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NINA-B50 series

Stand-alone Bluetooth 5.3 low energy modules

System integration manual

Abstract

Targeted towards hardware and software engineers, this document describes how to integrate NINA-B50 series stand-alone Bluetooth® 5.3 Low energy module in an application product. It explains the hardware design-in, software, component handling, regulatory compliance, and testing of the modules. It also lists the external antennas approved for use with the module.

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This document applies to the following products:

Product name	**Document status**
NINA-B501	Early production information
NINA-B506	Early production information

☞ For information about the related hardware, software, and status of listed product types, see also the NINA-B50 data sheet [2].

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1 Product overview

Built on the NXP K32W1480 chip [4] for professional applications and NXP KW45 chip [6] for automotive applications, NINA-B50 series modules feature Bluetooth 5.3 LE connectivity and a robust multicore MCU with and Arm® Cortex®-M33 with Floating Point Unit (FPU) as the application core.

NINA-B50 module series offer cutting-edge power performance and also incorporates state-of-the-art security features through the Arm TrustZone-M® secure storage and EdgeLock® Secure Enclave, including hardware cryptographic accelerators, random number generators, secure key generation, storage and management, secure boot and secure debug.

For professional applications, NINA-B50 supports IEEE 802.15.4 including Thread®, Matter™, and Zigbee™. For automotive applications, NINA-B50 supports FlexCAN and LIN bus. As the module design of NINA-B50 is common with other modules following the NINA form factor, NINA-B50 offers flexibility for similar product variants when designing the host platform.

1.1 Module architecture

NINA-B50 series modules integrate internal power management circuitry that requires only a single supply voltage in the range of 1.71–3.60 V. This wide supply range also enhances the suitability of the modules in battery powered systems.

Select the module variant that best suits your application design: NINA-B501 which can be used with an arbitrary external antenna, or NINA-B506 which comes equipped with its own internal antenna.

Table 1 describes the available NINA-B50 series module variants.

Ordering code	Product
NINA-B501-00A	NINA-B50 automotive grade module with Bluetooth Low Energy and CAN and LIN interface. Equipped with an antenna pin for external antenna and open CPU for custom applications.
NINA-B506-00A	NINA-B50 automotive grade module with Bluetooth Low Energy and CAN and LIN interface. Includes an internal PCB trace antenna and open CPU for custom applications.
NINA-B501-00B	NINA-B50 professional grade module with Bluetooth Low Energy and 802.15.4. Includes an antenna pin for external antenna and an open CPU architecture for custom applications.
NINA-B506-00B	NINA-B50 professional grade module with Low Energy and 802.15.4. Equipped with an internal PCB trace antenna and open CPU for custom applications.

Table 1: Supported configurations of the NINA-B50 module series

☞ Already globally certified for use with an internal antenna or range of external antennas, the time, cost, and effort required to deploy NINA-B50 modules into customer applications is significantly reduced.

2 Module integration

NINA-B50 series modules come in a stand-alone (host-less), open CPU configuration that allows customer applications to run on the module itself – without any need for a supporting host MCU. The module supports Bluetooth® 5.3 Low Energy (LE) and 802.15.4 with Thread®, Matter™ and Zigbee™. NINA-B50 series modules support a wide range of IO interfaces, such as GPIO, UART, SPI, I3C, I2C, PWM, and QDEC.

Figure 1 shows a typical integration in which NINA-B50 is configured as a host.

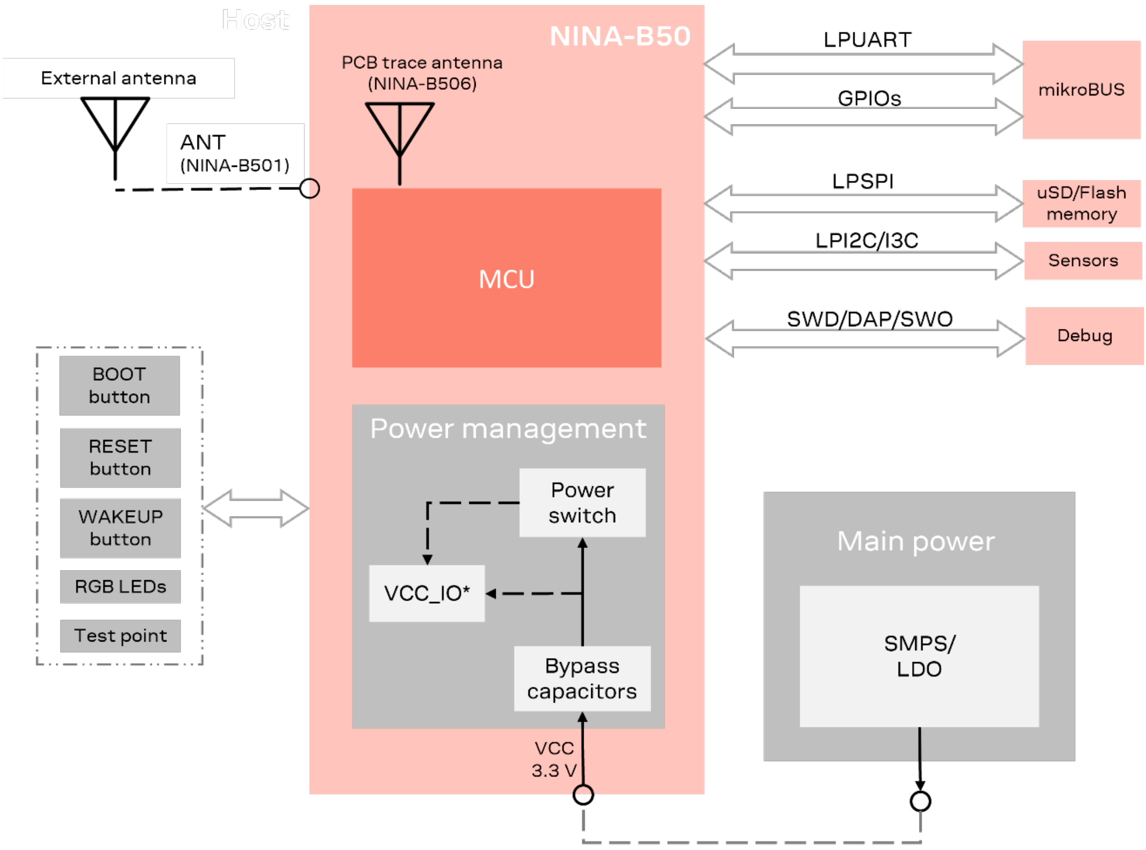


Figure 1: Example of NINA-B50 integrated as a host

Figure 2 shows how to control NINA-B50 series modules through a host CPU and interface connections.

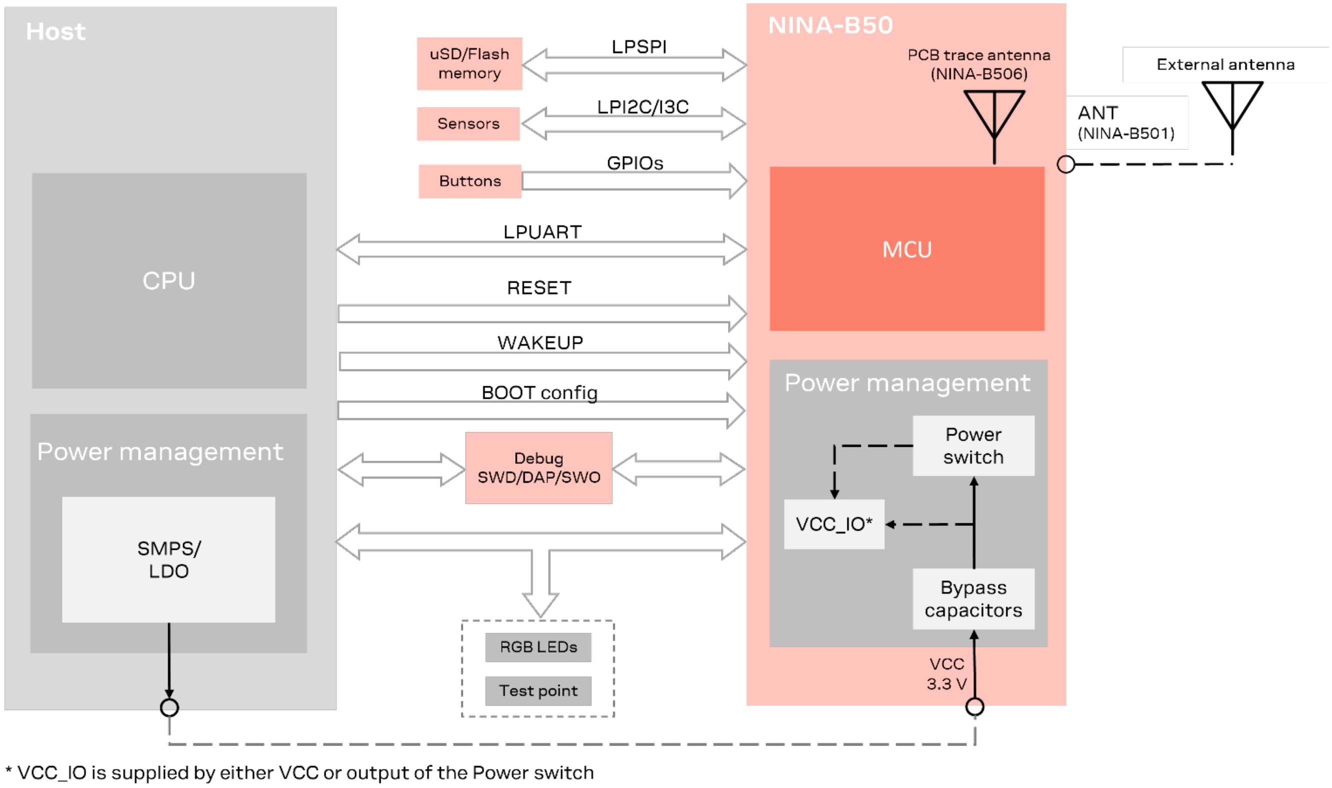


Figure 2: Example of NINA-B50 integration in a host system with external CPU

With NINA-B50, application designs are simplified. Developers can either connect an external antenna via the antenna pin on NINA-B501 or utilize the internal antenna on NINA-B506. The footprint compatibility with other NINA modules ensures that NINA-B50 series modules offer maximum flexibility for developing similar devices with various radio technologies.

2.1 Power Supply

2.1.1 Power switch

The power switch input supply **VCC** must be supplied permanently to support the standby RAM LDO and RAM power switch. The power switch output, **VOUT_SWITCH,** is configurable as either enabled or disabled.

The power switch can be turned on using:

- The Power-On-Reset (POR) of the power switch input supply **VCC**
- External **SWITCH_WAKEUP** (pin 45) – driven low to turn on the power switch
- Internal wakeup logic from SPC – when **VSYS** is powered ON

2.1.2 VCC application circuits

The power for NINA-B50 series modules is applied through the **VCC** pins. These supplies are taken from either of the following sources:

- Switching Mode Power Supply (SMPS)
- Low Drop Out (LDO) regulator

An SMPS is the ideal design choice when the available primary supply source is significantly higher than the operating supply voltage of the module. This offers the best power efficiency for the application design and minimizes the amount of current drawn from the main supply source.

⚠ When taking VCC supplies from an SMPS, make sure that the AC ripple voltage is kept as low as possible at the switching frequency. Design layouts should focus on minimizing the impact of any high-frequency ringing.

Use an LDO linear regulator for primary VCC supplies that have a relatively low voltage. As LDO regulators dissipate power linearly related to the step-down voltage, LDOs are not recommended for the step down of high voltages.

DC/DC efficiency should be regarded as a trade-off between the active and idle duty cycles of an application. Although some DC/DC devices achieve high efficiency at light loads, these efficiencies typically degrade as soon as the idle current drops below a few milliamps. This can have a negative impact on the life of the battery.

If decoupling capacitors are needed on the supply rails, it is best practice to position these as close as possible to the NINA-B50 series module. The power routing of some host system designs makes decoupling capacitance unnecessary.

For electrical specifications, see NINA-B50 series data sheet [2].

2.1.3 Power supply configuration

NINA-B50 series modules support two power supply configurations that determine how the power switch is applied:

- Power efficient configuration
- Power switch configuration

☞ A voltage level less than 3 V on **VCC** and **VCC_IO** has an adverse effect on Tx output power.

☞ The on-module power switch can be disabled when it is not used. This means that the **VOUT_SWITCH** pin can be left floating.

2.1.3.1 Power efficient configuration

In Power efficient configuration:

- **VCC** is supplied by an eternal power
- **VCC_IO** is supplied from **VCC**
- VDD_LDO_CORE and VDD_RF are supplied from the DCDC output, VDCDC_OUT
- VPA is supplied from VDD_RF

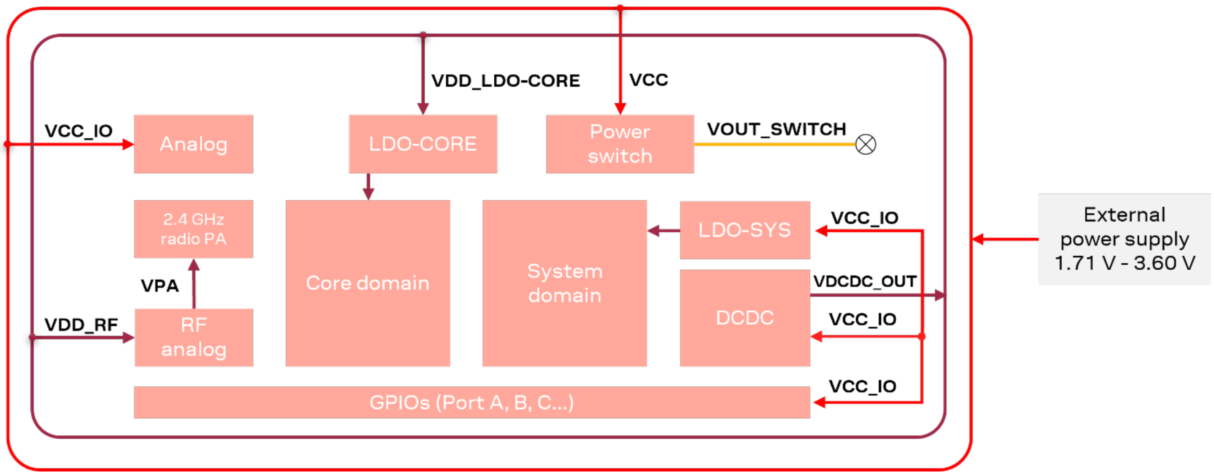


Figure 3: Power efficient configuration

2.1.3.2 Power switch configuration

In Power switch configuration:

- **VCC** is supplied by an eternal power
- **VCC_IO** is supplied by the power switch output **VOUT_SWITCH**
- VDD_LDO_CORE and VDD_RF are supplied from the DCDC output, VDCDC_OUT
- VPA is supplied from VDD_RF

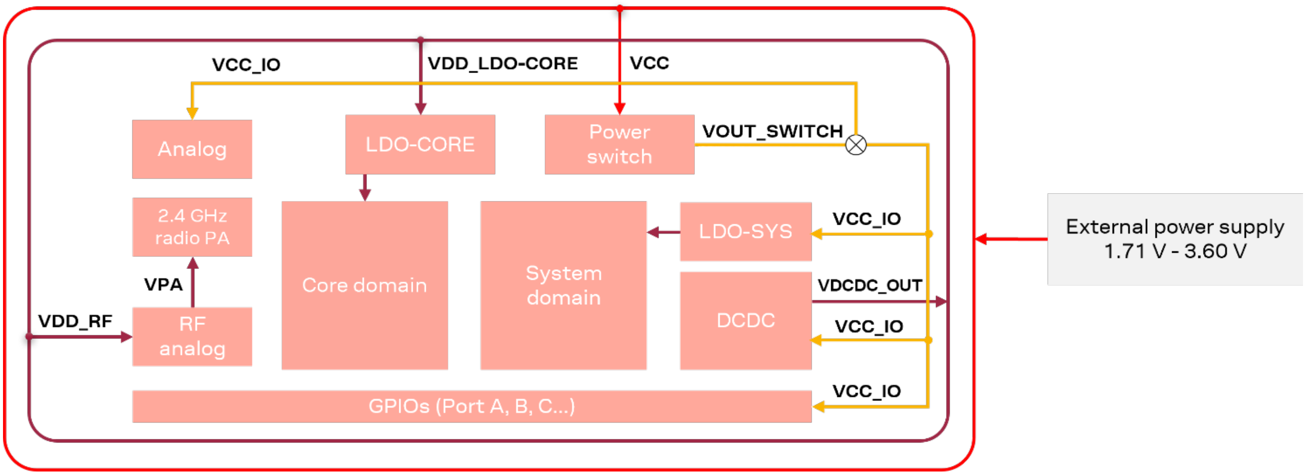


Figure 4: Power switch configuration

2.1.4 Battery

The low current consumption and wide voltage range of NINA-B50 series modules means that a battery can be used as a main supply. In which case, the capacity of the battery must be selected to match the application. Ensure that the battery can deliver the peak current required by the module.

