $\Omega$  common mode) and should not be routed close to any RF line / part.
- ☑ Ensure appropriate RF precautions for the GNSS and Cellular technologies coexistence.

### 2.15.3 Antenna checklist

- ☑ Antenna termination should provide 50  $\Omega$  characteristic impedance with V.S.W.R at least less than 3:1 (recommended 2:1) on operating bands in deployment geographical area.
- ☑ Follow the recommendations of the antenna producer for correct antenna installation and deployment (PCB layout and matching circuitry).
- ☑ Ensure compliance with any regulatory agency RF radiation requirement, as reported in section 4.2.2 for FCC United States, in section 4.3.1 forISED Canada, in section 4.4 for RED Europe, in section 4.9 for GITEKI Japan, etc.
- ☑ Ensure high isolation between the cellular antenna and any other antennas or transmitters present on the end device.
- ☑ Using the SARA-R422M8S and SARA-R422M10S modules, ensure high isolation between the Cellular and the GNSS antennas.

## 3 Handling and soldering



No natural rubbers, no hygroscopic materials or materials containing asbestos are employed.

### 3.1 Packaging, shipping, storage and moisture preconditioning

For information pertaining to SARA-R4 series reels / tapes, Moisture Sensitivity levels (MSD), shipment and storage information, as well as drying for preconditioning, see the SARA-R4 series data sheet [1] and the u-blox package information user guide [19].

### 3.2 Handling

The SARA-R4 series modules are Electro-Static Discharge (ESD) sensitive devices.



Ensure ESD precautions are implemented during handling of the module.



Electrostatic discharge (ESD) is the sudden and momentary electric current that flows between two objects at different electrical potentials caused by direct contact or induced by an electrostatic field. The term is usually used in the electronics and other industries to describe momentary unwanted currents that may cause damage to electronic equipment.

The ESD sensitivity for each pin of SARA-R4 series modules (as Human Body Model according to JESD22-A114F) is specified in the SARA-R4 series data sheet [1].

ESD prevention is based on establishing an Electrostatic Protective Area (EPA). The EPA can be a small working station or a large manufacturing area. The main principle of an EPA is that there are no highly charging materials near ESD sensitive electronics, all conductive materials are grounded, workers are grounded, and charge build-up on ESD sensitive electronics is prevented. International standards are used to define typical EPA and can be obtained for example from the International Electrotechnical Commission (IEC) or the American National Standards Institute (ANSI).

In addition to standard ESD safety practices, the following measures should be taken into account whenever handling the SARA-R4 series modules:

- Unless there is a galvanic coupling between the local GND (i.e. the work table) and the PCB GND, then the first point of contact when handling the PCB must always be between the local GND and PCB GND.
- Before mounting an antenna patch, connect the ground of the device.
- When handling the module, do not come into contact with any charged capacitors and be careful when contacting materials that can develop charges (e.g. patch antenna, coax cable, soldering iron).
- To prevent electrostatic discharge through the RF pin, do not touch any exposed antenna area. If there is any risk that such exposed antenna area is touched in a non-ESD protected work area, implement adequate ESD protection measures in the design.
- When soldering the module and patch antennas to the RF pin, make sure to use an ESD-safe soldering iron.

## 3.3 Soldering


### 3.3.1 Soldering paste

"No Clean" soldering paste is strongly recommended for SARA-R4 series modules, as it does not require cleaning after the soldering process has taken place. The paste listed in the example below meets these criteria.

|                      |  |
|----------------------|--|
| Soldering Paste:     | OM338 SAC405 / Nr.143714 (Cookson Electronics)   |
| Alloy specification: | 95.5% Sn / 3.9% Ag / 0.6% Cu (95.5% Tin / 3.9% Silver / 0.6% Copper)<br>95.5% Sn / 4.0% Ag / 0.5% Cu (95.5% Tin / 4.0% Silver / 0.5% Copper) |
| Melting Temperature: | 217 °C   |
| Stencil Thickness:   | 150 µm for base boards   |

The final choice of the soldering paste depends on the approved manufacturing procedures.

The paste-mask geometry for applying soldering paste should meet the recommendations in section [2.12](#).

 The quality of the solder joints should meet the appropriate IPC specification.

### 3.3.2 Reflow soldering

**A convection type-soldering oven is strongly recommended** for SARA-R4 series modules over the infrared type radiation oven. Convection heated ovens allow precise control of the temperature and all parts will be heated up evenly, regardless of material properties, thickness of components and surface color.

Consider the "IPC-7530A Guidelines for temperature profiling for mass soldering (reflow and wave) processes".

Reflow profiles are to be selected according to the following recommendations.

 Failure to observe these recommendations can result in severe damage to the device!

#### Preheat phase

Initial heating of component leads and balls. Residual humidity will be dried out. Note that this preheat phase will not replace prior baking procedures.

- Temperature rise rate: max 3 °C/s      If the temperature rise is too rapid in the preheat phase it may cause excessive slumping.
- Time: 60 – 120 s      If the preheat is insufficient, rather large solder balls tend to be generated. Conversely, if performed excessively, fine balls and large balls will be generated in clusters.
- End Temperature: +150 - +200 °C      If the temperature is too low, non-melting tends to be caused in areas containing large heat capacity.

#### Heating/ reflow phase

The temperature rises above the liquidus temperature of +217 °C. Avoid a sudden rise in temperature as the slump of the paste could become worse.

- Limit time above +217 °C liquidus temperature: 40 - 60 s
- Peak reflow temperature: +245 °C

## Cooling phase

A controlled cooling avoids negative metallurgical effects (solder becomes more brittle) of the solder and possible mechanical tensions in the products. Controlled cooling helps to achieve bright solder fillets with a good shape and low contact angle.

- Temperature fall rate: max 4 °C/s

To avoid falling off, modules should be placed on the topside of the motherboard during soldering.

The soldering temperature profile chosen at the factory depends on additional external factors like choice of soldering paste, size, thickness and properties of the base board, etc.

Exceeding the maximum soldering temperature and the maximum liquidus time limit in the recommended soldering profile may permanently damage the module.

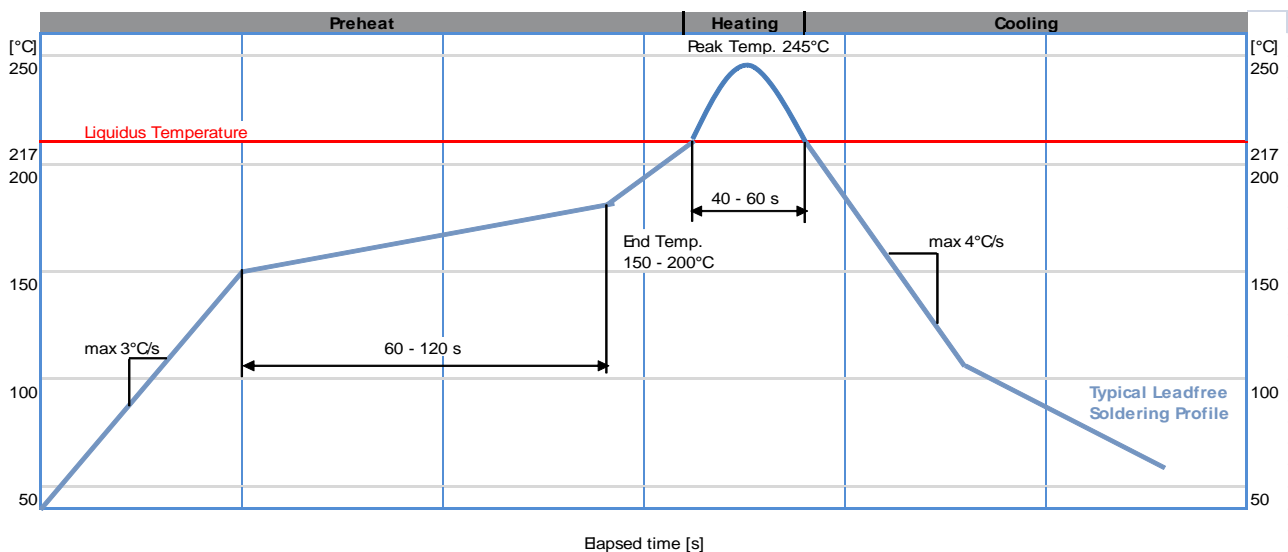


Figure 72: Recommended soldering profile

The modules must not be soldered with a damp heat process.

## 3.3.3 Optical inspection

After soldering the module, inspect it optically to verify that it is correctly aligned and centered.

## 3.3.4 Cleaning

Cleaning the modules is not recommended. Residues underneath the modules cannot be easily removed with a washing process.


- Cleaning with water will lead to capillary effects where water is absorbed in the gap between the baseboard and the module. The combination of residues of soldering flux and encapsulated water leads to short circuits or resistor-like interconnections between neighboring pads. Water will also damage the sticker and the ink-jet printed text.
- Cleaning with alcohol or other organic solvents can result in soldering flux residues flooding into the two housings, areas that are not accessible for post-wash inspections. The solvent will also damage the sticker and the ink-jet printed text.
- Ultrasonic cleaning will permanently damage the module, in particular the quartz oscillators.

For best results, use a "no clean" soldering paste and eliminate the cleaning step after the soldering.

### 3.3.5 Repeated reflow soldering

Repeated reflow soldering processes and soldering the module upside-down are not recommended.


Boards with components on both sides may require two reflow cycles. In this case, the module should always be placed on the side of the board that is submitted into the last reflow cycle. The reason for this (besides others) is the risk of the module falling off due to the significantly higher weight in relation to other components.


 u-blox gives no warranty against damages to the SARA-R4 series modules caused by performing more than a total of two reflow soldering processes (one reflow soldering process to mount the SARA-R4 series module, plus one reflow soldering process to mount other parts).

### 3.3.6 Wave soldering

SARA-R4 series LGA modules must not be soldered with a wave soldering process.

Boards with combined through-hole technology (THT) components and surface-mount technology (SMT) devices require wave soldering to solder the THT components. No more than one wave soldering process is allowed for a board with a SARA-R4 series module already populated on it.

 Performing a wave soldering process on the module can result in severe damage to the device!


 u-blox gives no warranty against damages to the SARA-R4 series modules caused by performing more than a total of two soldering processes (one reflow soldering process to mount the SARA-R4 series module, plus one wave soldering process to mount other THT parts on the application board).

### 3.3.7 Hand soldering

Hand soldering is not recommended.

### 3.3.8 Rework

Rework is not recommended.


 Never attempt a rework on the module itself, e.g. replacing individual components. Such actions immediately terminate the warranty.

### 3.3.9 Conformal coating

Certain applications employ a conformal coating of the PCB using HumiSeal® or other related coating products.

These materials affect the HF properties of the cellular modules and it is important to prevent them from flowing into the module.

The RF shields do not provide 100% protection for the module from coating liquids with low viscosity, therefore care is required in applying the coating.

 Conformal Coating of the module will void the warranty.


### 3.3.10 Casting

If casting is required, use viscose or another type of silicon pottant. The OEM is strongly advised to qualify such processes in combination with the cellular modules before implementing this in production.

 Casting will void the warranty.


### 3.3.11 Grounding metal covers

Attempts to improve grounding by soldering ground cables, wick or other forms of metal strips directly onto the EMI covers is done at the customer's own risk. The numerous ground pins should be sufficient to provide optimum immunity to interference and noise.

-  u-blox gives no warranty for damages to the cellular modules caused by soldering metal cables or any other forms of metal strips directly onto the EMI covers.

### 3.3.12 Use of ultrasonic processes

The cellular modules contain components which are sensitive to ultrasonic waves. Use of any ultrasonic processes (cleaning, welding etc.) may cause damage to the module.

-  u-blox gives no warranty against damages to the cellular modules caused by any ultrasonic processes.

## 4 Approvals


### 4.1 Product certification approval overview

Product certification approval is the process of certifying that a product has passed all tests and criteria required by specifications, typically called “certification schemes”, which can be divided into:

- Regulatory certifications
  - Country-specific approval required by local government in most regions and countries, as:
    - CE (European Conformity) marking for European Union
    - FCC (Federal Communications Commission) approval for the United States
- Industry certifications
  - Telecom industry-specific approval verifying interoperability between devices and networks:
    - GCF (Global Certification Forum)
    - PTCRB (PCS Type Certification Review Board)
- Operator certifications
  - Operator-specific approvals required by some mobile network operator, such as:
    - AT&T network operator in United States
    - Verizon Wireless network operator in United States


The manufacturer of the end-device that integrates a SARA-R4 series module must take care of all certification approvals required by the specific integrating device to be deployed in the market.


The required certification scheme approvals and relative testing specifications applicable to the end-device that integrates a SARA-R4 series module differ depending on the country or the region where the integrating device is intended to be deployed, on the relative vertical market of the device, on type, features and functionalities of the whole application device, and on the network operators where the device is intended to operate.

 Check the appropriate applicability of the SARA-R4 series module’s approvals while starting the certification process of the device integrating the module: the re-use of the u-blox cellular module’s approval can significantly reduce the cost and time to market of the application device certification.





The SARA-R4 series modules include the capability to configure the device by selecting the operating mobile network operator profile, radio access technology, and bands. In the SARA-R4 series AT commands manual [\[2\]](#), see the +UMNOPROF, +URAT, and +UBANDMASK AT commands.

As these configuration decisions are made, u-blox reminds manufacturers of the end-device integrating the SARA-R4 series modules to take care of compliance with all the certification approvals requirements applicable to the specific integrating device to be deployed in the market.

 It is strongly recommended to configure the module to the applicable MNO profile, RAT, and LTE bands intended for the application device and within regulatory compliance.

 The certification of the application device that integrates a SARA-R4 series module and the compliance of the application device with all the applicable certification schemes, directives and standards are the sole responsibility of the application device manufacturer.


SARA-R4 series modules are certified according to all capabilities and options stated in the Protocol Implementation Conformance Statement document (PICS) of the module. The PICS, according to the 3GPP TS 51.010-2 [14], 3GPP TS 36.521-2 [16] and 3GPP TS 36.523-2 [17], is a statement of the implemented and supported capabilities and options of a device.

-  The PICS document of the application device integrating SARA-R4 series modules must be updated from the module PICS statement if any feature stated as supported by the module in its PICS document is not implemented or disabled in the application device. For more details regarding the AT commands settings that affect the PICS, see the SARA-R4 series AT commands manual [2].
-  Check the specific settings required for mobile network operators approvals as they may differ from the AT commands settings defined in the module as integrated in the application device.
-  For further guidelines about certification of end-devices integrating a SARA-R41 series module, see the u-blox SARA-R41 series application development guide application note [3].
-  For further guidelines about certification of end-devices integrating a SARA-R42 series module, see the u-blox SARA-R42 series application development guide application note [4].

**Table 50** summarizes the main approvals for the SARA-R410M-02B, the SARA-R410M-52B and the SARA-R412M modules product versions (LTE-M = LTE Cat M1, NB1 = LTE Cat NB1).

| Certification      | SARA-R410M-02B  | SARA-R410M-52B              | SARA-R412M-02B   |
|--------------------|---|-----------------------------|--|
| PTCRB              | LTE Cat M1, NB1 band 2,3,4,5,8,12,13,20,28  | LTE Cat M1 band 2,4,5,12,13 | LTE Cat M1, NB1 band 2,4,5,12                            |
| GCF                |   | LTE Cat M1 band 2,4,5,12,13 |  |
| CE Europe          | LTE Cat M1, NB1 band 3,8,20   |                             | LTE Cat M1, NB1 band 3,8,20<br>2G band 900,1800          |
| UKCA Great Britain | LTE Cat M1, NB1 band 3,8,20   |                             | LTE Cat M1, NB1 band 3,8,20<br>2G band 900,1800          |
| FCC US             | LTE Cat M1, NB1 band 2,4,5,12,13,25 <sup>46</sup>   | LTE Cat M1 band 2,4,5,12,13 | LTE Cat M1, NB1 band 2,4,5,12,13<br>2G band 850,1900     |
| FCC ID             | XPY2AGQN4NNN  | XPY2AGQN4NNN                | XPYUBX18ZO01   |
| ISED Canada        | LTE Cat M1, NB1 band 2,4,5,12,13  | LTE Cat M1 band 2,4,5,12,13 | LTE Cat M1, NB1 band 2,4,5,12,13<br>2G band 850,1900     |
| ISED ID            | 8595A-2AGQN4NNN   | 8595A-2AGQN4NNN             | 8595A-UBX18ZO01  |
| ACMA RCM Australia | LTE Cat M1 band 3,5,8,28  |                             | LTE Cat M1, NB1 band 3,5,8,28                            |
| NCC Taiwan         | LTE Cat M1, NB1 band 3,8,28   |                             |  |
| ANATEL Brazil      | LTE Cat M1, NB1 band 3,5,28   |                             | LTE Cat M1, NB1 band 3,5,28<br>2G band 850,900,1800,1900 |
| GITEKI Japan       | LTE Cat M1, NB1 band 1,8,18,19,26   |                             |  |
| Verizon            | LTE Cat M1 band 4,13  | LTE Cat M1 band 4,13        |  |
| AT&T               | LTE Cat M1 band 2,4,5,12  | LTE Cat M1 band 2,4,5,12    | LTE Cat M1 band 2,4,5,12                                 |
| T-Mobile US        | LTE Cat M1 band 2,12  |                             |  |
| Deutsche Telekom   | LTE Cat M1, NB1 band 3,8,20   |                             | LTE Cat M1, NB1 band 3,8,20<br>2G band 900,1800          |
| Note:              | Certification of cellular radio modules is no longer mandatory according to current IFT Mexico regulatory rules |                             |  |

**Table 50: Summary of certification approvals for the SARA-R410M-02B, SARA-R410M-52B and SARA-R412M**

-  The certification approvals listed in **Table 50** above might not be available for all the different product type numbers. Please contact the u-blox office or sales representative nearest you for the full comprehensive list of approvals and for further specific info about all country, conformance and network operators' certifications available for the selected product ordering number.

<sup>46</sup> LTE Cat M1 only



**Table 51** summarizes how some of the SARA-R41 series modules are identified by various bodies.


| Body               | Description              | SARA-R410M-01B  | SARA-R410M-02B  | SARA-R410M-52B  | SARA-R412M-02B  |
|--------------------|--------------------------|-----------------|-----------------|-----------------|-----------------|
| PTCRB              | Model Name               | SARA-R410M      | SARA-R410M-02B  | SARA-R410M-52B  | SARA-R412M      |
| GCF                | Model Name               | --              | --              | SARA-R410M-52B  | --              |
|                    | Marketing Name           | --              | --              | SARA-R410M-52B  | --              |
| GSMA               | Model Name               | SARA-R410M      | SARA-R410M      | SARA-R410M-52B  | SARA-R412M      |
|                    | Marketing Name           | SARA-R410M      | SARA-R410M-02B  | SARA-R410M-52B  | SARA-R412M      |
| FCC US             | ID                       | XPY2AGQN4NNN    | XPY2AGQN4NNN    | XPY2AGQN4NNN    | XPYUBX18ZO01    |
|                    | Product Name             | SARA-R410M      | SARA-R410M-02B  | SARA-R410M-02B  | SARA-R412M      |
| ISED Canada        | Certification Number     | 8595A-2AGQN4NNN | 8595A-2AGQN4NNN | 8595A-2AGQN4NNN | 8595A-UBX18ZO01 |
|                    | HVIN                     | SARA-R410M      | SARA-R410M      | SARA-R410M      | SARA-R412M      |
|                    | PMN                      | SARA-R410M      | SARA-R410M      | SARA-R410M      | SARA-R412M      |
| RED Europe         | Model Name               | --              | SARA-R410M-02B  | --              | SARA-R412M      |
| UKCA Great Britain | Model Name               | --              | SARA-R410M-02B  | --              | SARA-R412M      |
| ACMA RCM Australia | Model Number             | --              | SARA-R410M-02B  | --              | SARA-R412M-02B  |
| NCC Taiwan         | Model Name               | --              | SARA-R410M      | --              | --              |
|                    | Certification Number     | --              | CCAA18NB0010T3  | --              | --              |
| ANATEL Brazil      | Model Name               | --              | SARA-R410M      | --              | SARA-R412M      |
|                    | Marketing Name           | --              | SARA-R410M-02B  | --              | SARA-R412M-02B  |
|                    | Certification Number     | --              | 07889-19-05903  | --              | 07927-19-05903  |
| GITEKI Japan       | Model Name               | --              | SARA-R410M      | --              | --              |
|                    | [R] Certification Number | --              | 003-180155      | --              | --              |
|                    | [T] Certification Number | --              | D180083003      | --              | --              |
| AT&T               | Model Name               | SARA-R410M      | SARA-R410M-02B  | SARA-R410M-52B  | SARA-R412M      |
| Verizon            | Model Name               | --              | SARA-R410M-02B  | SARA-R410M-52B  | --              |
| T-Mobile US        | Model Name               | --              | SARA-R410M-02B  | --              | --              |
| Deutsche Telekom   | Model Name               | --              | SARA-R410M-02B  | --              | SARA-R412M-02B  |