Figure 5 shows recommended circuit to connect Battery with module's power rail.

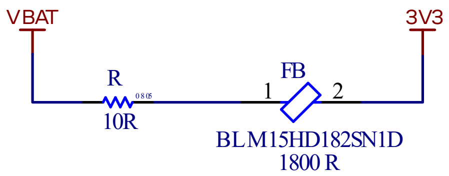


Figure 5: Example of battery connection

⚠ A voltage level less than 3 V on **VCC** and **VCC_IO** has negative impact on Tx output power.

☞ A series resistor 10R added to minimize the risk of current peaks.

For further information about current consumption and other performance data, see also the electrical specifications in the NINA-B50 series data sheet [2].

It is best practice to include bypass capacitors on the supply rails close to the NINA-B50 series module. Depending on the design of the power routing on the host system, capacitance might not be needed.

2.2 System functions

2.2.1 Power modes

NINA-B50 series modules support following power modes:

- Active
- Sleep
- Deep sleep
- Power down
- Deep power down

For detailed description of each power mode, see also the NINA-B50 data sheet [2].

2.2.2 Module reset

NINA-B50 series module is reset / rebooted through the **RESET_N** pin:

- **RESET_N** has an internal pull-up resistor that sets its default state to high. Setting the pin low triggers a "hardware reset" of the module.
- **RESET_N** should be driven by either an open-drain or open-collector output or a contact switch.

NINA-B50 series modules can also be reset using other methods. For more information, see also NINA-B50 data sheet [2].

2.2.3 Real Time Clock (RTC)

NINA-B50 series modules use a 32.768 kHz low power clock to enable different sleep modes.

The Real Time Clock (RTC) can be generated from either of the following sources:

- Internal 32 kHz FRO
- External crystal or clock source

You can source the clock from an external 32 kHz Crystal Oscillator (OSC) or from the embedded 32 kHz Free Running Oscillator (FRO). The RTC block includes an internal clock validation mechanism to verify the stability of the clock from OSC. It also features a clock switch that enables the module to transition from the 32 kHz FRO to OSC when the OSC clock is stable. If the software disables the 32 kHz OSC, the module can revert to the 32 kHz FRO clock.

To achieve the lowest sleep current consumption in the module, use an external crystal or external clock source. Although the 32 kHz FRO consumes slightly more sleep current, it provides a leaner Bill of Materials (BOM).

The RTC functions in all low power modes and can generate an interrupt to exit any low power mode. See also Power Modes. The module operates in one of two modes:

- **Power-on mode:** RTC remains powered during module power-up and all RTC registers are accessible by software and all functions are operational. If enabled, the 32.768 kHz clock can be supplied to the rest of the module.
- **Power-down mode:** During module power-down, RTC is powered and is electrically isolated from the rest of the chip but continues to increment the time counter (if enabled) and retain the state of the RTC registers. The RTC registers are not accessible. The time counter can generate multiple interrupts and events to the CPU and radio as well as internal and external hardware blocks. The frequency of the interrupt is 1 Hz by default but can also be configured to trigger every 2, 4, 8, 16, 32, 64, or 128 Hz.

☞ For RTC pinout information, see also NINA-B50 data sheet [2].

2.2.3.1 32 kHz FRO – Internal oscillator

Sourcing the module clock from the embedded 32 kHz FRO can lead to a slight increase in power consumption. However, this choice of oscillator offers a more cost-effective BOM that reduces the cost to end users.

If the module clock is sourced from the FRO, pins **EXTAL32K** and **XTAL32K** can be reassigned as GPIOs.

The 32 kHz FRO is enabled after Power-On-Reset (POR) and can be disabled by software only if external crystal is connected. For more information, see also NINA-B50 data sheet [2].

2.2.3.2 External crystal

NINA-B50 series modules NINA-B50 supports two input pins for connecting an optional external low-frequency crystal (LFXO) as the RTC source. In this configuration, the module operates with the lowest overall power consumption. The specification for the optional low-frequency crystal is available in the NINA-B50 series data sheet [2].

Table 2 describes the specification of the crystal used on EVK-NINA-B506. Note that the 32 kHz crystal is not mounted on EVK-NINA-B501.

Component	Value	Note
Crystal	32.768 kHz – 20 ppm	EPSON FC-12M used on NINA-B50 EVK

Table 2: Specification of the low-frequency crystal used on the NINA-B506 EVK evaluation kit

2.3 Antenna integration

Antenna interfaces vary for each module variant in the NINA-B50 series. The modules support either an internal antenna (NINA-B506) or external antennas connected through a dedicated antenna pin (NINA-B501).

2.3.1 Antenna solutions

NINA-B50 series modules support three different antenna solutions:

- NINA-B501 includes an antenna pin that connects to an external antenna to the NINA-B501 module. The antenna can be either:
  - An antenna external to the end product – typically used in end products with a metal enclosure.
  - An antenna external to the NINA-B501 module but internal to the end product. Examples of this include a chip antenna on the host PCB or a flex film antenna.
- NINA-B506 is equipped with an internal PCB trace antenna that is custom-designed and optimized for the module. With this configuration, there's no requirement for an RF trace design on the host PCB – which means less effort during the host PCB design and testing in the lab.

Figure 6 provides a summary of all the available antenna options.

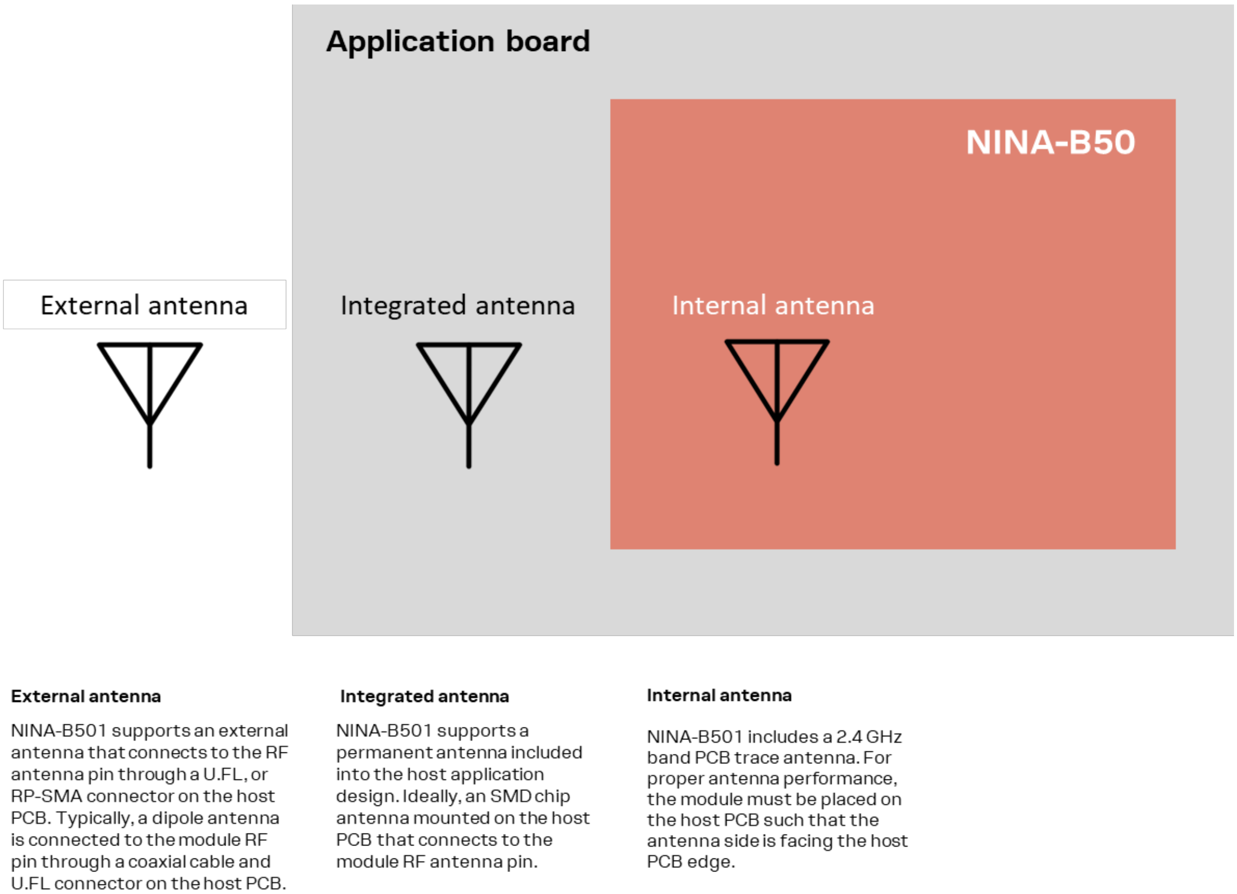


Figure 6: Antenna options

2.3.2 Approved antenna designs

NINA-B50 series modules come with a pre-certified design that can significantly reduce costs and save time during the certification process. To leverage this benefit, customers must implement an antenna layout that fully complies with the u-blox reference design outlined in Appendix B: Antenna reference designs and in the Reference design source files – available from u-blox on request.[1]

Designers integrating a u-blox reference design into an end-product assumes sole responsibility for any unintentional emission levels produced by the end product.

[1] Reference design files are made available only after certification

For Bluetooth operation, NINA-B50 series modules have been tested and approved for use with the antennas listed in the Pre-approved antennas list.

⚠ To ensure that the compliance and pre-certification of u-blox modules with the various regulatory bodies remains valid, use only the external antennas listed in the Pre-approved antennas list. Reference design source files are available from u-blox on request.

⚠ If the module is integrated with other antennas, the OEM installer must certify the design with respective regulatory agencies.

2.4 Data interfaces

2.4.1 Low Power Universal Asynchronous Receiver/Transmitter (LPUART)

NINA-B50 series modules support two LPUART interfaces, **LPUART0** and **LPUART1**, for data communication and firmware upgrade. The LPUART can continue operating while the processor is in low-power mode if an appropriate peripheral clock is available.

Each UART supports the following signals:

- Data lines (**RXD** as input, **TXD** as output)
- Hardware flow control lines (**CTS** as input, **RTS** as output)

Both UARTs can be used in 4-wire mode with hardware flow control, or in 2-wire mode with **TXD** and **RXD** only.

☞ 2-wire mode is not recommended as it is prone to buffer overruns.

The UART interface is also used for firmware upgrade. See also Open CPU software.

It is advisable to connect **LPUART0** to a header for firmware upgrade or make the interface signals accessible as test points.

The IO level of the UARTs follows **VCC_IO**.

2.4.2 Low Power Serial peripheral interface (LPSPI)

NINA-B50 supports two Low-power Serial Peripheral Interface (LPSPI) interfaces, **LPSPI0** and **LPSPI1**.

Main and Sub node operations are possible on both interfaces. When configured in **MAIN** mode, both the interfaces support up to four peripheral chip selects each.

The LPSPI interfaces use the following signals:

Signal name	Description
LPSPIx_SCK	Serial clock output, up to 24 MHz
LPSPIx_SIN	MISO serial input data/ Data 1 I/O signal
LPSPIx_SOUT	MOSI serial output data/ Data 0 I/O signal
LPSPIx_PCS2	Data 2 I/O signal
LPSPIx_PCS3	Data 3 I/O signal
LPSPIx_PCS0	Chip/Sub node select output, active low, selects which Sub node to communicate with over the bus

Table 3: LPSPI signals in Main mode

☞ For an external storage example and pin assignment information, see also the NINA-B50 data sheet [2].

2.4.3 Low Power Inter-Integrated Circuit (LPI2C)

NINA-B50 series modules have two instances of the LPI2C module, **LPI2C0**, and **LPI2C1**.

The LPI2C interfaces can operate as both Controller and Target devices on the I2C bus and support standard-mode (100 kbps), fast-mode (400 kbps), fast-mode plus (1 Mbps) and ultra-fast mode (3.2/3.33 Mbps) operation.

The interface uses the **SCL** signal to clock instructions and data on the **SDA** signal.

- I2C 2-wire pin configuration:
  - SCL - Clock output in Controller device and input in Target device
  - SDA - Data input/output pin
- I2C 4-wire pin configuration:
  - SCL - Clock input pin
  - SDA - Data input pin
  - SCLS - Secondary clock, line-output pin on the Controller device. If LPI2C Controller/Target devices are configured to use separate pins, then this is the LPI2C SCL pin for the Controller device.
  - SDAS - Secondary data, line-output pin on the Controller device. If LPI2C Controller/Target devices are configured to use separate pins, then this is the LPI2C SDA pin for Controller device.

2.4.4 Improved Inter-Integrated Circuit (I3C)

NINA-B50 supports a single Improved Inter-Integrated Circuit (I3C) interface, **I3C0**. The I3C bus is designed to support future sensor interface architectures in Internet-of-Things applications. To operate in the I3C mode, PV (pull value), PE (pull enable) and PS (pull select) in the corresponding **PORT_PCR** registers should be correctly configured to support I3C pull-up resistor control in advance.

Up to 11 devices can be connected on I3C interface.

2.4.5 Inter-IC Sound interface (I2S)

- Pin configuration:
  - MCK, Central clock
  - LRCK, Left Right/Word/Sample clock
  - SCK, Serial clock
  - SDIN, Serial data in
  - SDOUT, Serial data out

An I2S interface always provides the LRCK and SCK clock signals in the Central device, but some Central devices can't generate an MCK clock signal. NINA-B50 can supply a MCK clock signal to both external Central and Peripheral systems that can't generate their own clock signal. The two data signals, SDIN and SDOUT, allow for simultaneous bi-directional audio streaming. The interface supports 8, 16, and 24-bit sample widths with up to 48 kHz sample rate.

2.4.6 FlexCAN

The FlexCAN interface on the NINA-B50 automotive grade modules is a full implementation of the CAN protocol specification, the CAN with Flexible Data Rate (CAN FD) protocol, and the CAN 2.0 version B protocol, which supports both standard and extended message frames and long payloads.

Figure 7 shows a basic implementation of CAN interface. A CAN transceiver is required to communicate with CAN-compatible devices over CAN interface pins of NINA-B50 automotive grade modules.

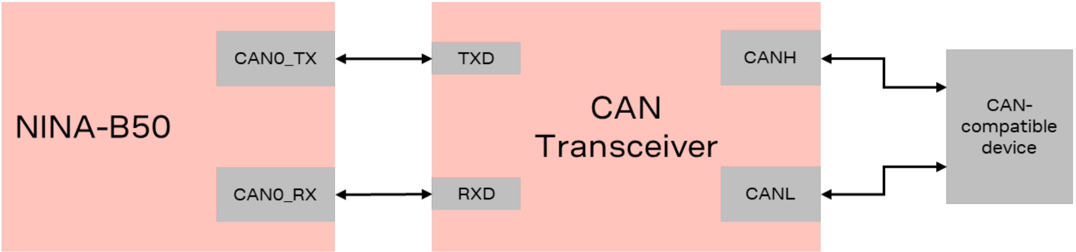


Figure 7: FlexCAN implementation

☞ FlexCAN is supported only on the NINA-B50 automotive grade modules.

2.4.7 LIN

The single-wire LIN bus is a communication standard to complement high-end automotive buses, like CAN, with lower-cost solutions where less performance suffices.

Figure 8 shows a basic implementation of LIN interface. A LIN transceiver is required to communicate with LIN bus line over one of the two LPUART interfaces in NINA-B50 automotive grade modules.

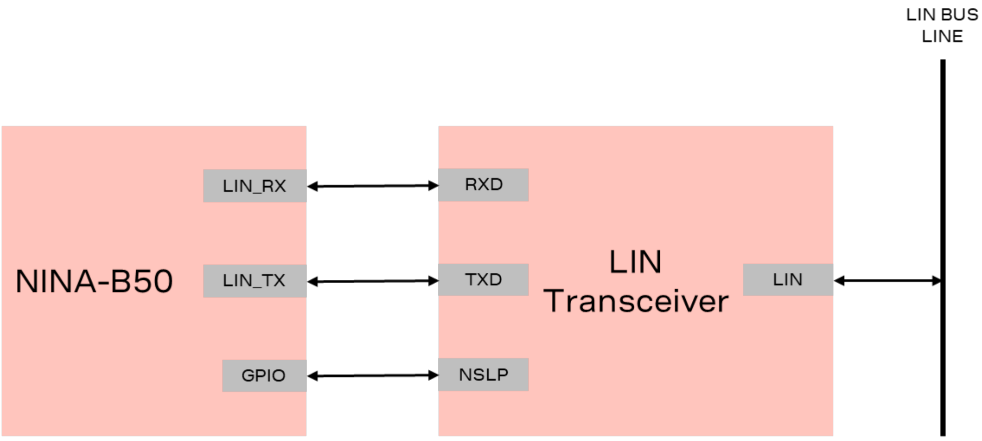


Figure 8: LIN implementation

☞ LIN is supported only on the NINA-B50 automotive grade module.

2.5 Other Digital interfaces

2.5.1 Timer/ PWM Module (TPM)

NINA-B50 modules support three Pulse Width Modulation timers, TPM0, TPM1 and TPM2. TPM0 is a 2-channel 32-bit timer and TPM1 and TPM2 are 6-channel 32-bit timers.

The counter, compare, and capture registers are clocked by an asynchronous clock that can remain enabled in low power modes.

2.5.2 Quadrature Decoder (QDEC)

The quadrature decoder (QDEC) is used to read quadrature encoded data from mechanical and optical sensors in the form of digital waveforms. Quadrature encoded data is often used to indicate rotation of a mechanical shaft in either a positive or negative direction.

The QDEC uses two inputs, **channel 0** (**PHASE_A)** and **channel 1 (PHASE_B)**, to control incremental and decremental counting in the TPM counter. The QDEC supports two encoding modes: count and direction encoding mode and phase encoding mode. See also Timer/ PWM Module (TPM).

The TPM counter is clocked by the channel 0 and channel 1 input signals when quadrature decoder mode is selected. Therefore, In quadrature decoder mode, channel 0 and channel 1 can only be used in software compare mode. Other TPM channels can only be used in input capture or output compare modes.

2.6 Analog interfaces

14 out of the 29 digital GPIOs can be multiplexed to analog functions. The following analog functions are available:

- 1x 16-bit Analog to Digital Converter (ADC)
- 2x Low-power Comparator (LPCMP)
- 1x Voltage Reference (Vref)

☞ For detailed information on ADC, LPCMP and VREF, see also the NINA-B50 data sheet [2].

2.7 Debug interfaces

2.7.1 SWD

NINA-B50 series modules provide a 2-pin, serial-wire, debug interface with a clock (**SWDCLK**) and a single bi-directional data pin (**SWDIO**) for debug and test functionality.

Pin name	**SWD**		**Internal pull-up/pull-down**
	Type	**Description**	
SWDCLK	I	Clock	Pull-down
SWDIO	I/O	Data	Pull-up

Table 4: SWD signals

For information about authenticated debug please refer to the NXP application note Debug Authentication on KW45/K32W148 [29].

2.7.2 DAP

NINA-B50 series modules provide a Debug Access Port (DAP) to debug and trace the core system of the module. On NINA-B50 series modules, the SWD interface is used as the external connection interface of DAP.

2.7.3 SWO

NINA-B50 supports a 1-bit Serial Wire Output (SWO) trace port for efficiently accessing core trace information from outside of the module. The SWO pin is used to stream-out trace information from various parts of the module, including the Data Watchpoint and Trace (DWT) part, Instrumentation Trace Macrocell (ITM) part, and Breakpoint Unit (BPU) part.

3 Design-in

Follow the design guidelines in this chapter to optimize the integration of NINA-B50 series modules in the final application board.

3.1 Overview

All application circuits must be properly designed, but several points require special attention during the application design. In an order of importance:

- Module antenna connection: **ANT** pad RF transmission lines connecting the **ANT** pad with the related antenna connector or antenna, must be designed with a 50 Ω impedance characteristic. See also RF transmission line design.
- Module supply: **VCC**, **VCC_IO**, and **GND** pins.
  Supply circuits can affect RF performance, so it is important to observe the schematic and layout design for these supplies. See also VCC application circuits. Select appropriate power supply source and bypass capacitors, and carefully route the power supply nets or planes. Modules normally include several supply pins described in the pin out of the NINA-B50 series data sheet [2].
- High-speed interfaces: **LPUART, LPSPI, LPI2C** pins.
  High-speed interfaces are a potential source of radiated noise that can affect the regulatory compliance standards for radiated emissions. It is important to follow the schematic and layout design recommendations described in the General layout guidelines.
- System functions: **RESET_N**, GPIO, and other System input and output pins
  Careful utilization of these pins in the application design is required to guarantee for correct boot up and system operation. Ensure that the voltage level is correctly defined during module boot. It is important to follow the schematic and layout design recommendations described in the General layout guidelines.
- Other pins: **ADC**, **I2S, QDEC,** and NC pins.
  Careful utilization of these pins is required to guarantee proper functionality. It is important to follow the schematic and layout design recommendations described in the General layout guidelines.

3.2 RF interface

As the module must be strategically mounted, careful consideration should be given to its placement to avoid interference with radio communication. NINA-B506 modules include an internal PCB trace antenna, which makes them unsuitable for mounting in a metal enclosure. No metal casing or plastics using metal flakes should be used. Avoid metallic based paint or lacquer as well. NINA-B501 modules offer more freedom as an external antenna can be mounted further away from the module.

⚠ According to the FCC regulations, the transmission line from the module's antenna pin to the antenna or antenna connector on the host PCB is considered part of the approved antenna design. Therefore, module integrators must either follow exactly one of the antenna reference designs used in the module's FCC type approval or certify their own designs.

3.2.1 Antenna integration

At the start the application design phase, when the mechanical design and the physical dimensions of the board are still under analysis/decision, the antenna integration shall be considered. Apart from the product's performance, the compliance and subsequent certification of the RF design depends heavily on the radiating performance of the antennas. Note also that the RF certification of the module is extended through to the application design.

Adhere to the following guidelines to ensure proper performance of the application product:

- External antennas, including, linear monopole classes:
  - Place the module and antenna in any convenient area on the board. External antennas don't impose any restriction on where the module is placed on the PCB.
  - Select antennas with an optimal radiating performance in the operating bands. The radiation performance depends mainly on the antennas.
  - Choose RF cables that offer minimum insertion loss. Unnecessary insertion loss is introduced by low quality or long cables. Large insertion losses reduce radiation performance.
  - Use a high-quality 50 Ω coaxial connector for proper PCB-to-RF-cable transition.
- Integrated antennas, such as patch-like antennas:
  - Internal integrated antennas impose some physical restrictions on the PCB design. Given that the orientation of the ground plane related to the antenna element must be considered:
    - Integrated antennas excite 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 to a minimum size that should not be smaller than a quarter of the wavelength of the minimum frequency that is to be radiated.
    - Find a numerical example to estimate the physical restrictions on a PCB, where: Frequency = 2.4 GHz → Wavelength = 12.5 cm → Quarter wavelength = 3.5 cm in free space or 1.5 cm on a FR4 substrate PCB.
- Choose antennas with optimal radiating performance in the operating bands. Radiation performance depends on the complete product and antenna system design, including the mechanical design and usage of the product. Table 5 summarizes the requirements for the antenna RF interface.

Item	Requirements	Remarks
Impedance	50 Ω nominal characteristic impedance	The impedance of the antenna RF connection must match the 50 Ω impedance of the ANT pin.
Frequency Range	2400 - 2500 MHz	Bluetooth Low Energy.
Return loss	S_{11} < -10 dB (VSWR < 2:1) recommended S_{11} < -6 dB (VSWR < 3:1) acceptable	The return loss or S_{11}. As a parameter of the of the standing waves ratio (VSWR) measurement, S_{11} refers to the amount of reflected power. This parameter indicates how well the primary antenna RF connection matches the 50 Ω characteristic impedance of the ANT pin. To maximize the amount of the power transferred to the antenna, the impedance of the antenna termination must match (as much as possible) the 50 Ω nominal impedance of the ANT pin over the entire operating frequency range.
Efficiency	> -1.5 dB (> 70%) recommended > -3.0 dB (> 50%) acceptable	The radiation efficiency is the ratio of the radiated power against the power delivered to the antenna input; the efficiency is a measure of how well an antenna receives or transmits.
Maximum Gain	+3 dBi	Although higher gain antennas can be used, these must be evaluated and/or certified. To comply with regulatory agencies radiation exposure limits, the maximum antenna gain must not exceed the value specified in the Pre-approved antennas list. See also Regulatory compliance.

Table 5: Summary of antenna interface requirements for NINA-B50

3.2.2 RF transmission line design

RF transmission lines connecting the **ANT** pad with the related antenna connector or antenna, must be designed with a 50 Ω impedance characteristic.

Figure 9 shows the design options for PCB transmission lines, where:

- Microstrip: trace coupled to a single ground plane, separated by dielectric material.
- Coplanar microstrip: trace coupled to ground plane and adjacent conductors, separated by dielectric materials).
- Stripline: track separated by dielectric material and sandwiched between two parallel ground planes.

The parameters shown in the cross-sectional area of each trace design include:

- Width (W) – shows the width of the copper layer on the top layer
- Distance (S) – shows the distance between the top copper layer and the two adjacent GND planes.
- Dielectric substrate thickness (H) – shows the distance between the GND reference on the bottom plane and the copper layer on the top layer.
- Thickness of the copper layer (T) – can also be represented by "Base Copper Weight", which is commonly used as the parameter for PCB stack-up.

Dielectric constant (ε_r) defines the ratio between the electric permeability of the material against the electric permeability of free space.

☞ The width of a 50 Ω microstrip depends on mainly "ε_r" and "H", which must be calculated for each PCB layer stack-up.

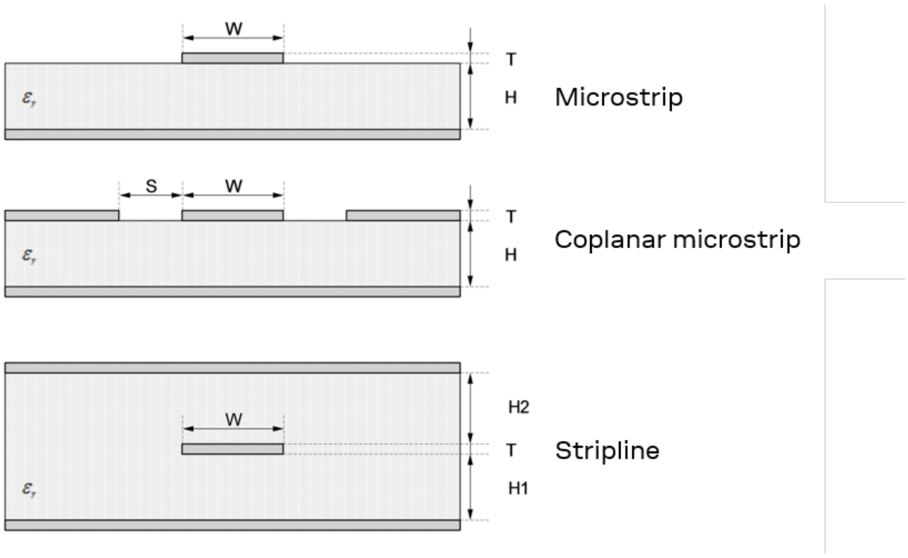


Figure 9: Transmission line trace design

Follow these recommendations to design a 50 Ω transmission line correctly:

- The designer should provide enough clearance from surrounding traces and ground in the same layer; in general, a trace to ground clearance of at least two times the trace width should be considered. The transmission line should also be "guarded" by ground plane area on each side.
- The characteristic impedance can be calculated as first iteration using tools provided by the layout software. It is advisable to ask the PCB manufacturer to provide the final values that are usually calculated using dedicated software and available stack-ups from production. It could also be possible to request an impedance coupon on panel's side to measure the real impedance of the traces.

- FR-4 dielectric material, despite its high losses at high frequencies, can be considered in RF designs – provided that:
  - RF trace length must be minimized to reduce dielectric losses.
  - If traces longer than few centimeters are needed, it is recommended to use a coaxial connector and cable to reduce losses.
  - Stack-up should allow for thick 50 Ω traces and at least 200 µm trace width is recommended to assure good impedance control over the PCB manufacturing process.
  - FR-4 material exhibits poor thickness stability and thus less control of impedance over the trace length. Contact the PCB manufacturer for specific tolerance of controlled impedance traces.
- The transmission lines width and spacing to the GND must be uniform and routed as smoothly as possible: route RF lines in 45 °C angle or in arcs.
- Add GND stitching vias around transmission lines.
- 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.
- Route RF transmission lines far from any noise source (as switching supplies and digital lines) and from any sensitive circuit to avoid crosstalk between RF traces and Hi-impedance or analog signals.
- Avoid stubs on the transmission lines, any component on the transmission line should be placed with the connected pad over the trace. Also avoid any unnecessary component on RF traces.

3.2.3 NINA-B501

NINA-B501 is suited for designs that, due to mechanical integration or placement of the module, require an external antenna.

At the beginning of the design phase, when the physical dimensions of the application board are under analysis/decision, designers must take care of the antennas from all perspectives. RF compliance of the device, integrating NINA-B501 module with all the applicable required certification schemes, heavily depends on the radiating performance of the antennas. Designers are encouraged to consider one of the u-blox suggested antennas and follow the layout requirements.

3.2.3.1 RF connector design

If an external antenna is required, designers should use a proper RF connector. It is the responsibility of the designer to verify the compatibility between plugs and receptacles used in the design.

Table 6 suggests several RF connector plugs that designers can use to connect RF coaxial cables based on the declaration of the respective manufacturers.

Manufacturer	Series	Remarks
Hirose	U.FL® Ultra Small Surface Mount Coaxial Connector	Recommended
I-PEX	MHF® Micro Coaxial Connector	
Tyco	UMCC® Ultra-Miniature Coax Connector	
Amphenol RF	AMC® Amphenol Micro Coaxial	
Lighthorse Technologies, Inc.	IPX ultra micro-miniature RF connector	

Table 6: U.FL compatible plug connector

The Hirose U.FL-R-SMT RF receptacles (or similar parts) require a suitable mated RF plug from the same connector series. Due to wide usage of this connector, several manufacturers offer compatible equivalents. It is the responsibility of the designer to verify the compatibility between plugs and receptacles used in the design.

Typically, the RF plug is available as a cable assembly. Different types of cable assemblies are available, and the user should select the cable assembly best suited for the application. The key characteristics of an appropriate plug include:

- RF plug type: Select U.FL or equivalent
- Nominal impedance: 50 Ω
- Cable thickness: Select thicker cables, typically those with a thickness between 0.8 mm to 1.37 mm, to minimize insertion loss.
- Cable length: The standard cable length is typically 100 mm or 200 mm; custom lengths are available on request. Select shorter cables to minimize insertion loss.
- RF connector terminating the other side of the cable: for example, another U.FL (for board-to-board connection) or SMA (for panel mounting).

SMT connectors are typically rated for a limited number of insertion cycles. In addition, the RF coaxial cable may be relatively fragile compared to other types of cables. To increase application ruggedness, connect the U.FL connector to a more robust connector such as SMA fixed on panel.

☞ A de-facto standard for SMA connectors suggests that the usage of reverse polarity connectors (RP-SMA) on Wi-Fi and Bluetooth end products make it more difficult for end users to replace the antenna with higher gain versions that exceed regulatory limits.

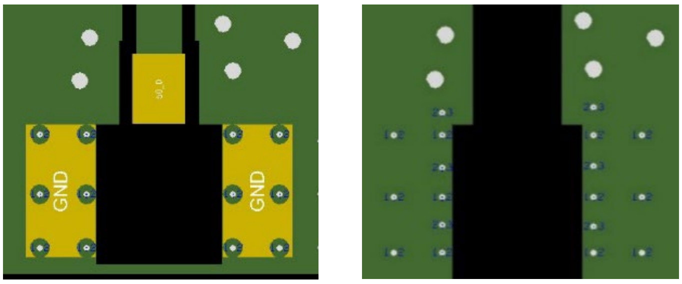


Figure 10: U.FL connector layout showing top layer (left) and inner layer 1 (right)

Strictly follow the connector manufacturer's recommended layout:

- SMA Pin-Through-Hole connectors require a void GND keep-out clearance area on all the layers around the central pin – up to annular pads of the four GND posts.
- UFL surface mounted connectors require no conductive traces in the area below the connector between the GND land pads.

If the connector's RF pad size is wider than the microstrip, remove the GND layer beneath the RF connector to minimize the stray capacitance and keep the RF line to an impedance of 50 Ω. To reduce parasitic capacitance-to-ground for example, the active pad of the U.FL. connector must include (at the very least) a void GND keep-out clearance area on the first inner layer.