**Table 51: Summary of some SARA-R41 series modules' identification by various bodies**

**Table 52** summarizes the main approvals for the SARA-R410M-63B, the SARA-R410M-73B, and the SARA-R410M-83B modules product versions.

| Certification      | SARA-R410M-63B                    | SARA-R410M-73B         | SARA-R410M-83B                |
|--------------------|-----------------------------------|------------------------|-------------------------------|
| CE Europe          |                                   |                        | LTE Cat M1, NB1 band 3,8,20   |
| UKCA Great Britain |                                   |                        | LTE Cat M1, NB1 band 3,8,20   |
| ACMA RCM Australia |                                   |                        | LTE Cat M1, NB1 band 3,5,8,28 |
| NCC Taiwan         |                                   |                        | LTE Cat M1, NB1 band 3,8,28   |
| GITEKI Japan       | LTE Cat M1, NB1 band 1,8,18,19,26 |                        |                               |
| KC Korea           |                                   | LTE Cat M1 band 3,5,26 |                               |
| Telstra            |                                   |                        | LTE Cat M1, NB1 band 3,5,8,28 |
| Softbank           | LTE Cat M1 band 1,8               |                        |                               |
| NTT DOCOMO         | LTE Cat M1 band 1,19              |                        |                               |
| SKT                |                                   | LTE Cat M1 band 3,5,26 |                               |
| LGU+               |                                   | LTE Cat M1 band 5      |                               |


**Table 52: Summary of main certification approvals for SARA-R410M-63B, SARA-R410M-73B, SARA-R410M-83B**

 The certification approvals listed in **Table 52** above might not be available for all the different product type numbers. Please contact the u-blox office or sales representative nearest you for the full comprehensive list of approvals and for further specific info about all country, conformance, and network operators' certifications available for the selected product ordering number.

**Table 53** summarizes the main approvals for the SARA-R422-00B, the SARA-R422S-00B and the SARA-R422M8S-00B modules product versions.

| Certification      | SARA-R422-00B / SARA-R422S-00B / SARA-R422M8S-00B   |
|--------------------|---|
| PTCRB              | LTE-M bands 1, 2, 3, 4, 5, 8, 12, 13, 20, 25, 26, 28, 66; NB-IoT bands 1, 2, 3, 4, 5, 8, 12, 13, 20, 28, 66, 85; 2G Quad-band |
| GCF                | LTE-M bands 1, 2, 3, 4, 5, 8, 12, 13, 20, 25, 26, 28, 66; NB-IoT bands 1, 2, 3, 4, 5, 8, 12, 13, 20, 28, 66, 85; 2G Quad-band |
| CE Europe          | LTE-M bands 1, 3, 8, 20, 28; NB-IoT bands 1, 3, 8, 20, 28; 2G bands 900, 1800   |
| UKCA Great Britain | LTE-M bands 1, 3, 8, 20, 28; NB-IoT bands 1, 3, 8, 20, 28; 2G bands 900, 1800   |
| FCC US             | LTE-M bands 2, 4, 5, 8, 12, 13, 25, 26, 66; NB-IoT bands 2, 4, 5, 8, 12, 13, 66, 85; 2G bands 850, 1900                       |
| FCC ID             | XPYUBX20VA01  |
| ISED Canada        | LTE-M bands 2, 4, 5, 12, 13, 25, 26, 66; NB-IoT bands 2, 4, 5, 12, 13, 66, 85; 2G bands 850, 1900                             |
| ISED ID            | 8595A-UBX20VA01   |
| ACMA RCM Australia | LTE-M bands 1, 3, 5, 8, 28; NB-IoT bands 1, 3, 5, 8, 28   |
| NCC Taiwan         | LTE-M bands 3, 8, 28; NB-IoT bands 3, 8, 28   |
| ANATEL Brazil      | LTE-M bands 1, 2, 3, 5, 8, 28; NB-IoT bands 1, 2, 3, 5, 8, 28; 2G Quad-band   |
| GITEKI Japan       | LTE-M bands 1, 3, 8, 26, 28; NB-IoT bands 1, 3, 8, 26, 28   |
| Vodafone           | NB-IoT bands 3, 8, 20; 2G bands 900, 1800   |
| Deutsche Telekom   | LTE-M bands 3, 8, 20; NB-IoT bands 3, 8, 20; 2G bands 900, 1800   |
| Note:              | Certification of cellular radio modules is no longer mandatory with current IFT Mexico regulatory rules                       |


**Table 53: Summary of main certification approvals for the SARA-R422-00B, SARA-R422S-00B and SARA-R422M8S-00B**

 The certification approvals listed in **Table 53** above might not be available for all the different product type numbers. Please contact the u-blox office or sales representative nearest you for the full comprehensive list of approvals and for further specific info about all country, conformance and network operators' certifications available for the selected product ordering number.

**Table 54** summarizes the main approvals for the SARA-R422-01B, the SARA-R422S-01B and the SARA-R422M10S-01B modules product versions.

| Certification      | SARA-R422-01B / SARA-R422S-01B / SARA-R422M10S-01B  |
|--------------------|---|
| PTCRB              | LTE-M bands 1, 2, 3, 4, 5, 8, 12, 13, 18, 19, 20, 25, 26, 28, 66; NB-IoT bands 1, 2, 3, 4, 5, 8, 12, 13, 18, 19, 20, 28, 66, 85; 2G Quad-band |
| GCF                | LTE-M bands 1, 2, 3, 4, 5, 8, 12, 13, 18, 19, 20, 25, 26, 28, 66; NB-IoT bands 1, 2, 3, 4, 5, 8, 12, 13, 18, 19, 20, 28, 66, 85; 2G Quad-band |
| CE Europe          | LTE-M bands 1, 3, 8, 20, 28; NB-IoT bands 1, 3, 8, 20, 28; 2G bands 900, 1800   |
| UKCA Great Britain | LTE-M bands 1, 3, 8, 20, 28; NB-IoT bands 1, 3, 8, 20, 28; 2G bands 900, 1800   |
| FCC US             | LTE-M bands 2, 4, 5, 8, 12, 13, 25, 26, 66; NB-IoT bands 2, 4, 5, 8, 12, 13, 66, 85; 2G bands 850, 1900                                       |
| FCC ID             | XPYUBX20VA01  |
| ISED Canada        | LTE-M bands 2, 4, 5, 12, 13, 25, 26, 66; NB-IoT bands 2, 4, 5, 12, 13, 66, 85; 2G bands 850, 1900   |
| ISED ID            | 8595A-UBX20VA01   |
| ACMA RCM Australia | LTE-M bands 1, 3, 5, 8, 28; NB-IoT bands 1, 3, 5, 8, 28   |
| NCC Taiwan         | LTE-M bands 3, 8, 28; NB-IoT bands 3, 8, 28   |
| ANATEL Brazil      | LTE-M bands 1, 2, 3, 5, 8, 28; NB-IoT bands 1, 2, 3, 5, 8, 28; 2G Quad-band   |
| GITEKI Japan       | LTE-M bands 1, 3, 8, 18, 19, 26, 28; NB-IoT bands 1, 3, 8, 18, 19, 26, 28   |
| KC Korea           | LTE-M bands 3, 5, 26; NB-IoT bands 5  |
| AT&T               | LTE-M bands 2, 4, 5, 12; FirstNet   |
| Verizon            | LTE-M bands 4, 13   |
| Vodafone           | LTE-M bands 3, 8, 20; NB-IoT bands 3, 8, 20; 2G bands 900, 1800   |
| Deutsche Telekom   | LTE-M bands 3, 8, 20; NB-IoT bands 3, 8, 20; 2G bands 900, 1800   |
| Note:              | Certification of cellular radio modules is no longer mandatory with current IFT Mexico regulatory rules                                       |

**Table 54: Summary of main certification approvals for the SARA-R422-01B, SARA-R422S-01B and SARA-R422M10S-01B**

 The certification approvals listed in **Table 54** above might not be available for all the different product type numbers. Please contact the u-blox office or sales representative nearest you for the full comprehensive list of approvals and for further specific info about all country, conformance and network operators' certifications available for the selected product ordering number.

## 4.2 US Federal Communications Commission notice

United States Federal Communications Commission (FCC) IDs:

- |  |              |
|--|--------------|
| • u-blox SARA-R410M:   | XPY2AGQN4NNN |
| • u-blox SARA-R412M:   | XPYUBX18ZO01 |
| • u-blox SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S: | XPYUBX20VA01 |


### 4.2.1 Safety warnings review the structure


- Equipment for building-in. Requirements for fire enclosure must be evaluated in the end product
- The clearance and creepage current distances required by the end product must be withheld when the module is installed
- The cooling of the end product shall not negatively be influenced by the installation of the module
- Excessive sound pressure from earphones and headphones can cause hearing loss
- No natural rubbers, hygroscopic materials, or materials containing asbestos are employed

### 4.2.2 Declaration of Conformity

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

- this device may not cause harmful interference
- this device must accept any interference received, including interference that may cause undesired operation

 Radiofrequency radiation exposure information: this equipment complies with the radiation exposure limits prescribed for an uncontrolled environment for fixed and mobile use conditions. This equipment should be installed and operated with a minimum distance of 20 cm between the radiator and the body of the user or nearby persons. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter except as authorized in the certification of the product.





 The gain of the system antenna(s) used for the SARA-R4 series modules (i.e. the combined transmission line, connector, cable losses and radiating element gain) must not exceed the value specified in the FCC Grant for mobile and fixed or mobile operating configurations:

- SARA-R410M-01B modules:
  - 3.67 dBi in 700 MHz, i.e. LTE FDD-12 band uplink
  - 4.10 dBi in 850 MHz, i.e. LTE FDD-5 band uplink
  - 6.74 dBi in 1700 MHz, i.e. LTE FDD-4 band uplink
  - 7.12 dBi in 1900 MHz, i.e. LTE FDD-2 band uplink
- SARA-R410M-02B and SARA-R410M-52B modules:
  - 3.66 dBi in 700 MHz, i.e. LTE FDD-12 band uplink
  - 3.94 dBi in 750 MHz, i.e. LTE FDD-13 band uplink
  - 4.41 dBi in 850 MHz, i.e. LTE FDD-5 band uplink
  - 6.75 dBi in 1700 MHz, i.e. LTE FDD-4 band uplink
  - 7.00 dBi in 1900 MHz, i.e. LTE FDD-2 band uplink
  - 9.40 dBi in 1900 MHz, i.e. LTE FDD-25 band uplink
- SARA-R412M-02B modules:
  - 8.69 dBi in 700 MHz, i.e. LTE FDD-12 band uplink
  - 9.15 dBi in 750 MHz, i.e. LTE FDD-13 band uplink
  - 9.41 dBi in 850 MHz, i.e. GSM 850 / LTE FDD-5 band uplink
  - 12.01 dBi in 1700 MHz, i.e. LTE FDD-4 band uplink
  - 12.01 dBi in 1900 MHz, i.e. GSM 1900 / LTE FDD-2 band uplink

- SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules:
  - 8.7 dBi in 700 MHz, i.e. LTE FDD-12 / LTE FDD-85 band uplink
  - 9.2 dBi in 750 MHz, i.e. LTE FDD-13 band uplink
  - 8.4 dBi in 850 MHz, i.e. GSM 850 / LTE FDD-5 / LTE FDD-26 band uplink
  - 9.8 dBi in 900 MHz, i.e. LTE FDD-8 band uplink
  - 4.7 dBi in 1700 MHz, i.e. LTE FDD-4 / LTE FDD-66 band uplink
  - 4.0 dBi in 1900 MHz, i.e. GSM 1900 / LTE FDD-2 / LTE FDD-25 band uplink

### 4.2.3 Modifications

The FCC requires the user to be notified that any changes or modifications made to this device that are not expressly approved by u-blox could void the user's authority to operate the equipment.

-  Manufacturers of mobile or fixed devices incorporating the SARA-R4 series modules are authorized to use the FCC Grants of the SARA-R4 series modules for their own final products according to the conditions referenced in the certificates.
-  The FCC Label shall in the above case be visible from the outside, or the host device shall bear a second label stating:
  - "Contains FCC ID: XPY2AGQN4NNN" for host device integrating SARA-R410M modules
  - "Contains FCC ID: XPYUBX18ZO01" for host device integrating SARA-R412M modules
  - "Contains FCC ID: XPYUBX20VA01" for host device integrating SARA-R422, SARA-R422S, SARA-R422M8S, or SARA-R422M10S modules
-  **IMPORTANT:** Manufacturers of portable applications incorporating the SARA-R4 series modules are required to have their final product certified and apply for their own FCC Grant related to the specific portable device. This is mandatory to meet the SAR requirements for portable devices. Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.
-  **Additional Note:** pursuant to part 15 of FCC Rules, limits for a Class B digital device are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
  - Reorient or relocate the receiving antenna
  - Increase the separation between the equipment and receiver
  - Connect the equipment into an outlet on a circuit different from that to which the receiver is connected
  - Consult the dealer or an experienced radio/TV technician for help

## 4.3 Innovation, Science, Economic Development Canada notice


ISED Canada (formerly known as IC - Industry Canada) Certification Numbers:


- u-blox SARA-R410M: 8595A-2AGQN4NNN
- u-blox SARA-R412M: 8595A-UBX18ZO01
- u-blox SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S: 8595A-UBX20VA01

### 4.3.1 Declaration of Conformity

This device complies with the ISED Canada license-exempt RSS standard(s). Operation is subject to the following two conditions:

- this device may not cause harmful interference
- this device must accept any interference received, including interference that may cause undesired operation



 Radiofrequency radiation exposure information: this equipment complies with the radiation exposure limits prescribed for an uncontrolled environment for fixed and mobile use conditions. This equipment should be installed and operated with a minimum distance of 20 cm between the radiator and the body of the user or nearby persons. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter except as authorized in the certification of the product.

 The gain of the system antenna(s) used for the SARA-R4 series modules (i.e. the combined transmission line, connector, cable losses and radiating element gain) must not exceed the value stated in the ISED Canada Grant for mobile and fixed or mobile operating configurations:

- SARA-R410M-01B modules:
  - 3.67 dBi in 700 MHz, i.e. LTE FDD-12 band uplink
  - 4.10 dBi in 850 MHz, i.e. LTE FDD-5 band uplink
  - 6.74 dBi in 1700 MHz, i.e. LTE FDD-4 band uplink
  - 7.12 dBi in 1900 MHz, i.e. LTE FDD-2 band uplink
- SARA-R410M-02B and SARA-R410M-52B modules:
  - 3.66 dBi in 700 MHz, i.e. LTE FDD-12 band uplink
  - 3.94 dBi in 750 MHz, i.e. LTE FDD-13 band uplink
  - 4.41 dBi in 850 MHz, i.e. LTE FDD-5 band uplink
  - 6.75 dBi in 1700 MHz, i.e. LTE FDD-4 band uplink
  - 7.00 dBi in 1900 MHz, i.e. LTE FDD-2 band uplink
- SARA-R412M-02B modules:
  - 5.63 dBi in 700 MHz, i.e. LTE FDD-12 band uplink
  - 5.94 dBi in 750 MHz, i.e. LTE FDD-13 band uplink
  - 6.12 dBi in 850 MHz, i.e. GSM 850 / LTE FDD-5 band uplink
  - 8.29 dBi in 1700 MHz, i.e. LTE FDD-4 band uplink
  - 8.52 dBi in 1900 MHz, i.e. GSM 1900 / LTE FDD-2 band uplink
- SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules:
  - 5.6 dBi in 700 MHz, i.e. LTE FDD-12 / LTE FDD-85 band uplink
  - 6.0 dBi in 750 MHz, i.e. LTE FDD-13 band uplink
  - 6.1 dBi in 850 MHz, i.e. GSM 850 / LTE FDD-5 / LTE FDD-26 band uplink
  - 4.7 dBi in 1700 MHz, i.e. LTE FDD-4 / LTE FDD-66 band uplink
  - 4.0 dBi in 1900 MHz, i.e. GSM 1900 / LTE FDD-2 / LTE FDD-25 band uplink

### 4.3.2 Modifications

ISED Canada requires the user to be notified that any changes or modifications made to this device that are not expressly approved by u-blox could void the user's authority to operate the equipment.

-  Manufacturers of mobile or fixed devices incorporating the SARA-R4 series modules are authorized to use the ISED Canada Certificates of the SARA-R4 series modules for their own final products according to the conditions referenced in the certificates.
-  The ISED Canada Label shall in the above case be visible from the outside, or the host device shall bear a second label stating:
  - "Contains IC: 8595A-2AGQN4NNN" for host device integrating the SARA-R410M modules
  - "Contains IC: 8595A-UBX18ZO01" for host device integrating the SARA-R412M modules
  - "Contains IC: 8595A-UBX20VA01" for host device integrating the SARA-R422, SARA-R422S, SARA-R422M8S, or SARA-R422M10S modules

#### Innovation, Science and Economic Development Canada (ISED) Notices

This Class B digital apparatus complies with Canadian CAN ICES-3(B) / NMB-3(B).

Operation is subject to the following two conditions:

- this device may not cause interference
- this device must accept any interference, including interference that may cause undesired operation of the device

#### **Radio Frequency (RF) Exposure Information**

The radiated output power of the u-blox Cellular Module is below the Innovation, Science and Economic Development Canada (ISED) radio frequency exposure limits. The u-blox Cellular Module should be used in a manner such that the potential for human contact during normal operation is minimized.


This device has been evaluated and shown compliant with the IC RF Exposure limits under mobile exposure conditions (antennas are greater than 20 cm from a person's body).

This device has been certified for use in Canada. Status of the listing in the Industry Canada's REL (Radio Equipment List) can be found at the following web address:

<http://www.ic.gc.ca/app/sitt/relet/srch/nwRdSrch.do?lang=eng>

Additional Canadian information on RF exposure also can be found at the following web address:

<http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08792.html>

-  **IMPORTANT:** Manufacturers of portable applications incorporating the SARA-R4 series modules are required to have their final product certified and apply for their own Industry Canada Certificate related to the specific portable device. This is mandatory to meet the SAR requirements for portable devices.
- Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

- ⚠ Avis d'Innovation, Sciences et Développement économique Canada (ISDE)**
- Cet appareil numérique de classe B est conforme aux normes canadiennes CAN ICES-3(B) / NMB-3(B). Son fonctionnement est soumis aux deux conditions suivantes:
- cet appareil ne doit pas causer d'interférence
  - cet appareil doit accepter toute interférence, notamment les interférences qui peuvent affecter son fonctionnement

#### Informations concernant l'exposition aux fréquences radio (RF)

La puissance de sortie émise par l'appareil de sans-fil u-blox Cellular Module est inférieure à la limite d'exposition aux fréquences radio d'Innovation, Sciences et Développement économique Canada (ISDE). Utilisez l'appareil de sans-fil u-blox Cellular Module de façon à minimiser les contacts humains lors du fonctionnement normal.