3.2.3.2 Integrated antenna design

If integrated antennas are used, the transmission line is terminated by the integrated antennas themselves. Observe the following guidelines:

- The antenna design process should begin at the start of the whole product design process. Self-made PCBs and antenna assemblies are useful for estimating the overall efficiency and radiation path of the intended design.
- Use antenna manufacturer designs that provide the best possible return loss (or VSWR).
- Provide a ground plane large enough according to the related integrated antenna requirements. The ground plane of the application PCB may be reduced to a minimum size that must be similar to one quarter of wavelength of the minimum frequency that has to be radiated; however overall antenna efficiency may benefit from larger ground planes.

- Proper placement of the antenna and its surroundings is also critical for antenna performance. Avoid placing the antenna close to conductive or RF-absorbing parts, such as metal objects and ferrite sheets, as these may absorb part of the radiated power, shift the resonant frequency of the antenna, or otherwise affect the antenna radiation pattern.
- Strict adherence to the guidelines from antenna manufacturer is recommended. Consider carefully regarding their instructions for correctly installing and deploying the antenna system, including the design of the PCB layout and matching circuitry.
- Further to the custom PCB and product restrictions, antennas may require tuning/matching to comply with all the applicable required certification schemes. It is recommended that you plan measurement and validation activities with the antenna manufacturer before releasing the end-product to manufacturing.
- RF parts may be affected by noise sources like hi-speed digital buses. Avoid placing the antenna close to buses such as a Double Dara Rate (DDR) bus and consider taking specific countermeasures like metal shields or ferrite sheets to reduce the interference.

3.2.4 NINA-B506

NINA-B506 modules include an internal PCB trace antenna that is integrated on the module PCB using antenna technology from Abracon. The RF signal is completely internal and not connected to any module pin. NINA-B506 modules can't be mounted inside a metal enclosure. Metal casings or plastics that include metal flakes should not be used. Metallic-based paints and lacquers should also be avoided.

3.2.4.1 Internal PCB trace antenna

For optimal operating performance, observe the following layout considerations when developing the antenna layout:

- The module shall be placed in the center of an edge of the host PCB.
- A large ground plane on the host PCB is a prerequisite for good antenna performance. A ground plane extending at least 10 mm on the three non-edge sides of the module is recommend, as shown in Figure 11.
- Include a non-disruptive GND plane underneath the module with a cut out underneath the antenna, as shown in Figure 12.
- Observe the antenna "keep-out" area on all layers, as shown in figures Figure 11 and Figure 12.
- NINA-B506 has four GND pads located close to the antenna, as shown in Figure 11. Connect these pads to GND. Detailed dimensions of the footprint, including those related to these GND pads, can be found in the NINA-B50 series data sheet [2].
- To avoid degradation of the antenna characteristics, do not place physically tall or large components closer than 10 mm to the module antenna.
- To avoid any adverse impact on antenna performance, include a 10 mm clearance between the antenna and the casing. Polycarbonate (PC) and Acrylonitrile butadiene styrene (ABS) materials have less impact on antenna performance than other types of thermoplastics.
- Include plenty of stitching vias from the module ground pads to the GND plane layer. Ensure that the impedance between the module pads and ground reference is minimal.
- Connect all ground pads to the ground plane.
- Consider the end products use case and assembly to make sure that the antenna is not obstructed by any external item.

Figure 11 shows the ground plane on both sides of the module and the antenna “keep-out” area on all layers.

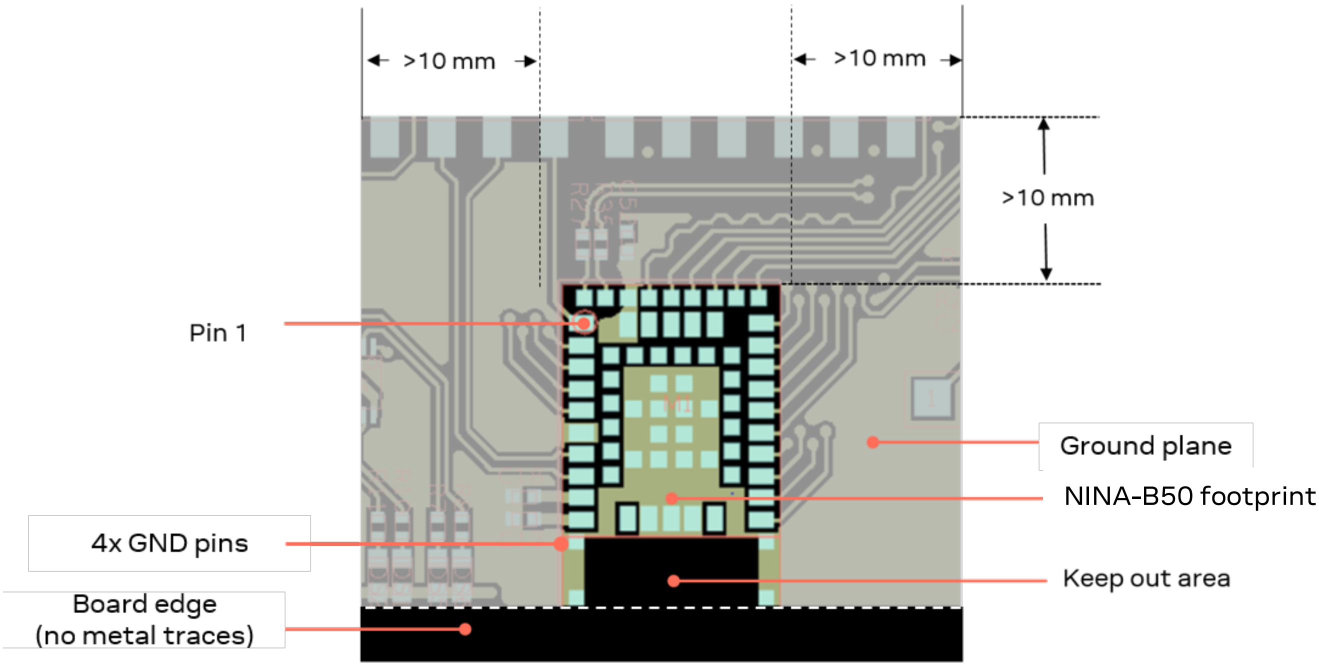


Figure 11: Extended host ground plane outside NINA-B506

Figure 12 shows a scaled image of the board that details the dimensions of the keep-out area.

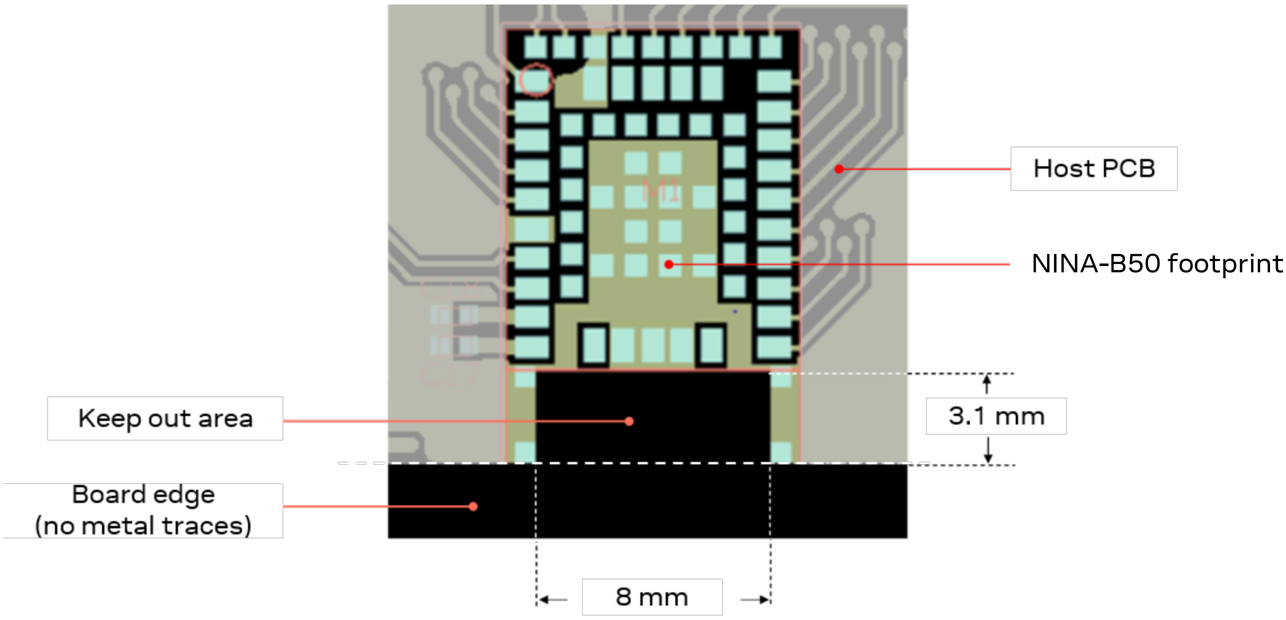


Figure 12: NINA-B506 keep out area

3.3 General layout guidelines

This section describes the best practice for the schematic design and circuit layout of the application.

3.3.1 Considerations for schematic design and PCB floor planning

- Low frequency signals are generally not critical to the layout and designers should focus on the higher speed buses. One exception to this general rule is when high impedance traces, such as signals driven by weak pull resistors, might be affected by crosstalk. For these and similar traces, a supplementary isolation of **4w** (four times the line width) from other buses is recommended.
- Verify which interface bus requires termination and add series resistor terminations to these buses.
- Carefully consider the placement of the module with respect to antenna position and host processor.
- Verify the controlled impedance dimensions of the selected PCB stack-up. The PCB manufacturer might be able to provide test coupons.
- Verify that the power supply design and power sequence are compliant with module specifications, as described in the module's data sheet.

⚠ Take particular care not to place components close to the antenna area and follow the recommendations from the antenna manufacturer to determine the safe distance between the antenna and any other part of the system. Designers should also maximize the distance between the antenna and high-frequency buses, like DDRs and related components, or consider the use of an optional metal shield to reduce the potential interference picked up by the module antenna.

3.3.2 Component placement

- Place the module such that it provides optimum RF performance. This includes short low loss antenna connections and unobstructed antenna placement. For more information about the module placement and other antenna considerations, see also Antenna Integration.
- Place bypass capacitors as close as possible to the module. Prioritize the placement of capacitors with the least capacitance so that these are closest to module pads. The supply rails must be routed through the capacitors from the power supply to the supply pad on the module.
- Do not place components close to the antenna area. Follow the recommendations of the antenna manufacturer to determine distance of the antenna in relation to other parts of the system. Designers should also maximize the distance of the antenna to High-frequency busses, like DDRs and related components. Alternatively, consider an optional metal shield to reduce interferences that might otherwise be picked up by the antenna and subsequently reduce module sensitivity.

3.3.3 Layout and manufacturing

- Avoid stubs on high-speed signals which might adversely affect signal quality. Test points or component pads should be placed over the PCB trace.
- Verify the recommended maximum signal skew for differential pairs and length matching of buses.
- Minimize the routing length. Ensure that the maximum allowable length for high-speed buses is not exceeded. Longer traces generally degrade signal performance.
- For impedance matched traces, consult with your PCB manufacturer early in the project for proper stack-up definition.
- Separate the RF and digital sections of the board.
- Don't split ground layers under the module.
- Minimize the routing length. Ensure that the maximum allowable length for high-speed buses is not exceeded. Longer traces generally degrade signal performance.
- Couple all traces (including low speed or DC traces) with a reference plane (GND or power), and reference all hi-speed buses against the ground plane. If any ground reference needs to be changed, add an adequate number of GND vias in the area in which the layer is switched. This is necessary to provide a low impedance path between the two GND layers for the return current.
- Don't change the reference plane for Hi-Speed buses. If changes in the reference plane are unavoidable, add capacitors in the transition area of the reference planes. This is necessary to ensure that a low impedance return path exists through the different reference planes.
- Following the "3w rule", keep traces at a distance no less than three times that of its own width from the routing edge of the ground plane.
- For EMC purposes and the need to shield against any potential radiation, it is advisable to add GND stitching vias around the edge of the PCB. Traces on the PCB peripheral are not recommended.

3.4 Module footprint and paste mask

Figure 13 shows the pin layout of NINA-B501 module. The proposed land pattern layout complements the pin layout of the module. Both Solder Mask Defined (SMD) and Non Solder Mask Defined (NSMD) pins can be used – with adherence to the following considerations:

- All pins should be Non-Solder Mask Defined (NSMD)
- To help with the dissipation of the heat generated by the module, GND pads must have good thermal bonding to PCB ground planes.

The suggested stencil layout for NINA-B501 is to follow the copper pad layout, as shown in Figure 13.

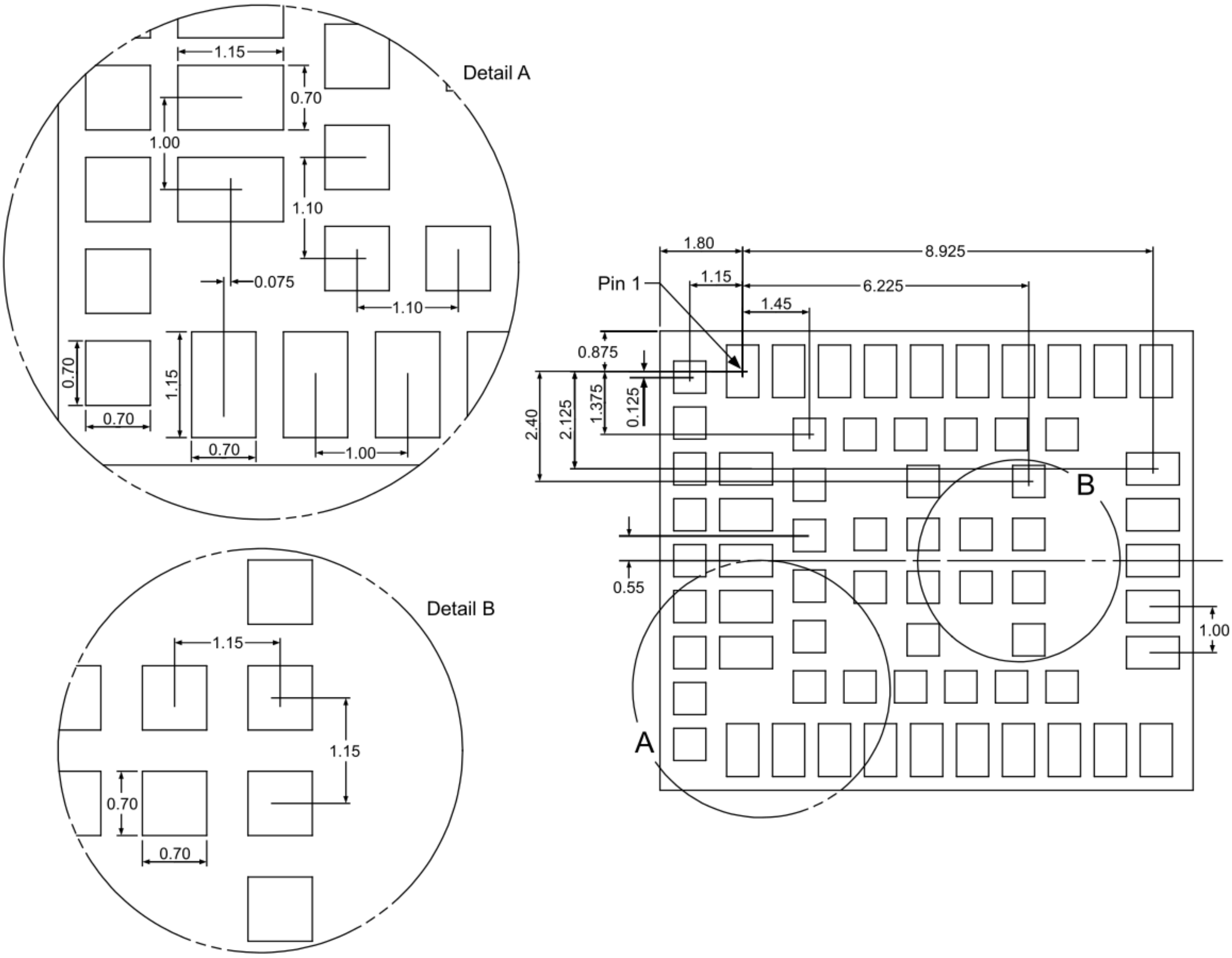


Figure 13: Recommended footprint for NINA-B501 (bottom view)

Figure 14 shows the pin layout of NINA-B506 module. The proposed land pattern layout complements the pin layout of the module. Both Solder Mask Defined (SMD) and Non Solder Mask Defined (NSMD) pins can be used with adherence to the following considerations:

- All pins should be Non-Solder Mask Defined (NSMD)
- To help with the dissipation of the heat generated by the module, GND pads must have good thermal bonding to PCB ground planes.