Ce périphérique a été évalué et démontré conforme aux limites d'exposition aux fréquences radio (RF) d'IC lorsqu'il est installé dans des produits hôtes particuliers qui fonctionnent dans des conditions d'exposition à des appareils mobiles (les antennes se situent à plus de 20 centimètres du corps d'une personne).

Ce périphérique est homologué pour l'utilisation au Canada. Pour consulter l'entrée correspondant à l'appareil dans la liste d'équipement radio (REL - Radio Equipment List) d'Industrie Canada rendez-vous sur: <http://www.ic.gc.ca/app/sitt/relet/srch/nwRdSrch.do?lang=fra>

Pour des informations supplémentaires concernant l'exposition aux RF au Canada rendez-vous sur: <http://www.ic.gc.ca/eic/site/smt-gst.nsf/fra/sf08792.html>

- ⚠ IMPORTANT:** les fabricants d'applications portables contenant les modules de la SARA-R4 series doivent faire certifier leur produit final et déposer directement leur candidature pour une certification FCC ainsi que pour un certificat ISDE Canada délivré par l'organisme chargé de ce type d'appareil portable. Ceci est obligatoire afin d'être en accord avec les exigences SAR pour les appareils portables.
- Tout changement ou modification non expressément approuvé par la partie responsable de la certification peut annuler le droit d'utiliser l'équipement.


## 4.4 European Conformance CE mark


SARA-R410M-02B, SARA-R410M-83B, SARA-R412M, SARA-R422, SARA-R422S, SARA-R422M8S, and SARA-R422M10S radio modules product versions have been evaluated against the essential requirements of the Radio Equipment Directive 2014/53/EU.

In order to satisfy the essential requirements of the 2014/53/EU RED, the modules are compliant with the following standards:

- Radio Spectrum Efficiency (Article 3.2):
  - EN 301 511
  - EN 301 908-1
  - EN 301 908-13
  - EN 303 413
- Electromagnetic Compatibility (Article 3.1b):
  - EN 301 489-1
  - EN 301 489-19
  - EN 301 489-52
- Health and Safety (Article 3.1a)
  - EN 62368-1
  - EN 62311



 Radiofrequency radiation exposure Information: this equipment complies with radiation exposure limits prescribed for an uncontrolled environment for fixed and mobile use conditions. This equipment should be installed and operated with a minimum distance of 20 cm between the radiator and the body of the user or nearby persons. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter except as authorized in the certification of the product.

 The gain of the system antenna(s) used for SARA-R410M-02B, SARA-R410M-83B, SARA-R412M, SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules (i.e. the combined transmission line, connector, cable losses and radiating element gain) must not exceed the values reported in the Declaration of Conformity of the modules, for mobile and fixed or mobile operating configurations:

- SARA-R410M-02B modules:
  - 8.2 dBi in 800 MHz, i.e. LTE FDD-20 band uplink
  - 8.4 dBi in 900 MHz, i.e. LTE FDD-8 band uplink
  - 11.3 dBi in 1800 MHz, i.e. LTE FDD-3 band uplink
- SARA-R410M-83B modules:
  - 7.61 dBi in 700 MHz, i.e. LTE FDD-28 band uplink
  - 8.28 dBi in 800 MHz, i.e. LTE FDD-20 band uplink
  - 8.53 dBi in 900 MHz, i.e. LTE FDD-8 band uplink
  - 11.43 dBi in 1800 MHz, i.e. LTE FDD-3 band uplink
  - 11.90 dBi in 2100 MHz, i.e. LTE FDD-1 band uplink
- SARA-R412M modules:
  - 8.2 dBi in 800 MHz, i.e. LTE FDD-20 band uplink
  - 3.21 dBi in 900 MHz, i.e. GSM 900 / LTE FDD-8 band uplink
  - 9.09 dBi in 1800 MHz, i.e. GSM 1800 / LTE FDD-3 band uplink
- SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules:
  - 7.47 dBi in 700 MHz, i.e. LTE FDD-28 band uplink
  - 8.20 dBi in 800 MHz, i.e. LTE FDD-20 band uplink
  - 7.45 dBi in 900 MHz, i.e. GSM 900 / LTE FDD-8 band uplink
  - 11.33 dBi in 1800 MHz, i.e. GSM 1800 / LTE FDD-3 band uplink
  - 11.84 dBi in 2100 MHz, i.e. LTE FDD-1 band uplink


The conformity assessment procedure for the SARA-R410M-02B, SARA-R412M-02B, SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules, referred to in Article 17 and detailed in Annex II of Directive 2014/53/EU, has been followed.

Thus, the following marking is included in the product:







## 4.5 UK Conformity Assessed (UKCA)

 The United Kingdom is made up of the Great Britain (including England, Wales and Scotland) and the Northern Ireland. The Northern Ireland continues to accept the CE marking. Following notice is applicable to the Great Britain only.

SARA-R410M-02B, SARA-R410M-83B, SARA-R412M, SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S radio modules product versions have been evaluated against the essential requirements of the Radio Equipment Regulations 2017 (SI 2017 No. 1206, as amended by SI 2019 No. 696). To satisfy the essential requirements of the UK Legislation, the modules are compliant with the following standards:

- Radio Spectrum Efficiency (Article 6.2):
  - EN 301 511
  - EN 301 908-1
  - EN 301 908-13
  - EN 303 413
- Electromagnetic Compatibility (Article 6.1b):
  - EN 301 489-1
  - EN 301 489-19
  - EN 301 489-52
- Health and Safety (Article 6.1a)
  - EN 62368-1
  - EN 62311

 Radiofrequency radiation exposure information: this equipment complies with radiation exposure limits prescribed for an uncontrolled environment for fixed and mobile use conditions. This equipment should be installed and operated with a minimum distance of 20 cm between the radiator and the body of the user or nearby persons. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter except as authorized in the certification of the product.

 The gain of the system antenna(s) used for SARA-R410M-02B, SARA-R410M-83B, SARA-R412M, SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules (i.e. the combined transmission line, connector, cable losses and radiating element gain) must not exceed the values reported in the Declaration of Conformity of the modules, for mobile and fixed or mobile operating configurations

- SARA-R410M-02B modules:
  - 8.2 dBi in 800 MHz, i.e. LTE FDD-20 band uplink
  - 8.4 dBi in 900 MHz, i.e. LTE FDD-8 band uplink
  - 11.3 dBi in 1800 MHz, i.e. LTE FDD-3 band uplink
- SARA-R410M-83B modules:
  - 7.61 dBi in 700 MHz, i.e. LTE FDD-28 band uplink
  - 8.28 dBi in 800 MHz, i.e. LTE FDD-20 band uplink
  - 8.53 dBi in 900 MHz, i.e. LTE FDD-8 band uplink
  - 11.43 dBi in 1800 MHz, i.e. LTE FDD-3 band uplink
  - 11.90 dBi in 2100 MHz, i.e. LTE FDD-1 band uplink
- SARA-R412M modules:
  - 8.2 dBi in 800 MHz, i.e. LTE FDD-20 band uplink
  - 3.21 dBi in 900 MHz, i.e. GSM 900 / LTE FDD-8 band uplink
  - 9.09 dBi in 1800 MHz, i.e. GSM 1800 / LTE FDD-3 band uplink

- SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules:
  - 7.47 dBi in 700 MHz, i.e. LTE FDD-28 band uplink
  - 8.20 dBi in 800 MHz, i.e. LTE FDD-20 band uplink
  - 7.45 dBi in 900 MHz, i.e. GSM 900 / LTE FDD-8 band uplink
  - 11.33 dBi in 1800 MHz, i.e. GSM 1800 / LTE FDD-3 band uplink
  - 11.84 dBi in 2100 MHz, i.e. LTE FDD-1 band uplink

The conformity assessment procedure for the modules, referred to Part 3 of the Radio Equipment Regulations 2017, has been followed.

Guidance about using the UKCA marking: <https://www.gov.uk/guidance/using-the-ukca-marking>



## 4.6 National Communication Commission Taiwan

- NCC type approval number of the NCC model SARA-R410M, that is the u-blox SARA-R410M-02B product version: CCAA18NB0010T3



減少電磁波影響，請妥適使用。

電波功率密度 MPE 標準值：0.45 mW/cm<sup>2</sup>,

送測產品實測值：0.084 mW/cm<sup>2</sup>,

建議使用時設備天線至少距離人體 20 公分。

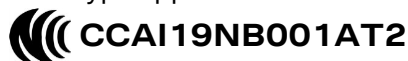
To reduce the influence of electromagnetic waves, please use it properly.

MPE limit value defined by the standard for radio wave power density: 0.45 mW/cm<sup>2</sup>,

Radio wave power density value measured on the product sent for testing: 0.084 mW/cm<sup>2</sup>,

It is advised to keep the device's antenna at least 20 cm away from human body when in use.

- NCC type approval number of SARA-R410M-83B modules: CCAI19NB001AT2



減少電磁波影響，請妥適使用。

電波功率密度 MPE 標準值：0.35 mW/cm<sup>2</sup>,

送測產品實測值：0.096 mW/cm<sup>2</sup>,




建議使用時設備天線至少距離人體 20 公分。

To reduce the influence of electromagnetic waves, please use it properly.

MPE limit value defined by the standard for radio wave power density: 0.35 mW/cm<sup>2</sup>,

Radio wave power density value measured on the product sent for testing: 0.096 mW/cm<sup>2</sup>,

It is advised to keep the device's antenna at least 20 cm away from human body when in use.

- SARA-R42 series modules “00B” product version:
  - NCC type approval number of SARA-R422M8S-00B modules: CCAI21Y00100T1  
 **CCAI21Y00100T1**
  - NCC type approval number of SARA-R422S-00B modules: CCAI21Y0010AT0  
 **CCAI21Y0010AT0**
  - NCC type approval number of SARA-R422-00B modules: CCAI21Y0010BT2  
 **CCAI21Y0010BT2**

減少電磁波影響，請妥適使用。




電波功率密度 MPE 標準值：0.35 mW/cm<sup>2</sup>,

送測產品實測值：0.122 mW/cm<sup>2</sup>,

建議使用時設備天線至少距離人體 20 公分。

To reduce the influence of electromagnetic waves, please use it properly.

MPE limit value defined by the standard for radio wave power density: 0.35 mW/cm<sup>2</sup>,  
 Radio wave power density value measured on the product sent for testing: 0.122 mW/cm<sup>2</sup>,  
 It is advised to keep the device's antenna at least 20 cm away from human body when in use.

- SARA-R42 series modules “01B” product version:
  - NCC type approval number of SARA-R422M10S-01B modules: CCAI21Y0010CT4  
 **CCAI21Y0010CT4**
  - NCC type approval number of SARA-R422S-01B modules: CCAI21Y0010AT0  
 **CCAI21Y0010AT0**
  - NCC type approval number of SARA-R422-01B modules: CCAI21Y0010BT2  
 **CCAI21Y0010BT2**

減少電磁波影響，請妥適使用。

電波功率密度 MPE 標準值：0.45 mW/cm<sup>2</sup>,

送測產品實測值：0.098 mW/cm<sup>2</sup>,

建議使用時設備天線至少距離人體 20 公分。

To reduce the influence of electromagnetic waves, please use it properly.

MPE limit value defined by the standard for radio wave power density: 0.45 mW/cm<sup>2</sup>,  
 Radio wave power density value measured on the product sent for testing: 0.098 mW/cm<sup>2</sup>,  
 It is advised to keep the device's antenna at least 20 cm away from human body when in use.

## 4.7 ANATEL Brazil

- SARA-R410M-02B modules  
ANATEL Certificate No. 07889-19-05903



Manufacturers of mobile or fixed devices incorporating the SARA-R410M-02B modules are authorized to use the ANATEL certificates of the modules for their own final products according to the conditions defined by ANATEL Brazil regulatory rules. If these conditions are met, the manufacturers of mobile or fixed devices incorporating the SARA-R410M-02B modules have to be aware that the following notice has to be included in the manual, or in the quick guide, or in a visible external label of the final product:

*“Incorpora produto homologado pela ANATEL sob número 07889-19-05903.  
Este equipamento não tem direito à proteção contra interferência prejudicial  
e não pode causar interferência em sistemas devidamente autorizados.  
Para mais informações, consulte o site da ANATEL [www.gov.br/anatel/pt-br](http://www.gov.br/anatel/pt-br)”*

- SARA-R412M-02B modules  
ANATEL Certificate No. 07927-19-05903



Manufacturers of mobile or fixed devices incorporating the SARA-R412M-02B modules are authorized to use the ANATEL certificates of the modules for their own final products according to the conditions defined by ANATEL Brazil regulatory rules. If these conditions are met, the manufacturers of mobile or fixed devices incorporating the SARA-R412M-02B modules have to be aware that the following notice has to be included in the manual, or in the quick guide, or in a visible external label of the final product:

*“Incorpora produto homologado pela ANATEL sob número 07927-19-05903.  
Este equipamento não tem direito à proteção contra interferência prejudicial  
e não pode causar interferência em sistemas devidamente autorizados.  
Para mais informações, consulte o site da ANATEL [www.gov.br/anatel/pt-br](http://www.gov.br/anatel/pt-br)”*

- SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S modules  
ANATEL Certificate No. 05377-21-05903





Manufacturers of mobile or fixed devices incorporating SARA-R422, SARA-R422S, SARA-R422M8S or SARA-R422M10S modules are authorized to use the ANATEL certificates of the modules for their own final products according to the conditions defined by ANATEL Brazil regulatory rules. If these conditions are met, manufacturers of mobile or fixed devices incorporating SARA-R422, SARA-R422S, SARA-R422M8S or SARA-R422M10S modules have to be aware that the following notice has to be included in the manual, or in the quick guide, or in a visible external label of the final product:

*“Incorpora produto homologado pela ANATEL sob número 05377-21-05903.  
Este equipamento não tem direito à proteção contra interferência prejudicial  
e não pode causar interferência em sistemas devidamente autorizados.  
Para mais informações, consulte o site da ANATEL [www.gov.br/anatel/pt-br](http://www.gov.br/anatel/pt-br)”*


## 4.8 Australian Conformance


The u-blox SARA-R410M-02B, SARA-R410M-83B, SARA-R412M-02B, SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules are compliant with the applicable standards made by the Australian Communications and Media Authority (ACMA).

The devices are “solder-down” modules (soldered to the PCB of the final product) and they do not have a stand-alone function. The devices are not within the scope of any RCM Labelling notice accordingly. The devices are excluded under Schedule 2 of the ACMA Telecommunications Labelling Notice 2015 and under Schedule 2 of the EMC Labelling Notice.

-  Responsibility for compliance with any ACMA RCM Labelling notice rests solely with the integrator of the u-blox modules.
-  The antenna used for the u-blox modules must not be closer than 20 cm to the nearest person, otherwise Specific Absorption Rate (SAR) evaluation is required to prevent possible RF exposure exceeding the limits defined by the Australian Radiation Protection and Nuclear Safety Agency – Radiation Protection Series 3 (ARPANSA-RSP3).

## 4.9 GITEKI Japan

- SARA-R410M-02B, SARA-R410M-63B  




|   |            |
|---|------------|
| T | D180083003 |
| R | 003-180155 |
- SARA-R422, SARA-R422S, SARA-R422M8S, SARA-R422M10S  


|   |            |
|---|------------|
| T | D210191003 |
| R | 003-210249 |

The gain of the system antenna used for the SARA-R410M-02B, SARA-R410M-63B, SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules must not exceed 3 dBi to comply with Japan Technical Standard Conformity Certification (GITEKI Certification) requirements.

Additionally, the antenna used in the end-device system for SARA-R410M-02B, SARA-R410M-63B, SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S modules have to be listed on the technology conformity certified Antenna list of the related module. Please contact u-blox for more information about how to add the antenna used in the end-device system into the Antenna list of the related module.

## 4.10 KC South Korea

- SARA-R410M-73B modules  
 R-C-ULX-SARA-R410
- SARA-R422-01B, SARA-R422S-01B, SARA-R422M10S  
 R-C-ULX-SARA-R422S-31B

## 5 Product testing

### 5.1 Validation testing and qualification

SARA-R4 series modules are validated and tested by u-blox in the operating conditions and in certain integration, but not all the specific characteristics of the host application end-product integrating the module can be validated and tested by u-blox.

SARA-R4 series modules are also qualified by u-blox according to u-blox reliability stress tests policy, but the specific characteristics of the host application end-product integrating the module cannot be qualified by u-blox.

Therefore, and to be on the safe side, u-blox recommends integrators of SARA-R4 series modules to validate, verify, qualify and test in details the host product integrating the SMD module considering all the possible aspects, to make sure that the specific characteristics of the host application do not lead to reduced / non-performance of SARA-R4 series modules.

Host product manufacturers are responsible to follow all the integration guidelines included in this manual, and to perform a set of verification testing to ensure the host end-product complies with applicable functional and/or conformity requirements.

Care has to be taken in the validation of the antennas RF circuits implemented in the host product for the module, as they may affect compliance with applicable RF conformity requirements.

The 50  $\Omega$  characteristic impedance of the antenna trace design on a host printed circuit board can be verified using a Vector Network Analyzer, as done on the u-blox host PCB, with calibrated RF coaxial cable soldered at the pad corresponding to RF input/output of the module and with the transmission line terminated to a 50  $\Omega$  load at the 50  $\Omega$  SMA female connector.


Compliance of the design with RF regulatory rules defined by the FCC, ISSED, RED, etc. can be verified using a radio communication tester (callbox) as the Rohde & Schwarz CMW500, or any equivalent equipment for multi-technology signaling conformance tests.

Care has to be taken in the validation of the VCC power supply circuit implemented in the host product for the module, as the specific characteristics of the power supply circuit may affect compliance with applicable functional and/or conformity requirements.

Adequateness of the power supply circuit capability can be checked by forcing the module to transmit at the maximum power level in the supported radio access technologies using a radio communication tester (callbox) as the Rohde & Schwarz CMW500 or any equivalent equipment.

Care has to be taken in the validation of the SIM interface circuit implemented in the host product for the module, checking in particular rise times of the signals, as the external circuit design may affect compliance with applicable functional and/or specification requirements.

Care has to be taken in the validation of any interface circuit connected to the module as implemented in the host product, checking in particular the power-on, power-off and reset circuits with also any related switch-on, switch-off and reset procedure, the communication interfaces (as UARTs, USB, I2C), and any other circuit designed in the host product in combination with any other interface of the module (as audio, GPIOs, etc.), as the external design implemented in the host product may affect compliance with applicable functional requirements.

 The validation, verification, qualification, and testing of the application host device integrating a SARA-R4 series module and the compliance of the application host device with all the applicable functional and/or conformity specifications and requirements are under the sole responsibility of the application host device manufacturer.