The suggested stencil layout for the NINA-B506 module should follow the copper pad layout, as shown in Figure 14. NINA-B506 modules also follow Detail A and Detail B dimensions mentioned in Figure 13.

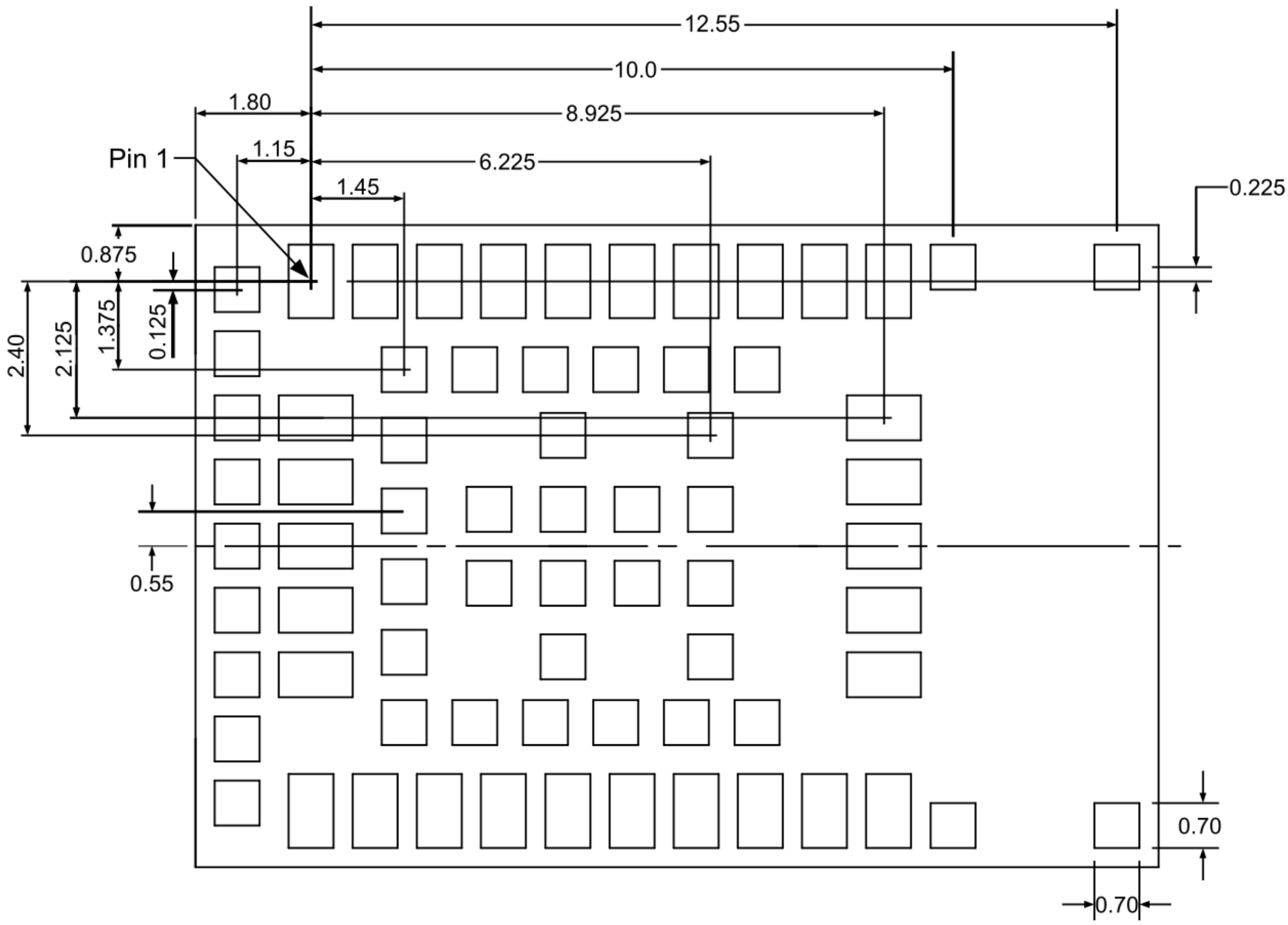


Figure 14: Recommended footprint for NINA-B506 (bottom view)

3.5 Thermal guidelines

NINA-B50 series modules are designed to operate in a specified temperature range at an ambient temperature inside the enclosure box. The PCB generates heat during high loads that must be dissipated to sustain the lifetime of the components.

The improvement of thermal dissipation in the module decreases its internal temperature and consequently increases the long-term reliability of device applications operating at high ambient temperatures.

For best performance, layouts should adhere to the following guidelines:

- Vias specification for ground filling: $300/600\mu m$, with no thermal reliefs allowed on vias.
- Ground via densities under the module: $50\ vias/cm^2$; thermal vias can be placed in gaps between the thermal pads of the module.

- Minimum layer count and copper thickness: $4\ layers, 35\ \mu m$.
- Minimum board size: $55x70\ mm$.
- To optimize the heat flow from the module, power planes and signal traces should not cross the layers beneath the module.

These recommendations facilitate a design that can achieve a thermal characterization parameter of $\psi_{JB} = 18.2\ °C/W$ for NINA-B501 and $\psi_{JB} = 19.4\ °C/W$ for NINA-B506, where JB refers to the "module's junction to main PCB bottom side".

Use the following hardware techniques to further improve thermal dissipation in the module and optimize its performance in customer applications:

- Maximize the return loss of the antenna to reduce reflected RF power to the module.
- Improve the efficiency of any component that generates heat, including power supplies and processor, by dissipating it evenly throughout the application device.
- Provide sufficient ventilation in the mechanical enclosure of the application.
- For continuous operation at high temperatures, particularly in high-power density applications or smaller PCB sizes, include a heat sink on the bottom side of the main PCB. The heat sink is best connected using electrically insulated / high thermal conductivity adhesive[2].

3.6 ESD guidelines

Device immunity against Electrostatic Discharge (ESD) is a requirement for Electromagnetic Compatibility (EMC) conformance and use of the CE marking for products intended for sale in Europe. To bear the CE mark, all application products integrating u-blox modules must be conformance tested in accordance with the R&TTE Directive (99/5/EC), the EMC Directive (89/336/EEC) and the Low Voltage Directive (73/23/EEC) issued by the Commission of the European Community.

Compliance with the above directives implies conformity to the following European Norms for device ESD immunity: ESD testing standard CENELEC EN 61000-4-2 and the radio equipment standards ETSI EN 301 489-1, ETSI EN 301 489-7, ETSI EN 301 489-24, the requirements of which are summarized in Table 7 .

The ESD immunity test is performed at the enclosure port, defined by *ETSI EN 301 489-1* as the physical boundary through which the electromagnetic field radiates. If the device implements an integral antenna, the enclosure port is seen as all-insulating and includes conductive surfaces to house the device. If the device implements a removable antenna, the antenna port can be separated from the enclosure port. The antenna port includes the antenna element and its interconnecting cable surfaces.

Any extension of the ESD immunity test to the whole device is dependent on the device classification, as defined by *ETSI EN 301 489-1*. Applicability of ESD immunity test to the related device ports or the related interconnecting cables to auxiliary equipment, depends on the device accessible interfaces and manufacturer requirements, as defined by the *ETSI EN 301 489-1*.

Contact discharges are performed at conductive surfaces, while air discharges are performed at insulating surfaces. Indirect contact discharges are performed on the measurement setup horizontal and vertical coupling planes as defined in the *CENELEC EN 61000-4-2*.

☞ The terms "integral antenna", "removable antenna", "antenna port", "device classification" used in the context of this guideline are defined in ETSI EN 301 489-1. The terms "contact discharge" and "air discharge" are defined in CENELEC EN 61000 4-2.

[2] Typically, not required.

Table 7 describes the ESD immunity requirements as defined by CENELEC EN 61000-4-2, ETSI EN 301 489-1, ETSI EN 301 489-7, ETSI EN 301 489-24.

Parameter	Min.	Typical	Max.	Unit	Remarks
ESD immunity. All exposed surfaces of the radio equipment and ancillary equipment in a representative configuration			8*	kV	Indirect discharge according to IEC 61000-4-2
ESD sensitivity, tested for all pins except ANT and RSVD pins #11, #15, #33			2.0*	kV	Human body model according to JEDEC JS001

* Test pending

Table 7 : Electro-Magnetic Compatibility ESD immunity requirements

NINA-B50 is manufactured with consideration to the specific standards for minimizing the occurrence of ESD events. The highly automated process complies with the IEC61340-5-1 (STM5.2-1999 Class M1 devices) standard, and designers should implement proper measures to protect devices from ESD events on any pin that might be exposed to the end user.

Compliance with standard protection level specified in the EN61000-4-2 is achieved by including ESD protection as close to any areas accessible to the end user.

3.7 Design-in checklists

3.7.1 Schematic checklist

- ☐ All module pins are properly numbered and designated in the schematic (including thermal pins).
- ☐ Power supply design complies with the specification.
- ☐ The power sequence is properly implemented.
- ☐ Adequate bypassing is included in front of each power pin.
- ☐ Each signal group is consistent with its own power rail supply or proper signal translation has been provided.
- ☐ Configuration pins are properly set at bootstrap.
- ☐ SDIO bus includes series resistors and pull-ups, if needed.
- ☐ Unused pins are properly terminated.
- ☐ A pi-filter is provided in front of each antenna for final matching.
- ☐ Additional RF co-location filters have been considered in the design.

3.7.2 Layout checklist

- ☐ PCB stack-up and controlled impedance traces follow the recommendations given by the PCB manufacturer.
- ☐ All pins are properly connected, and the footprint follows u-blox pin design recommendations.
- ☐ Proper clearance is provided between the RF and digital sections of the design.
- ☐ Proper isolation is provided between antennas (RF co-location, diversity, or multi-antenna design).
- ☐ Bypass capacitors have been placed close to the module.
- ☐ Controlled impedance traces are properly implemented in the layout (both RF and digital) and the recommendations provided by the PCB manufacturer have been followed.
- ☐ 50 Ω RF traces and connectors follow the rules described in Antenna Integration.
- ☐ Antenna design is reviewed by the antenna manufacturer.
- ☐ Proper grounding is provided to the module for the low impedance return path and heat sink.
- ☐ Reference plane skipping is minimized for high frequency busses.
- ☐ All traces and planes are routed inside the area defined by the main ground plane.
- ☐ u-blox has reviewed and approved the PCB[3].

[3] Applicable only for end-products based on u-blox reference designs

4 Open CPU software

NINA-B50 series modules are delivered without any pre-flashed software. Customers need to develop their own application using an SDK provided by NXP.

4.1 MCUXpresso SDK

To develop customer applications NXP provide the MCUXpresso IDE [27] and SDK [26] for development using FreeRTOS. The most recent application development guidelines are included in the MCUXpresso SDK API Reference Manual [19].

The chapter describes how to get started with the MCUXpresso SDK, MCUXpresso IDE, and the K32W1480 MCU integrated in NINA-B50.

4.1.1 Getting started with the MCUXpresso SDK

When working with the MCUXpresso SDK on the NINA-B50 series module, follow the steps below to get started with the MCUXpresso SDK toolchain and examples:

1. Download MCUXpresso SDK from the MCUXpresso SDK builder [28].
   Select K32W148-EVK when building the SDK.
2. Download and open the MCUXpresso IDE [27].

☞ When installing the SDK, be sure not to include any space characters in the file path. Keep the folder structure intact. The examples in the SDK use relative folder references.

3. Drag and drop the SDK zip file into the Installed SDKs view to install an SDK.
4. Import a General or Bluetooth LE example from the SDK via the Import SDK example button.
5. Build and flash the example on the NINA-B50 EVK via the Build and Debug section.

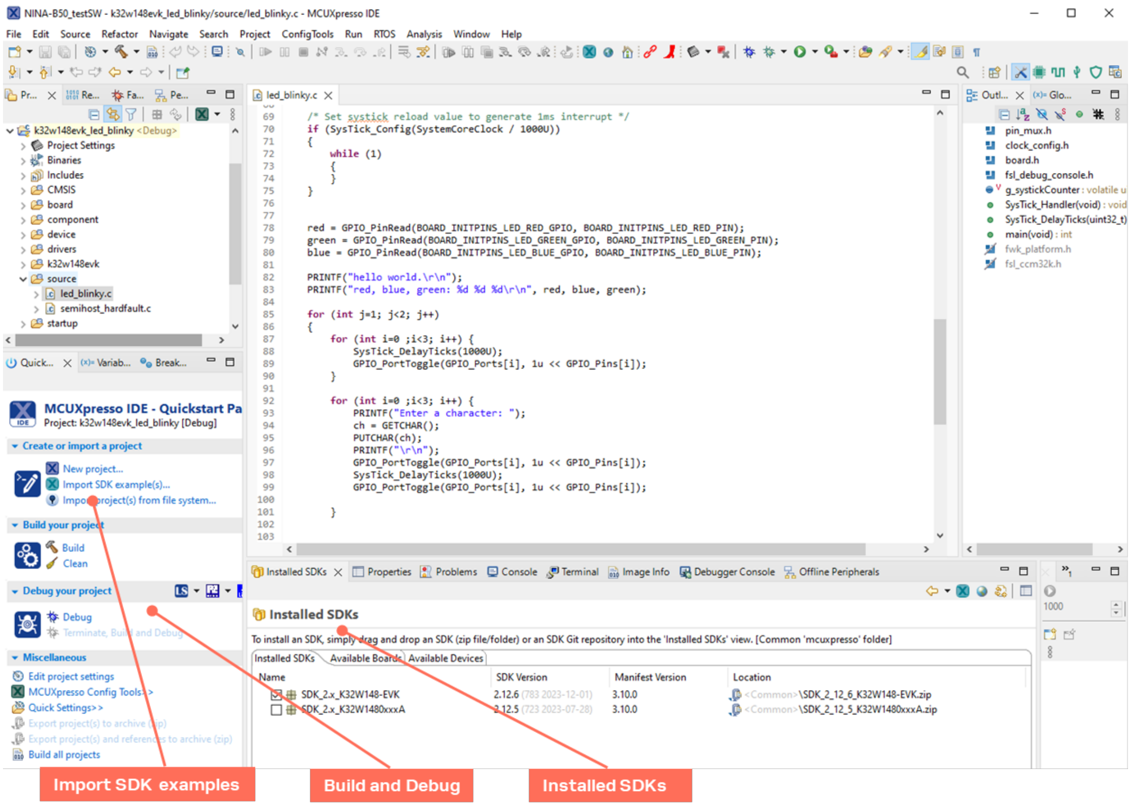


Figure 15: Installed SDKs

4.1.1.1 Create a custom board support file for MCUXpresso SDK

The predefined hardware boards included in the MCUXpresso SDK are for NXP development boards only. To add support for a custom board, create a support file with board Macro definitions on the following path: `<MY_project>/board`

Alternatively, use the MCUXpresso Config Tools to build a custom SDK and to leverage pins, clocks, and peripherals to generate initialization C code or register values for custom board support. The tools are provided as a standalone package for MAC OS, Linux, and Windows. A web version is also available. For EVK-NINA-B5, example pinmux files are available in the open CPU GitHub repository [22].

☞ When using the MCUXpresso IDE, no additional download of Config Tools is required.

4.1.1.2 Support – NXP Community forum

For support on questions related to the development of software using the MCUXpresso SDK, check out the NXP Community forum.

4.2 Bluetooth device (MAC) address and other production data

During module production the information shown in Table 8 is stored on the NINA-B50 flash memory.

Parameter	Size (bytes)	Remark
Identification word	10	"PROD_DATA:"
Bluetooth address	6	Unique, public Bluetooth device (MAC) address that can be used by the customer application.
IEEE 802.15.4 address	8	MAC address
32 MHz crystal trim value	1	Module internal crystal, trim value set by u-blox
32 kHz crystal capacitance value	1	☞ Must be set by customer when using an external 32 kHz crystal.
u-blox type number	16	
u-blox serial number	8	

Table 8: Production parameters stored on NINA-B50

The parameters are stored in the PROD_DATA_BASE_ADDR register.