## 5.2 Production testing

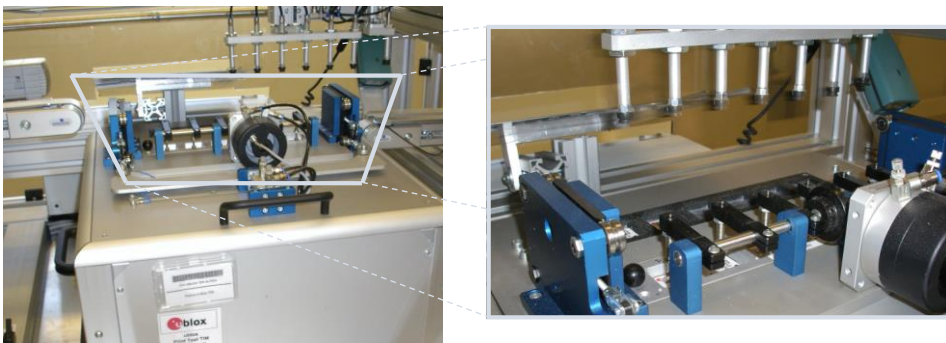
### 5.2.1 u-blox in-line production tests

u-blox focuses on high quality for its products. All units produced are tested automatically in all their interfaces along the production line. Stringent quality control processes have been implemented in the production line. Defective units are analyzed in detail to improve production quality.

This is achieved with automatic test equipment (ATE) in the production line, which logs all production and measurement data. A detailed test report for each unit can be generated from the system. The [Figure 73](#) illustrates the typical automatic test equipment (ATE) in a production line.

The following typical tests are among the production tests.

- Digital self-test (firmware download, flash firmware verification, IMEI programming)
- Measurement of voltages and currents
- Adjustment of ADC measurement interfaces
- Functional tests (serial interface communication, SIM card communication)
- Digital tests (GPIOs and other interfaces)
- Measurement and calibration of RF characteristics in all supported bands (such as receiver S/N verification, frequency tuning of the reference clock, calibration of transmitter and receiver power levels, etc.)
- Verification of the RF characteristics after calibration (i.e. modulation, power levels, spectrum, etc. are checked to ensure they are all within tolerances when calibration parameters are applied)



**Figure 73:** Automatic test equipment for module tests

### 5.2.2 Production test parameters for OEM manufacturers

Because of the testing done by u-blox (with 100% coverage), an OEM manufacturer does not need to repeat the firmware tests or measurements of the module RF performance or tests over analog and digital interfaces in their production test.

However, an OEM manufacturer should focus on:

- Module assembly on the device; it should be verified that:
  - The soldering and handling process did not damage the module components
  - All module pins are well soldered on the device board
  - There are no short circuits between pins
- Component assembly on the device; it should be verified that:
  - Communication with the host controller can be established
  - The interfaces between the module and device are working
  - The RF interfaces of the device including the antennas are working

Dedicated tests can be implemented to check the device. For example, the consumption measured in a specified status can help detect a short circuit if compared with a “Golden Device” result.


In addition, module AT commands can be used to perform functional tests on the digital interfaces. For example (for more details about AT commands, see the AT commands manual [2]):

- Communication with the host controller can be checked by AT command,
- Communication with the SIM card/chip can be checked using the dedicated +CPIN read command,
- Communication with external I2C devices can be checked using dedicated I2C AT commands,
- GPIO functionality can be checked using the dedicated +UGPIOC AT command, etc.

Please contact the u-blox office or sales representative nearest you for further guidelines about OEM production testing guidelines.

### 5.2.2.1 “Go/No go” production tests for integrated devices

A “Go/No go” test is typically used to compare the signal quality with a “Golden Device” in a location with excellent network coverage and known signal quality. This test should be performed after the data connection has been established. AT+CSQ is the typical AT command used to check signal quality in term of RSSI. See the AT command manual [2] for detail usage of the AT command.

 These kinds of test may be useful as a “go/no go” test but not for RF performance measurements.

This test is suitable to check the functionality of communications with the host controller, the SIM , and the power supply. It is also a means to verify if parts at the antenna interface are well-soldered.

### 5.2.2.2 Functional production tests providing GNSS RF operation

The best way to test the GNSS RF functionality is with the use of a Multi-GNSS signal generator, as it assures reliable and constant signals at every measurement.

u-blox recommends the Spirent GSS6300 Multi-GNSS signal generator ([www.spirent.com](http://www.spirent.com)).

Guidelines for GNSS RF functionality tests:

1. Connect a Multi-GNSS generator to the OEM product.
2. Choose the power level in a way that the “Golden Device” would report a C/No ratio of 38-40 dBHz.
3. Power up the DUT (Device Under Test) and allow enough time for the acquisition.
4. Read the C/No value from the NMEA GSV or the UBX-NAV-SVININFO message (e.g. with u-center).
5. Compare the results to a “Golden Device”.

### 5.2.2.3 Persistent configurations

The modules are delivered by u-blox with predefined factory-programmed settings that can be changed using AT commands according to application-specific requirements. Some settings are persistent, stored in the module’s non-volatile memory, and re-used at any subsequent reboot. Among these, for example, there are the UART interfaces’ baud rate, frame format, flow control, etc., the greeting text, the MNO profile, the APN for Internet connectivity, etc. (For more details, see the AT command manual [2]).


After verifying the proper assembly of the module and related parts on the application device, execute a persistent configuration setting phase in OEM production line, configuring the module according to the intended use in the specific application, as the persistent configurations are intended to be set only once and then re-used at any subsequent reboot.

During the persistent configuration setting phase, it is recommended to configure the baud rate, frame format, flow control and any other settings for the serial UART interfaces according to the use case. It is also recommended to configure the greeting text, the MNO profile and the APN for internet connectivity, etc.. For more details and guidelines regarding persistent configurations of user settings, see the SARA-R4 series application development guide [3][4].



# Appendix

## A Migration between SARA modules

 Detailed and updated guidelines to migrate between the u-blox SARA-G3, SARA-G4, SARA-U2, SARA-N2, SARA-N3, SARA-R4 and SARA-R5 series modules are available in the u-blox SARA modules migration guidelines application note [\[20\]](#).

## B Glossary


| Abbreviation | Definition   |
|--------------|--|
| 2G           | 2 <sup>nd</sup> Generation Cellular Technology (GSM, GPRS, EGPRS)                  |
| 3G           | 3 <sup>rd</sup> Generation Cellular Technology (UMTS, HSDPA, HSUPA)                |
| 3GPP         | 3 <sup>rd</sup> Generation Partnership Project                                     |
| ACMA         | Australian Communications and Media Authority                                      |
| ADC          | Analog to Digital Converter  |
| ANATEL       | Agência Nacional de Telecomunicações – National Telecommunications Agency (Brazil) |
| AT           | AT Command Interpreter Software Subsystem, or attention                            |
| BeiDou       | Chinese satellite navigation system  |
| BJT          | Bipolar Junction Transistor  |
| C/No         | Carrier to Noise ratio   |
| Cat          | Category   |
| CE           | European Conformity  |
| CSFB         | Circuit Switched Fall Back   |
| DC           | Direct Current   |
| DCE          | Data Communication Equipment   |
| DDC          | Display Data Channel interface   |
| DL           | Down-Link (Reception)  |
| DTE          | Data Terminal Equipment  |
| EDGE         | Enhanced Data rates for GSM Evolution (EGPRS)                                      |
| eDRX         | Extended Discontinuous Reception   |
| EGPRS        | Enhanced General Packet Radio Service (EDGE)                                       |
| EMC          | Electro-Magnetic Compatibility   |
| EMI          | Electro-Magnetic Interference  |
| ESD          | Electro-Static Discharge   |
| ESR          | Equivalent Series Resistance   |
| E-UTRA       | Evolved Universal Terrestrial Radio Access   |
| FCC          | Federal Communications Commission United States                                    |
| FDD          | Frequency Division Duplex  |
| FOAT         | Firmware Over AT commands  |
| FOTA         | Firmware Over The Air  |
| FTP          | File Transfer Protocol   |
| FW           | Firmware   |
| Galileo      | European satellite navigation system   |
| GCF          | Global Certification Forum   |

| Abbreviation | Definition   |
|--------------|--|
| GITEKI       | Gijutsu kijun tekigō shōmei – technical standard conformity certification (Japan)                  |
| GLONASS      | GLObal Navigation Satellite System (Russian satellite navigation system)                           |
| GMSK         | Gaussian Minimum-Shift Keying modulation   |
| GND          | Ground   |
| GNSS         | Global Navigation Satellite System   |
| GPIO         | General Purpose Input Output   |
| GPRS         | General Packet Radio Service   |
| GPS          | Global Positioning System  |
| HBM          | Human Body Model   |
| HTTP         | HyperText Transfer Protocol  |
| HW           | Hardware   |
| I2C          | Inter-Integrated Circuit interface   |
| I2S          | Inter IC Sound interface   |
| IFT          | Federal Telecommunications Institute Mexico  |
| ISED         | Innovation, Science and Economic Development Canada  |
| ITU-T        | International Telecommunication Union - Telecommunication Standardization Sector                   |
| KC           | Korean Certification   |
| LDO          | Low-Dropout  |
| LGA          | Land Grid Array  |
| LNA          | Low Noise Amplifier  |
| LPWA         | Low Power Wide Area  |
| LTE          | Long Term Evolution  |
| LWM2M        | Open Mobile Alliance Lightweight Machine-to-Machine protocol                                       |
| M2M          | Machine-to-Machine   |
| MNO          | Mobile Network Operator  |
| MOSFET       | Metal–Oxide–Semiconductor Field-Effect Transistor  |
| MQTT         | Message Queuing Telemetry Transport  |
| N/A          | Not Applicable   |
| NAS          | Non-Access Stratum   |
| NCC          | National Communications Commission Taiwan  |
| OEM          | Original Equipment Manufacturer device: an application device integrating a u-blox cellular module |
| OTA          | Over The Air   |
| PA           | Power Amplifier  |
| PCM          | Pulse Code Modulation  |
| PCN          | Product Change Notification / Sample Delivery Note / Information Note                              |
| PFM          | Pulse Frequency Modulation   |
| PICS         | Protocol Implementation Conformance Statement  |
| PSM          | Power Saving Mode  |
| PTCRB        | PCS Type Certification Review Board  |
| PWM          | Pulse Width Modulation   |
| QZSS         | Quasi-Zenith Satellite System  |
| RAT          | Radio Access Technology  |
| RCM          | Regulatory Compliance Mark   |
| RED          | Radio Equipment Directive  |
| RF           | Radio Frequency  |
| RSE          | Radiated Spurious Emission   |