Example code for reading the parameters stored in u-blox production can be found on the u-blox open CPU GitHub repository [22]. A representation of the parameters in "C" language is shown in Figure 16.

```
Typedef PACKED_STRUCT hardwareParameters_tag
{
    uint8_t identificationWord[10]; /* internal usage only: valid data present */
    uint8_t bluetooth_address[6];     /*!< Bluetooth address */
    uint8_t ieee_802_15_4_address[8]; /*!< IEEE 802.15.4 MAC address - K32W1 only */
    uint8_t xtalTrim;                 /*!< XTAL Trim value */
    uint8_t xtalCap32K;               /*!< XTAL 32k capacitance value */
    /* For forward compatibility additional fields may be added here
       Existing data in flash will not be compatible after modifying the
       hardwareParameters_t typedef*/
    uint8_t type_number[16];        /* u-blox Type number */
    uint8_t serial_number[8];         /* u-blox Serial number */

    uint8_t reserved[39]; /*!< reserved for adding field to the structure without
                             changing the Crc field adress location*/
    uint16_t hardwareParamsCrc; /* internal usage only: crc for data between start
                                   of reserved area and start of
                                   hardwareParamsCrc field (not included). */
}
hardwareParameters_t;
```

Figure 16: C language representation of production data

The API call NV_ReadHWParameters() (SDK 2.12.5) is used to read the parameters.

4.3 32 kHz crystal

The NINA-B50 module does not include a 32 kHz crystal, but it is possible to connect an external one or alternatively use the FRO-32K internal clock source.

When using an external 32 kHz crystal the crystal capacitance must be configured to the correct frequency in the software, as described in Bluetooth device (MAC) address and other production data. This value is then be used by the framework by calling the BOARD_InitHardware() framework function in the MCUXpresso SDK.

When using the internal Free Running Oscillator (FRO32K), the software must be configured to use this oscillator. This is typically done by setting the flag gBoardUseFro32k_d (SDK 2.12.5) to 1 in the software before calling BOARD_InitHardware().

4.4 Setting output power

Output power for advertising and connections can be configured separately from within the MCUXpresso SDK, using the following API:

```
typedef enum txChannelType_tag {
    gAdvTxChannel_c,
    gConnTxChannel_c
} txChannelType_t;

/*! ********************************************************************************
 * \brief  Sets the TX Power on the advertising or connection channel.
 * \param[in]  level_dbm    Power level in dBm.
 * \param[in]  channel      Advertising or connection channel.
 *
 * \return KOSA_StatusSuccess or KOSA_StatusError.
 *
 * \remarks This function executes synchronously.
 ******************************************************************************** */
osa_status_t Controller_SetTxPowerLevelDbm(int8_t level_dbm, txChannelType_t channel);
```

Figure 17: API for setting output power

For more information about antenna gain and regulatory compliance, see Antenna integration and Regulatory compliance.

4.5 Flashing open CPU software

Modules with an open CPU configuration can be flashed using various utility programs over the SWD debugger interface, as well as the serial I2C, SPI, or UART interfaces via the ROM bootloader.

4.5.1 Flashing over the SWD interface

To flash NINA-B50 modules over the Serial Wire Debug (SWD) interface, an external debugger must be connected to the SWD interface of the module.

Third-party tools, like J-Link Commander and J-Flash, are used to flash the module:

- SEGGER J-Link BASE external debugger works with NINA-B50 modules.
- EVK-NINA-B50 incorporates an onboard debugger, which means that it can be flashed without an external debugger.

☞ Always make a note of your Bluetooth device address before starting the flashing procedure. As flashing the software can erase the original u-blox Bluetooth device address, this address might need to be reinstated. The Bluetooth device address can be re-written manually.

4.5.2 Flashing over the serial interfaces

For information about flashing over the serial interfaces, see "Boot ROM" in the NXP K32W1480 Reference Manual [5].

4.5.3 Loading NBU firmware into the module

To run applications using radio protocols, for example the Bluetooth LE demos in the MCUXpresso SDK, you must first program the NINA-B50 modules with Narrow band unit (NBU) firmware images provided in the SDK.

After downloading the SDK package, you can find the secure NBU binary files in the following path: `<SDK location>\middleware\wireless\ble_controller\bin`.

☞ NBU firmware files come in two different versions: unsecure `.xip` files and signed `.sb3` files. The `.sb3` files provided in the SDK are produced using the default OEM keys in the SDK. For further information, see also the KW45 flash programming the KW45 flash reference [24] and the MCUXpresso Secure Provisioning Tool User Guide [25].

☞ The procedure for loading the NBU requires that the correct signing keys are burnt to the OTP of the module.

☞ On the EVK-NINA-B50 the default OEM keys are fused to the module in EVK production.

☞ The OEM can produce `.sb3` images and a fuse configuration with their own keys as described in the KW45 flash programming reference [24] and MCUXpresso Secure Provisioning Tool User Guide [25].

To load NBU firmware to the module you need:

- NINA-B50 board (EVK-NINA-B50 or other board with NINA-50 mounted and UART available)
- MCUXpresso SDK
- NXP `blhost` command-line utility

4.5.3.1 Hardware setup

To load the binary NBU image, NINA-B50 must be set in ROM bootloader mode:

- Connect **GPIO_7** (chip pin PTA4) to logical 1, or
- On the EVK-NINA-B5, remove the jumper at **J19:9-10** and connect a wire between **3V3** and **J19:9**, before powering up the evaluation board, as shown in Figure 18.

During power up, the board enters ROM bootloader mode.

Figure 18 shows the jumper positions and wire connection points to set NINA-B50 in bootloader mode.

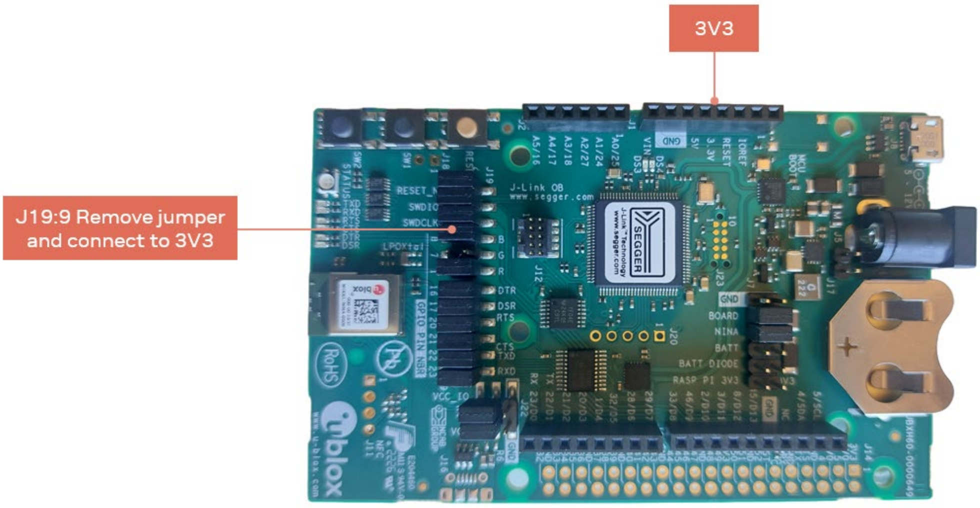
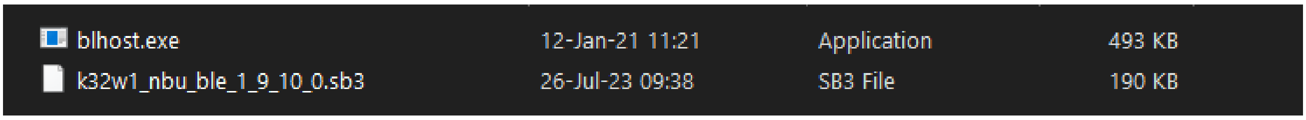


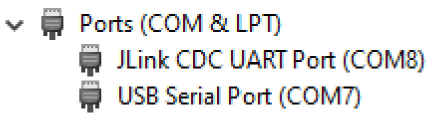
Figure 18: EVK-NINA-B5 jumper settings and wiring for entering bootloader mode

4.5.3.2 Use blhost to flash the NBU image

1. Use the `blhost.exe` command-line utility to communicate and send commands to the bootloader. It can be found in the SDK in the following path:
   `<SDK location\middleware\tfm\tf-m\platform\ext\target\nxp\common\secure_boot\tools\`
2. Copy the secure binary NBU image file (`.xb3`), either one you have signed with your own keys or the file supplied for EVKs signed with evaluation keys, into the same folder.



3. Open Windows Device Manager and identify the COM port assigned to EVK-NINA-B50 board or custom board (COM7 in screenshot below).



4. Run `blhost` in command prompt and change the COM port number and the secure NBU file.

```
blhost.exe -p COMXX -- receive-sb-file .\k32w1_nbu_ble_1_9_10_0.sb3
```

5. Wait for flashing to start and progress reaches 100%.

```
Ping responded in 1 attempt(s)
Inject command 'receive-sb-file'
Preparing to send 194240 (0x2f6c0) bytes to the target.
Successful generic response to command 'receive-sb-file'
(1/1)100% Completed!
Successful generic response to command 'receive-sb-file'
Response status = 0 (0x0) Success.
Wrote 194240 of 194240 bytes.
```

6. Power cycle the board.

4.6 Secure boot

NINA-B50 is delivered in an open, unsecure version, which makes it possible for the user to insert signing keys of their choice to create a secure boot chain. The state is called OEM-OPEN in the referenced NXP documents.

This procedure is further described in the NXP application notes *Managing Lifecycles on KW45 and K32W148* [23] and *Programming the KW45 flash for Application and Radio firmware via Serial Wire Debug during mass production* [24].

A GUI-based tool for secure provisioning is also available, as described in the *MCUXpresso Secure Provisioning Tool User Guide* [25].

5 Handling and soldering

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

⚠ NINA-B50 series modules are Electrostatic Sensitive Devices that demand the observance of special handling precautions against static damage. Failure to observe these precautions can result in severe damage to the product.

5.1 ESD handling precautions

As the risk of electrostatic discharge in the RF transceivers and patch antennas of the module is of particular concern, standard ESD safety practices are prerequisite. See also Figure 19.

Consider also:

- When connecting test equipment or any other electronics to the module (as a standalone or PCB-mounted device), the first point of contact must always be to local GND.
- Before mounting an antenna patch, connect the device to ground.
- When handling the RF pin, do not touch any charged capacitors. Be especially careful when handling materials like patch antennas (~10 pF), coaxial cables (~50-80 pF/m), soldering irons, or any other materials that can develop charges.
- To prevent electrostatic discharge through the RF input, do not touch any exposed antenna area. If there is any risk of the exposed antenna being touched in an unprotected ESD work area, be sure to implement proper ESD protection measures in the design.
- When soldering RF connectors and patch antennas to the RF pin on the receiver, be sure to use an ESD-safe soldering iron (tip).

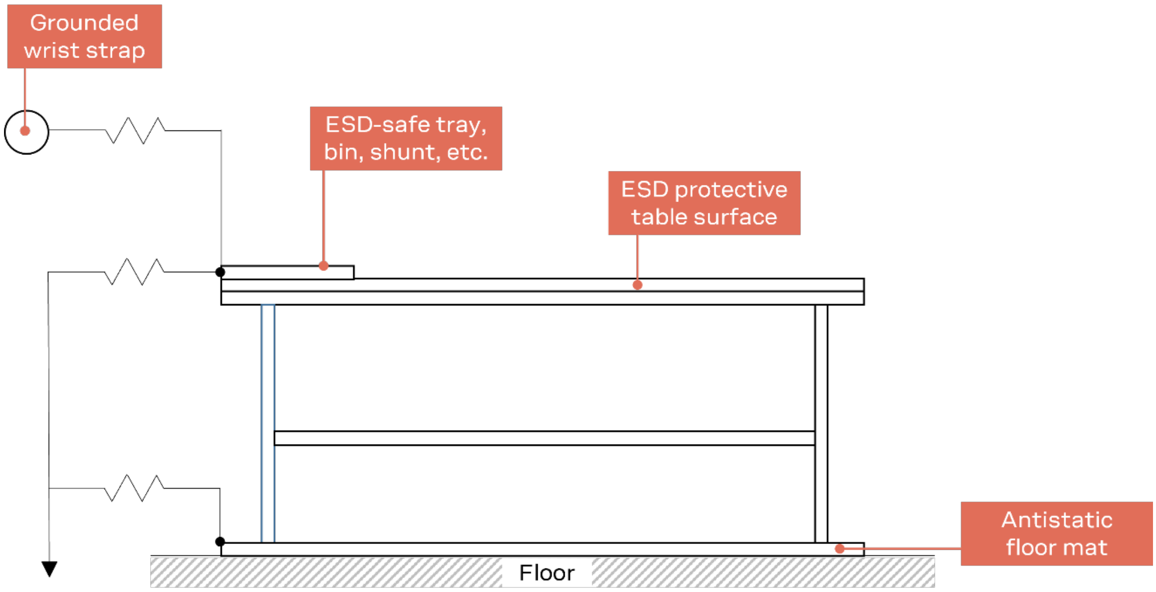


Figure 19: Standard workstation setup for safe handling of ESD-sensitive devices

5.2 Packaging, shipping, storage, and moisture preconditioning

For information pertaining to reels, tapes or trays, moisture sensitivity levels (MSL), shipment and storage, as well as drying for preconditioning, refer to the respective NINA-B50 series data sheet [2] and Product packaging reference guide [1].

5.3 Reflow soldering process

NINA-B50 series modules are surface mounted devices supplied in a Land Grid Array (LGA) package with gold-plated solder lands. The modules are manufactured in a lead-free process with lead-free soldering paste.

The thickness of solder resist between the host PCB top side and the bottom side of the module must be considered for the soldering process.

NINA-B50 modules are compatible with the industrial reflow profile for common SAC type RoHS solders. No-clean soldering paste is strongly recommended.

The reflow profile is dependent on the thermal mass over the entire area of the fully populated host PCB, the heat transfer efficiency of the oven, and the type of solder paste that is used. The optimal soldering profile that is used must be trimmed for each case depending on the specific soldering process and PCB layout.

⚠ The target values shown in Table 9 are only general guidelines for a Pb-free process. For further information, see also the JEDEC J-STD-020C standard [8].

Process parameter		Unit	Target
Pre-heat	Ramp up rate to T_{SMIN}	K/s	3
	T_{SMIN}	°C	150
	T_{SMAX}	°C	200
	t_S (from +25 °C)	s	150
	t_S (Pre-heat)	s	60 to 120
Peak	T_L	°C	217
	t_L (time above T_L)	s	40 to 60
	T_P (absolute max)	°C	245
Cooling	Ramp-down from T_L	K/s	4
	Allowed soldering cycles	-	1

Table 9: Recommended reflow profile

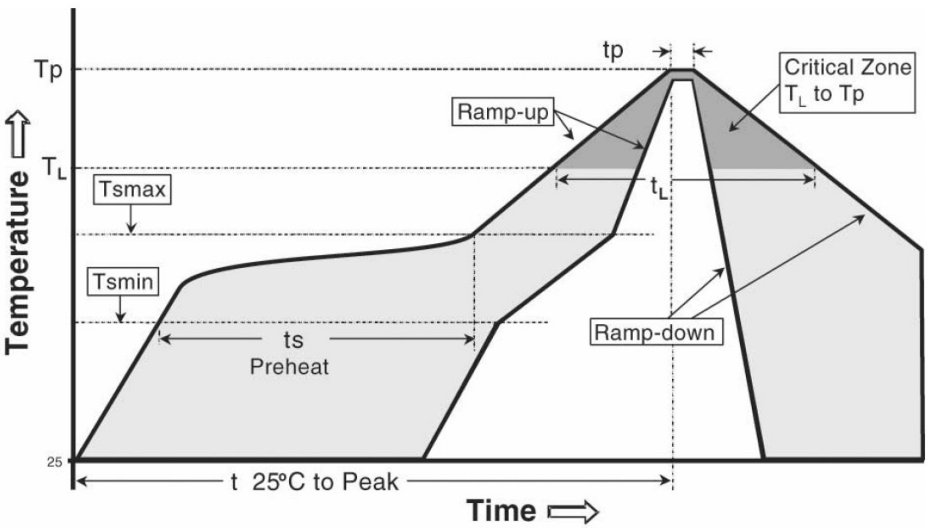


Figure 20: Reflow profile

☞ Lower value of T_P and slower ramp down rate (2–3 °C/sec) is preferred.

5.3.1 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 pins. 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 housing, 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 and the crystal oscillators in particular.

For best results use a "no clean" soldering paste and circumvent the need for a cleaning stage after the soldering process.