| Abbreviation | Definition   |
|--------------|--|
| RSSI         | Received Signal Strength Indication                  |
| RSVD         | Reserved   |
| RTC          | Real Time Clock                                      |
| SAIF         | Sub-meter-class Augmentation with Integrity Function |
| SAW          | Surface Acoustic Wave                                |
| SBAS         | Satellite-Based Augmentation System                  |
| SDIO         | Secure Digital Input Output                          |
| SI           | Statutory Instruments (United Kingdom)               |
| SIM          | Subscriber Identification Module                     |
| SMA          | Sub-Miniature version A                              |
| SMD          | Surface Mounting Device                              |
| SMS          | Short Message Service                                |
| SPI          | Serial Peripheral Interface                          |
| SRF          | Self-Resonant Frequency                              |
| SSL          | Secure Socket Layer                                  |
| TBD          | To Be Defined  |
| TCP          | Transmission Control Protocol                        |
| TDD          | Time Division Duplex                                 |
| TDMA         | Time Division Multiple Access                        |
| TIS          | Total Isotropic Sensitivity                          |
| TP           | Test-Point   |
| TRP          | Total Radiated Power                                 |
| UART         | Universal Asynchronous Receiver-Transmitter          |
| UDP          | User Datagram Protocol                               |
| UE           | User Equipment                                       |
| UICC         | Universal Integrated Circuit Card                    |
| UKCA         | United Kingdom Conformity Assessed                   |
| UL           | Up-Link (Transmission)                               |
| UMTS         | Universal Mobile Telecommunications System           |
| US           | United States  |
| USB          | Universal Serial Bus                                 |
| VoLTE        | Voice over LTE                                       |
| VSWR         | Voltage Standing Wave Ratio                          |

## Related documentation

- [1] u-blox SARA-R4 series data sheet, [UBX-16024152](#)
- [2] u-blox SARA-R4 series AT commands Manual, [UBX-17003787](#)
- [3] u-blox SARA-R41 series application development guide application note, [UBX-18019856](#)
- [4] u-blox SARA-R42 series application development guide application note, [UBX-20050829](#)
- [5] u-blox EVK-R4 user guide, [UBX-16029216](#)
- [6] Universal Serial Bus revision 2.0 specification, <https://www.usb.org/>
- [7] ITU-T Recommendation V.24 – 02-2000 – List of definitions for interchange circuits between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE), <http://www.itu.int/rec/T-REC-V.24-200002-I/en>
- [8] 3GPP TS 27.007 – AT command set for User Equipment (UE)
- [9] 3GPP TS 27.005 – Use of Data Terminal Equipment – Data Circuit terminating; Equipment (DTE – DCE) interface for Short Message Service (SMS) and Cell Broadcast Service (CBS)
- [10] 3GPP TS 27.010 – Terminal Equipment to User Equipment (TE-UE) multiplexer protocol
- [11] I2C-bus specification and user manual – UM10204 – NXP semiconductors, <https://www.nxp.com/docs/en/user-guide/UM10204.pdf>
- [12] GSM Association TS.09 – Battery Life Measurement and Current Consumption Technique, <https://www.gsma.com/newsroom/wp-content/uploads/TS.09-v12.pdf>
- [13] 3GPP TS 51.010-1 – Mobile Station conformance specification; part 1: conformance specification
- [14] 3GPP TS 51.010-2 – Technical Specification Group GSM/EDGE Radio Access Network; Mobile Station (MS) conformance specification; part 2: Protocol Implementation Conformance Statement (PICS)
- [15] 3GPP TS 36.521-1 – Evolved Universal Terrestrial Radio Access; User Equipment conformance specification; Radio transmission and reception; part 1: conformance testing
- [16] 3GPP TS 36.521-2 – Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment conformance specification; Radio transmission and reception; Part 2: Implementation Conformance Statement (ICS)
- [17] 3GPP TS 36.523-2 – Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); User Equipment conformance specification; Part 2: Implementation Conformance Statement (ICS)
- [18] u-blox end user test application note, [UBX-13001922](#)
- [19] u-blox package information user guide, [UBX-14001652](#)
- [20] u-blox SARA modules migration guidelines application note, [UBX-19045981](#)
- [21] u-blox SARA-R4 / SARA-R5 positioning implementation application note, [UBX-20012413](#)
- [22] u-blox GNSS antennas application note, [UBX-15030289](#)
- [23] u-blox B36 vehicle tracking blueprint product summary, [UBX-20012630](#)

 For regular updates to u-blox documentation and to receive product change notifications, register on our homepage ([www.u-blox.com](http://www.u-blox.com)).

# Revision history

| Revision | Date        | Name        | Comments   |
|----------|-------------|-------------|--|
| R01      | 31-Jan-2017 | sfal        | Initial release  |
| R02      | 05-May-2017 | sfal / sses | Updated supported features and characteristics<br>Extended document applicability to SARA-R410M-01B product version  |
| R03      | 24-May-2017 | sses        | Updated supported features and electrical characteristics  |
| R04      | 19-Jul-2017 | sses        | Updated supported features and electrical characteristics<br>Added FCC and ISED info for SARA-R410M-01B modules<br>Extended document applicability to SARA-R410M-02B product version   |
| R05      | 17-Aug-2017 | sses        | Updated supported features for "02B" product version   |
| R06      | 30-Oct-2017 | sses        | Updated supported features for "02B" product version   |
| R07      | 04-Jan-2018 | sses        | Updated SARA-R410M-02B product status<br>Updated USB, Power Saving and GPIO features description; Improved Power-on sequence guidelines description; Added I2C design guidelines description   |
| R08      | 26-Feb-2018 | sses        | Updated SARA-R410M-02B product status<br>Extended document applicability to SARA-R412M-02B product version<br>Corrected power-on sequence description and UART MUX description   |
| R09      | 10-Aug-2018 | sses        | Extended document applicability to SARA-R410M-52B and SARA-N410-02B<br>Updated SARA-R410M-02B and SARA-R412M-02B product status; Updated features support plan for product versions; Clarified supported bands; Updated UART TXD and CTS info; Updated Approvals info and related remarks; Added description of AT Inactivity Timer to enter power saving mode |
| R10      | 20-Sep-2018 | lpah / sses | Extended document applicability to SARA-R404M-00B-01 type number<br>Clarified mode supported in frequency bands<br>Added further guidelines for VCC and Antenna circuits design  |
| R11      | 20-Feb-2019 | sses        | Updated SARA-N410-02B and SARA-R412M-02B product status<br>Revised supported bands; Updated certification info; Clarified VCC and RESET_N guidelines; Other minor corrections.   |
| R12      | 14-Jun-2019 | sses        | Extended document applicability to the SARA-R410M-02B-01, SARA-R410M-52B-01 and SARA-R412M-02B-01 product versions.<br>Revised product description, approvals and other info according to extension of document applicability. Other minor corrections.  |
| R13      | 30-Sep-2019 | sses        | Extended document applicability to the SARA-R410M-03B, the SARA-R410M-63B, the SARA-R410M-73B, and the SARA-R412M-03B product versions.<br>Revised product description, approvals and other info according to extension of document applicability.<br>Updated product status of SARA-R410M-02B, SARA-R410M-52B, SARA-N410-02B<br>Other minor corrections.      |
| R14      | 23-Dec-2019 | sses        | Removed document applicability of product versions the SARA-R410M-03B and the SARA-R412M-03B.<br>Updated product status of SARA-R410M-63B. Other minor corrections.  |
| R15      | 12-Jun-2020 | sses        | Extended document applicability to SARA-R410M-83B product version.<br>Updated product status of SARA-R410M-63B, SARA-R410M-73B.<br>Added Brazil and Australia regulatory conformance sections.<br>Other minor corrections.   |
| R16      | 28-Aug-2020 | sses        | Extended document applicability to SARA-R410M-02B-02, SARA-R410M-52B-02, and SARA-R412M-02B-02 product versions  |
| R17      | 11-Nov-2020 | sses        | Extended document applicability to SARA-R410M-73B-01, SARA-R410M-83B-01  |
| R18      | 09-Dec-2020 | sses        | Extended document applicability to SARA-R410M-63B-01   |
| R19      | 23-Feb-2021 | sses        | Extended document applicability to SARA-R410M-02B-03, SARA-R412M-02B-03  |

| Revision | Date        | Name | Comments  |
|----------|-------------|------|---|
| R20      | 02-Apr-2021 | sses | Extended document applicability to SARA-R422-00B, SARA-R422M8S-00B, SARA-R422S-00B<br>Minor other corrections and clarifications.   |
| R21      | 07-Jul-2021 | sses | Updated product status of SARA-R422-00B, SARA-R422M8S-00B, SARA-R422S-00B.<br>Extended info in power-off and approvals sections.<br>Minor other corrections and clarifications.         |
| R22      | 22-Feb-2022 | sses | Extended document applicability to SARA-R410M-73B-02 product version.<br>Updated SARA-R410M-02B-03, SARA-R412M-02B-03 product status.<br>Editorial changes and clarifications made.     |
| R23      | 27-Apr-2022 | sses | Extended document applicability to SARA-R410M-02B-04 and SARA-R412M-02B-04, product versions.<br>Minor other corrections and clarifications.  |
| R24      | 24-May-2022 | sses | Extended document applicability to the SARA-R422-01B, SARA-R422S-01B and SARA-R422M10S-01B product versions.<br>Some editorial changes made, other minor clarifications and info added. |
| R25      | 27-Jun-2022 | sses | Updated status of SARA-R410M-83B, SARA-R422, SARA-R422S, SARA-R422M8S and SARA-R422M10S products.<br>Clarified reserved pin description. Other clarifications and minor corrections.    |
| R26      | 25-Nov-2022 | sses | Updated status of SARA-R422-01B, SARA-R422S-01B, and SARA-R422M10S-01B products.<br>Updated approvals sections. Other clarifications and minor corrections.                             |
| R27      | 21-Dec-2022 | yatu | Updated product status of SARA-R410M-63B and SARA-R410M-73B   |

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