5.3.2 Other notes

- Two reflow soldering processes are allowed for boards with a module soldered on it.
- Boards with combined through-hole technology (THT) components and surface-mount technology (SMT) devices may require wave soldering to solder the THT components. Only a single wave-soldering process is allowed for boards populated with the modules. Miniature Wave Selective Solder processes are preferred over traditional wave soldering processes.
- Hand-soldering is not recommended.
- Rework is not recommended.
- Conformal coating can affect the performance of the module, which means that it is important to prevent the liquid from flowing into the module. The RF shields do not provide protection for the module from coating liquids with low viscosity; therefore, care is required while applying the coating. Conformal Coating of the module will void the warranty.
- 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 so at the customer's own risk and will void the module warranty. The numerous ground pins are adequate to provide optimal immunity to interferences.
- The modules contain components which are sensitive to Ultrasonic Waves. Use of any Ultrasonic Processes (cleaning, welding, etc.) may damage the module. The use of ultrasonic processes during the integration of the module into an end product will void the warranty.

6 Regulatory compliance

This chapter describes the limitations and requirements that a module integrator must take into consideration and is divided into different sections for each market.

⚠ This information in this section reflects u-blox' interpretation of different regulatory requirements of a radio device in each country/region. It does not cover all the requirements placed on an end-product that uses the radio module of u-blox or any other manufacturer.

☞ For the certification approval status of each country/region in which NINA-B50 series modules are approved for use, see the NINA-B50 series data sheet [2].

6.1 Country approvals

Each market has its own regulatory requirements that must be fulfilled, and NINA-B50 series modules must comply with the requirements for a radio transmitter in each of the listed markets. In some cases, limitations must be placed on an end-product that integrates a NINA-B50 series module to comply with the regulatory requirements.

u-blox modules are certified for use in different regions and countries, such as Europe, Great Britain, USA, and Canada.

6.2 European Union regulatory compliance

Detailed information about European Union regulatory compliance for the NINA-B50 series modules is available in the NINA-B50 EU Declaration of Conformity [15].

6.2.1 Output power limitation

The Radio Equipment Directive requires radio transmitters that have an Effective Isotropic Radiated Power (EIRP) of 10 dBm or more, to either implement an adaptivity feature or reduce its medium utilization.

Since Bluetooth low energy does not support either adaptivity or reduced medium utilization, a NINA-B50 Bluetooth LE implementation on the European market must have an EIRP of less than 10 dBm.

⚠ In the European market, it is the end product manufacturer that holds the responsibility that these limitations are followed. If the u-blox module integrator is not the end product manufacturer, the module integrator should make sure that this information is shared with the end product manufacturer.

EIRP is calculated as:

$$EIRP(dBm) = P_{TX}(dBm) - L(dB) + G_{TX}(dBi)$$

where, P_{TX} is the output power of the transmitter, L is the path loss of the transmission line between the transmitter and antenna, and G_{TX} is the maximum gain of the transmit antenna. Consider the following for each of these components:

- Output power:
  - The output power setting of the NINA-B50 series modules. An end product user must not be able to increase the setting above the 10 dBm EIRP limit, by
  - sending configuration commands etc.

- The operating temperature of the end product. The output power of a transmitter is typically increased as the ambient temperature is lowered. The operating temperature range of NINA-B50 professional grade modules -40 to +85 °C, and across this range the output power can typically vary by 1 dB. The output power at the lowest operating temperature (yielding the highest output power) must be considered for the EIRP calculation.

- Path loss – Long antenna cables or PCB traces, RF switches, etc. will attenuate the power reaching the antenna. This path loss should be measured and taken into consideration for the EIRP calculation.
- Antenna gain - The maximum gain of the transmit antenna must be considered for the EIRP calculation.

6.2.2 Radio Equipment Directive (RED) 2014/53/EU

NINA-B50 series modules comply with the essential requirements and other relevant provisions of Radio Equipment Directive (RED) 2014/53/EU.

6.2.3 Compliance with the RoHS directive

NINA-B50 series modules comply with the Directive 2011/65/EU (EU RoHS 2) and its amendment Directive (EU) 2015/863 (EU RoHS 3).

6.2.4 CE End-product regulatory compliance

6.2.4.1 Safety standard

In order to fulfill the safety standard EN 62368-1 [13], the NINA-B50 series modules must be supplied with a Class-2 Limited Power Source.

6.2.5 CE Equipment classes

In accordance with Article 1 of Commission Decision 2000/299/EC[4], NINA-B50 is defined as either Class-1 or Class-2 radio equipment, the end-product integrating NINA-B50 inherits the equipment class of the module.

☞ For guidance concerning end product marking in accordance with RED go to: http://ec.europa.eu/.

6.3 Great Britain regulatory compliance

For information about the regulatory compliance of NINA-B50 series modules against requirements and provisions in Great Britain, see also the NINA-B50 UKCA Declaration of Conformity [16].

6.3.1 UK Conformity Assessed (UKCA)

☞ The United Kingdom is made up of the Great Britain (including England, Scotland, and Wales) and the Northern Ireland. Northern Ireland continues to accept the CE marking. The following notice is applicable to Great Britain only.

NINA-B50 series modules have been evaluated against the essential requirements of the Radio Equipment Regulations 2017 (SI 2017 No. 1206, as amended by SI 2019 No. 696).

Guidance about using the UKCA marking: https://www.gov.uk/guidance/using-the-ukca-marking

[4] 2000/299/EC: Commission Decision of 6 April 2000 establishing the initial classification of radio equipment and telecommunications terminal equipment and associated identifiers.

6.4 FCC/ISED compliance

NINA-B50 series modules have received Federal Communications Commission (FCC) CFR47 Telecommunications, Part 15 Subpart C "Intentional Radiators" modular approval in accordance with Part 15.247 Modular Transmitter approval.

Any changes or modifications NOT explicitly APPROVED by u-blox AG may cause the module to not comply with the FCC rules part 15 thus void the user's authority to operate the equipment.

Model	FCC ID	ISED certification number
NINA-B501	XPYNINAB5	8595A-NINAB5
NINA-B506	XPYNINAB5	8595A-NINAB5

Table 10 : FCC and ISED Certification Number for the NINA-B50 series modules

6.4.1 FCC compliance statements

NINA-B50 series modules are for OEM integrations only. The end-product will be professionally installed in such manner that only the authorized antennas can be used.

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

1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits 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 the 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.

⚠ NINA-B50 series modules are intended for OEM integrators only. End-products that include u-blox modules must be professionally installed in such a way that only the authorized antennas included in the Pre-approved antennas list can be used.

⚠ If the antenna connector is easily accessible to the end-user, only Reversed Polarity SMA connectors are allowed in the final end user product.

⚠ The details of the module implementation in the host device (end-product) should remain confidential. Integrators are reminded not to share the module installation instructions to the end-user of the end-product (host device).

⚠ Any changes or modifications NOT explicitly APPROVED by u-blox AG may invalidate compliance with FCC rules part 15 and subsequently void the user's authority to operate the equipment.

⚠ Any changes to hardware, hosts, or co-location configuration may require new radiated emission and SAR evaluation and/or testing.

⚠ The end-product manufacturer (OEM integrator) is responsible for verifying the end-product compliance with FCC Part 15, subpart B limits for unintentional radiators through an accredited test facility.

6.4.2 RF exposure statement

6.4.2.1 ISED compliance

All transmitters regulated by ISED must comply with RF exposure requirements listed in RSS-102 - Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands). This module is approved for installation into mobile and/or portable host platforms and must not be co-located or operating in conjunction with any other antenna or transmitter except in accordance with Industry Canada's multi-transmitter guidelines. End-users must be provided with transmitter operating conditions for satisfying RF Exposure compliance.

To fulfil the requirements of the SAR evaluation Exemption limits defined in RSS-102 issue 5, an OEM integrator implementing NINA-B50 Bluetooth LE capability into an end-product must ensure a separation distance of 16 mm between the user (or bystander) and the antenna (or radiating element).

6.4.2.2 FCC compliance

All transmitters regulated by FCC must comply with RF exposure requirements. KDB 447498 General RF Exposure Guidance provides guidance in determining whether proposed or existing transmitting facilities, operations or devices comply with limits for human exposure to Radio Frequency (RF) fields adopted by the Federal Communications Commission (FCC).

NINA-B50 series modules are approved for installation into mobile and/or portable host platforms and must not be co-located or operating in conjunction with any other antenna or transmitter – except in accordance with FCC multi-transmitter guidelines.

To ensure that the max output power of NINA-B50 remains below the SAR Test Exclusion Threshold defined in KDB 447498 D01v06, an OEM integrator implementing NINA-B50 Bluetooth LE capability into an end-product must ensure a separation distance of 5 mm between the user (or bystander) and the antenna (or radiating element).

☞ KDB 996369 D03 section 2.4 (limited module procedures) is not applicable to NINA-B50 series modules.

☞ KDB 996369 D03 section 2.5 (trace antenna designs) is not applicable to NINA-B50 series modules.

6.4.3 End-product user manual instructions

6.4.3.1 ISED compliance

NINA-B50 series module is certified for use in Canada under Innovation, Science and Economic Development Canada (ISED) Radio Standards Specification (RSS) RSS-247 Issue 2 and RSSGen. The host product shall be properly labelled to identify the modules within the host product.

☞ The final host device, into which this RF Module is integrated" has to be labeled with an auxiliary label stating the IC of the RF Module, such as" Contains transmitter module IC: TBD.

☞ Le périphériquehôte final, danslequelce module RF estintégré "doitêtreétiqueté avec uneétiquetteauxiliaireindiquant le CI du module RF, tel que" Contient le module émetteur IC: TBD.

☞ This device contains license-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's license-exempt RSS(s). Operation is subject to the following two conditions:

(1) This device may not cause interference.

(2) This device must accept any interference, including interference that may cause undesired operation of the device.

☞ L'émetteur/récepteur exempt de licencecontenudans le présentappareilestconforme aux CNR d'Innovation, Sciences et Développementéconomique Canada applicables aux appareils radio exempts de licence. L'exploitationestautorisée aux deux conditions suivantes:

(1) L' appareil ne doit pas produire de brouillage.

(2) L' appareildoit accepter tout brouillageradioélectriquesubi, mêmesi le brouillageest susceptible d' encompromettre le fonctionnement.

6.4.4 End-product labeling requirements

6.4.4.1 ISED Compliance

The host product shall be properly labelled to identify the modules within the host product.

The Innovation, Science and Economic Development Canada certification label of a module shall be clearly visible at all times when installed in the host product; otherwise, the host product must be labelled to display the Innovation, Science and Economic Development Canada certification number for the module, preceded by the word "contains" or similar wording expressing the same meaning, as shown in Figure 21.

Le produit hôte devra être correctement étiqueté, de façon à permettre l'identification des modules qui s'y trouvent.

L'étiquette d'homologation d'un module d'Innovation, Sciences et Développement économique Canada devra être posée sur le produit hôte à un endroit bien en vue, en tout temps. En l'absence d'étiquette, le produit hôte doit porter une 25ecessair sur laquelle figure le numéro d'homologation du module d'Innovation, Sciences et Développement économique Canada, précédé du mot « contient », ou d'une formulation similaire allant dans le même sens et qui va comme suit:

This device contains FCC ID: XPYNINAB5 IC: 8595A-NINAB5

Figure 21: Example of an end product label

6.4.4.2 FCC Compliance

For an end product that uses the NINA-B50 modules, there must be a label containing, at least, the information shown in Figure 21.

The label must be affixed on an exterior surface of the end product such that it will be visible upon inspection in compliance with the modular approval guidelines developed by the FCC.

☞ In accordance with 47 CFR § 15.19, the end product shall bear the following statement in a conspicuous location on the device:
"This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions;
(1) this device may not cause harmful interference, and
(2) this device must accept any interference received, including interference that may cause undesired operation."

The label must be affixed on an exterior surface of the end product such that it will be visible upon inspection in compliance with the modular approval guidelines developed by the FCC.

When the device is so small or for such use that it is not practicable to place the statement above on it, the information shall be placed in a prominent location in the instruction manual or pamphlet supplied to the user or, alternatively, shall be placed on the container in which the device is marketed.

In case, where the final product will be installed in locations where the end-user is not able to see the FCC ID and/or this statement, the FCC ID and the statement shall also be included in the end-product manual.

6.4.5 End-product compliance

6.4.5.1 General requirements

- Any changes to hardware, hosts or co-location configuration may require new radiated emission and SAR evaluation and/or testing.
- Only authorized antenna(s) may be used.
- Any notification to the end user about how to install or remove the integrated radio module is NOT allowed.
- The approval of the modular transmitter in NINA-B50 series modules does not exempt the end product from being evaluated against any applicable regulatory demands. The evaluation of the end product shall be performed with the NINA-B50 series module installed and operating in a way that reflects the intended use case of the end product. The upper frequency measurement range for the end product evaluation is the 5th harmonic of 2.4 GHz as declared in 47 CFR Part 15.33 (b)(1).
- The following requirements apply to all products that integrate a radio module:
  - Subpart B - UNINTENTIONAL RADIATORS
    To verify that the composite device of host and module complies with the requirements of FCC part 15B the integrator shall perform sufficient measurements using equipment compliant with ANSI 63.4-2014.
  - Subpart C - INTENTIONAL RADIATORS
    The integrator must carry out sufficient verification measurements, using compliant ANSI 63.10-2013 equipment, to validate that the fundamental and out-of-band emissions of the transmitter part of the composite device comply with the requirements of FCC part 15C.

  When the items listed above are fulfilled, the end product manufacturer can use the authorization procedures as mentioned in Table 1 of 47 CFR Part 15.101, before marketing the end product. This means the customer has to either market the end product under a Suppliers Declaration of Conformity (SDoC) or to certify the product using an accredited test lab.

6.4.5.2 Co-location (simultaneous transmission)

If the module is to be co-located with another transmitter, additional measurements for simultaneous transmission is required. The results must be added to the grant file as a Class II Permissive Change.

6.4.5.3 Adding a new antenna for authorization

If the authorized antennas and/or antenna trace design cannot be used, the new antenna and/or antenna trace designs must be added to the grant file. This is done by a Class I Permissive Change or a Class II Permissive Change, depending on the specific antenna and antenna trace design.

- Antennas of the same type and with less or same gain as an already approved antenna can be added under a Class I Permissive Change.
- Antenna trace designs deviating from the u-blox reference design and new antenna types are added under a Class II Permissive Change.

⚠ Integrators who want to refer to the u-blox FCC ID / IC certification ID should contact their local support team to discuss the Permissive Change Process. Class II Permissive Changes will be subject to NRE costs.

6.5 Japan radio equipment compliance

☞ For the certification approval status of each country/region in which NINA-B50 series modules are approved for use, see the NINA-B50 series data sheet [2].

6.5.1 Compliance statement

NINA-B50 series modules comply with the Japanese Technical Regulation Conformity Certification of Specified Radio Equipment (ordinance of MPT N°. 37, 1981), Article 2, Paragraph 1:

Item 19 "2.4 GHz band wide band low power data communication system".

6.5.2 End product labelling requirement

End products based on NINA-B50 series modules and targeted for distribution in Japan must be affixed with a label with the “Giteki” marking, as shown in Figure 22. The marking must be visible for inspection.

☞ xxx-yyyyyy must be replaced with the correct ID.

Figure 22: Giteki “R” mark and NINA-B50 MIC certification number

6.5.3 End product user manual requirement

As the MIC ID is not included on the NINA-B50 marking, the end product manufacturer must include a copy of the NINA-B50 Japan Radio Certificate in the end product technical documentation.

6.6 NCC Taiwan compliance

☞ For the certification approval status of each country/region in which NINA-B50 series modules are approved for use, see the NINA-B50 series data sheet [2]

6.6.1 Taiwan NCC Warning Statement

取得審驗證明之低功率射頻器材，非經核准，公司、商號或使用者均不得擅自變更頻率、加大功率或變更原設計之特性及功能。

低功率射頻器材之使用不得影響飛航安全及干擾合法通信；經發現有干擾現象時，應立即停用，並改善至無干擾時方得繼續使用。前述合法通信，指依電信管理法規定作業之無線電通信。低功率射頻器材須忍受合法通信或工業、科學及醫療用電波輻射性電機設備之干擾。

系統廠商應於平台上標示「本產品內含射頻模組： XXXyyyLPDzzzz-x」字樣。

Statement translation:

- Without permission granted by the NCC, any company, enterprise, or user is not allowed to change frequency, enhance transmitting power, or alter original characteristic as well as performance to an approved low power radio-frequency device.
- The low power radio-frequency devices shall not influence aircraft security and interfere legal communications; If any interference is found or suspected, the user shall immediately cease operating the equipment until the interference has been prevented. The said legal communications means radio communications is operated in compliance with the Telecommunications Act. The low power radio-frequency devices must accept interference from legal communications or ISM radio wave radiated devices.

6.6.2 Labeling requirements for end product

End products based on NINA-B50 series modules and targeted for distribution in Taiwan must carry labels with the textual and graphical elements shown below.

☞ xxxxxxxyyyyyyy must be replaced with the correct ID.

Contains Transmitter Module

內含發射器模組: xxxxxxxyyyyyyy

Other wording can be used, but only if the meaning of original messaging remains unchanged. The label must be physically attached to the product and made clearly visible for inspection.

6.7 KCC South Korea compliance

☞ For the certification approval status of each country/region in which NINA-B50 series modules are approved for use, see the NINA-B50 series data sheet [2].

NINA-B50 series modules are designed for certification by the Korea Communications Commission (KCC).

End products based on NINA-B50 series modules and targeted for distribution in South Korea must carry labels containing the KCC logo and certification number, as shown below. This information must also be included in the product user manuals.

☞ x-x-xx-x must be replaced with the correct ID.

x-x-xx-x

☞ The height of the KCC logo must be at least 5 mm.

6.8 Australia and New Zealand regulatory compliance

☞ For the certification approval status of each country/region in which NINA-B50 series modules are approved for use, see the NINA-B50 series data sheet [2].

The NINA-B50 modules are designed for compliance with the standards made by the Australian Communications and Media Authority (ACMA).

The modules are compliant with AS/NZS 4268:2012 standard – Radio equipment and systems – Short range devices – Limits and methods of standard measurement. The test reports for NINA-B50 modules can be used as part of the product certification and compliance folder. For more information on the test reports, email the respective support team at the local mail address in your region. To meet the overall Australian and/or New Zealand end product compliance standards, the integrator must create a compliance folder containing all the relevant compliance test reports such as RF, EMC, electrical safety and DoC (Declaration of Conformity). It is the responsibility of the integrator to know what is required in the compliance folder for ACMA compliance.

For more information on Australia compliance, refer to the Australian Communications and Media Authority web site http://www.acma.gov.au/.

For more information on New Zealand compliance, refer to the New Zealand Radio Spectrum Management Group web site www.rsm.govt.nz.

6.9 Safety compliance

For compliance with safety standard EN 62368-1, NINA-B50 series modules must be supplied with a Class-2 Limited Power Source.

6.10 Pre-approved antennas

This section describes external antennas that are pre-approved for use with NINA-B5 modules. The "Approvals" field featured in the given table data defines the certifications in which each pre-approved antenna is included. The definitions for each approval field are:

- FCC - The antenna is included in the FCC certifications and approved for use in countries that accept the FCC radio approvals, primarily US.
- ISED - The antenna is included in the ISED certifications and approved for use in countries that accept the ISED radio approvals, primarily Canada.
- RED - The antenna is included in the ETSI test reports and approved for use in countries that accept the Radio Equipment Directive, primarily the European countries.
- MIC - The antenna is included in the Japanese government affiliated MIC test reports and approved for use in the Japanese market.
- NCC - The antenna is included in the Taiwan NCC test reports and approved for use in Taiwan.
- KCC - The antenna is included in the KCC test reports and approved for use in South Korea.
- ACMA – The antenna is included in the Australia and New Zealand test reports and approved for use in Australia and New Zealand.

☞ Note that not all antennas are approved for use in all markets/regions.

☞ This radio transmitter 8595A-NINAB5 has been approved by Innovation, Science and Economic Development Canada to operate with the antenna types listed below, with the maximum permissible gain indicated. Antenna types not included in this list that have a gain greater than the maximum gain indicated for any type listed are strictly prohibited for use with this device. "

Le présent émetteur radio 8595A-NINAB5 a été approuvé par Innovation, Sciences et Développement économique Canada pour fonctionner avec les types d'antenne énumérés ci-dessous et ayant un gain admissible maximal. Les types d'antenne non inclus dans cette liste, et dont le gain est supérieur au gain maximal indiqué pour tout type figurant sur la liste, sont strictement interdits pour l'exploitation de l'émetteur.

6.10.1 Antenna accessories

Name	U.FL to SMA adapter cable
Connector	U.FL and SMA jack (outer thread and pin receptacle)
Impedance	50 Ω
Minimum cable loss	0.5 dB, The cable loss must be above the minimum cable loss to meet the regulatory requirements. Minimum cable length 100 mm.
Comment	The SMA connector can be mounted in a panel.
Approval	RED, UKCA, MIC, KCC and ACMA

Name	U.FL to Reverse Polarity SMA adapter cable
Connector	U.FL and Reverse Polarity SMA jack (outer thread and pin)
Impedance	50 Ω
Minimum cable loss	0.5 dB. The cable loss must be above the minimum cable loss to meet the regulatory requirements. Minimum cable length 100 mm.
Comment	The Reverse Polarity SMA connector can be mounted in a panel.
Approval	FCC, ISED, RED, UKCA, MIC, NCC, KCC and ACMA

6.10.2 Antennas

NINA-B506 internal antenna	
Manufacturer	Abracon
Gain	+3 dBi
Impedance	N/A
Size (HxWxL)	1.1 x 3.4 x 10 mm
Type	PCB trace
Comment	PCB antenna on NINA-B506. The antenna should not be mounted inside a metal enclosure.
Approval	FCC, ISED, RED, UKCA, MIC, NCC, KCC and ACMA

GW.26 2.4 GHz monopole antenna SMA, GW.26.0111	
Manufacturer	Taoglas
Polarization	Vertical
Gain	+2.24 dBi
Impedance	50 Ω
Size	Ø 7.9 x 30.0 mm
Type	Monopole
Connector	SMA (M) .
Comment	To be mounted with a U.FL to SMA adapter cable.
Approval	RED, UKCA, MIC, KCC and ACMA

Wi-Fi / Bluetooth external antenna, PRO-EX-296	
Manufacturer	Abracon
Polarization	Vertical
Gain	+3.0 dBi
Impedance	50 Ω
Size	Ø 12.0 x 28.0 mm
Type	Monopole
Cable length	100 mm
Connector	U.FL. connector
Comment	This antenna requires to be mounted on a metal ground plane for best performance. To be mounted with a U.FL connector. For information on how to integrate the U.FL connector, see RF connector design.
Approval	FCC, ISED, RED, UKCA, MIC, NCC, KCC and ACMA

Wi-Fi / Bluetooth / Bluetooth LE external whip antenna, PRO-EX-333	
Manufacturer	Abracon
Polarization	Vertical
Gain	+3.0 dBi
Impedance	50 Ω
Size	Ø 10 x 83 mm
Type	Monopole
Connector	Reverse Polarity SMA plug (inner thread and pin receptacle)
Comment	To be mounted with a U.FL to Reverse Polarity SMA adapter cable. An SMA version antenna is also available but not recommended for use (PN PRO-EX-332).
Approval	FCC, ISED, RED, UKCA, MIC, NCC, KCC and ACMA

Wi-Fi / Bluetooth / Bluetooth LE external antenna, PRO-EX-348	
Manufacturer	Abracon
Gain	+3.0 dBi
Impedance	50 Ω
Size	Ø12 x 28 mm
Type	Patch
Cable length	100 mm
Connector	Reverse Polarity SMA plug (inner thread and pin receptacle)
Comment	This antenna requires to be mounted on a metal ground plane for best performance. To be mounted with the U.FL to Reverse Polarity SMA adapter cable.
Approval	FCC, ISED, RED, UKCA, MIC, NCC, KCC and ACMA

7 Product testing

7.1 u-blox in-line production test

As part of our focus on high quality products, u-blox maintain stringent quality controls throughout the production process. This means that all units in our manufacturing facilities are fully tested and that any identified defects are carefully analyzed to improve future production quality.

The Automatic test equipment (ATE) deployed in u-blox production lines logs all production and measurement data – from which a detailed test report for each unit can be generated.
Figure 23 shows the ATE typically used during u-blox production.

u-blox in-line production testing includes:

- Digital self-tests (firmware download, MAC address programming)
- Measurement of voltages and currents
- Functional tests (host interface communication)
- Digital I/O tests
- Measurement and calibration of RF characteristics in all supported bands, including RSSI calibration, frequency tuning of reference clock, calibration of transmitter power levels, etc.
- Verification of Wi-Fi and Bluetooth RF characteristics after calibration, like modulation accuracy, power levels, and spectrum, are checked to ensure that all characteristics are within tolerance when the calibration parameters are applied.

Figure 23: Automatic test equipment for module test

7.2 OEM manufacturer production test

As all u-blox products undergo thorough in-series production testing prior to delivery, OEM manufacturers do not need to repeat any firmware tests or measurements that might otherwise be necessary to confirm RF performance. Testing over analog and digital interfaces is also unnecessary during an OEM production test.

OEM manufacturer testing should ideally focus on:

- Module assembly on the device; it should be verified that:
  - Soldering and handling process did not damage the module components
  - All module pins are well soldered on device board
  - There are no short circuits between pins
- Component assembly on the device; it should be verified that:
  - Communication with host controller can be established
  - The interfaces between module and device are working
  - Overall RF performance test of the device including antenna

In addition to this testing, OEMs can also perform other dedicated tests to check the device. For example, the measurement of module current consumption in a specified operating state can identify a short circuit if the test result deviates that from that taken against a “Golden Device”.

The standard operational module firmware and test software on the host can be used to perform functional tests (communication with the host controller, check interfaces) and perform basic RF performance testing. Special manufacturing firmware can also be used to perform more advanced RF performance tests.

7.2.1 “Go/No go” tests for integrated devices

A “Go/No go” test compares the signal quality of the Device under Test (DUT) with that of “Golden Device” in a location with a known signal quality. This test can be performed after establishing a connection with an external device.

A very simple test can be performed by just scanning for a known Bluetooth low energy device and checking that the signal level (Received Signal Strength Indicator (RSSI) is acceptable.

☞ Tests of this kind may be useful as a “go/no go” test but are not appropriate for RF performance measurements.

Go/No go tests are suitable for checking communication between the host controller and the power supply. The tests can also confirm that all components on the DUT are well soldered.

A basic RF functional test of the device that includes the antenna can be performed with standard Bluetooth low energy devices configured as remote stations. In this scenario, the device containing NINA-W and the antennas should be arranged in a fixed position inside an RF shield box. The shielding prevents interference from other possible radio devices to ensure stable test results.

Appendix

A Glossary

Abbreviation	Definition
ABS	Acrylonitrile butadiene styrene
ADC	Analog to Digital Converter
ATE	Automatic Test Equipment
LE	Bluetooth Low Energy
CTS	Clear To Send
DCX	Data/Command Signal
DFU	Device Firmware Update
DDR	Dual-Data Rate
EMC	Electro Magnetic Compatibility
EMI	Electro Magnetic Interference
ESD	Electro Static Discharge
FCC	Federal Communications Commission
GATT	Generic ATTribute profile
GND	Ground
GPIO	General Purpose Input/Output
I2C	Inter-Integrated Circuit
IDE	Integrated Development Environment
IEEE	Institute of Electrical and Electronics Engineers
LDO	Low Drop Out
LED	Light-Emitting Diode
MAC	Media Access Control
MISO	Main Input, Sub Output
MOSI	Main Output, Sub Input
MSL	Moisture Sensitivity Level
NBU	Narrow Band Unit
NFC	Near Field Communication
NSMD	Non Solder Mask Defined
PCB	Printed Circuit Board
PIFA	Planar Inverted-F Antenna
PC	Polycarbonate
QDEC	Quadrature DECoder
QSPI	Quad Serial Peripheral Interface
RF	Radio Frequency
RoHS	Restriction of Hazardous Substances
RSSI	Received Signal Strength Indicator
RTS	Request to Send
RXD	Receive Data
SCL	Signal Clock
SDL	Specification and Description Language
SMA	SubMiniature version A
SMD	Solder Mask Defined

Abbreviation	Definition
SMPS	Switching Mode Power Supply
SMT	Surface-Mount Technology
SPI	Serial Peripheral Interface
SWD	Serial Wire Debug
Thread	Networking protocol for Internet of Things (IoT) "smart" home automation devices to communicate on a local wireless mesh network
THT	Through-Hole Technology
TXD	Transmit Data
UART	Universal Asynchronous Receiver/Transmitter
UICR	User Information Configuration Registers
USB	Universal Serial Bus
VCC	IC power-supply pin
VSWR	Voltage Standing Wave Ratio
Zigbee	Open standard protocol, full-stack solution for most large smart home ecosystem providers

Table 11: Explanation of the abbreviations and terms used

B Antenna reference designs

Designers can take full advantage of NINA-B50's Single-Modular Transmitter certification approval by integrating the u-blox reference design into their products. This approach requires compliance with the following rules:

- Only listed antennas can be used. Refer to NINA-B50 series data sheet [2] for the listed antennas.
- Schematics and parts used in the design must be identical to the reference design. Use only parts validated by u-blox for antenna matching.
- PCB layout must be identical to the one provided by u-blox. Implement one of the reference designs described in this section or contact u-blox.
- The designer must use the PCB stack-up provided by u-blox. RF traces on the carrier PCB are part of the certified design.

When using the NINA-B501 with this antenna reference design, the circuit trace layout must be made in strict compliance with the antenna reference design described in this appendix.

B.1 Reference design for external antennas (U.FL connector)

The reference design uses a U.FL micro-coaxial connector to connect the external antenna via a 50 Ω coaxial cable. Figure 24 shows the placement of the connector in relation and module footprint. The components connected to the RF trace must be kept as shown in the reference design.

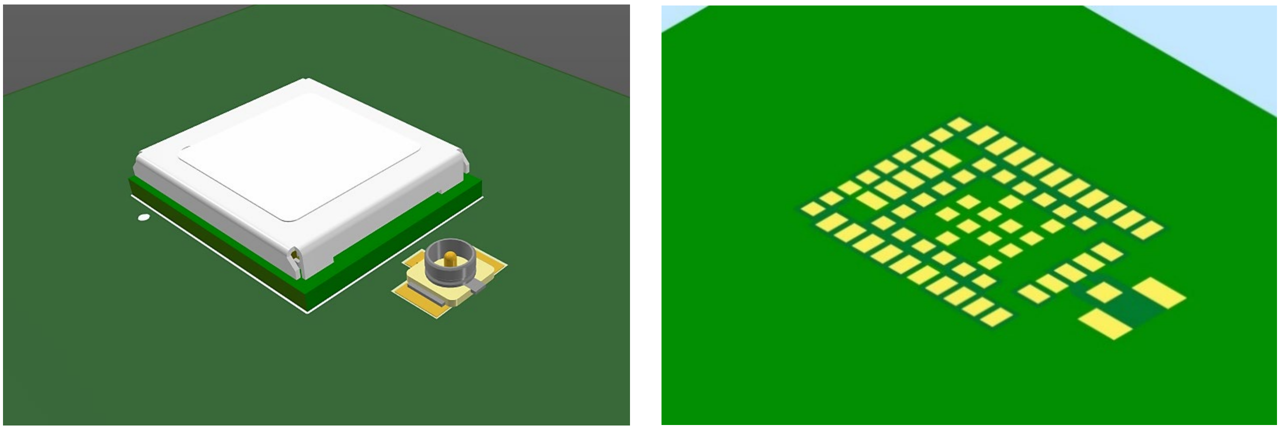
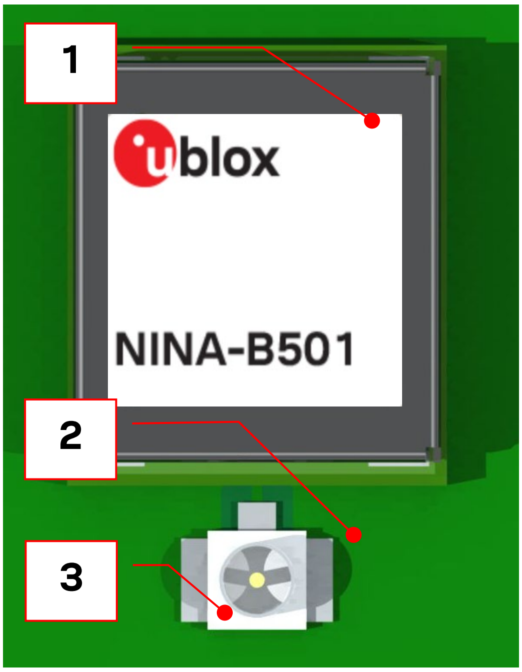


Figure 24: U.FL connector placement (left) and module footprint (right)

B.1.1 Floor plan

Figure 25 shows the critical components and positioning of the copper traces in the reference design. The itemized references are described in Table 12.



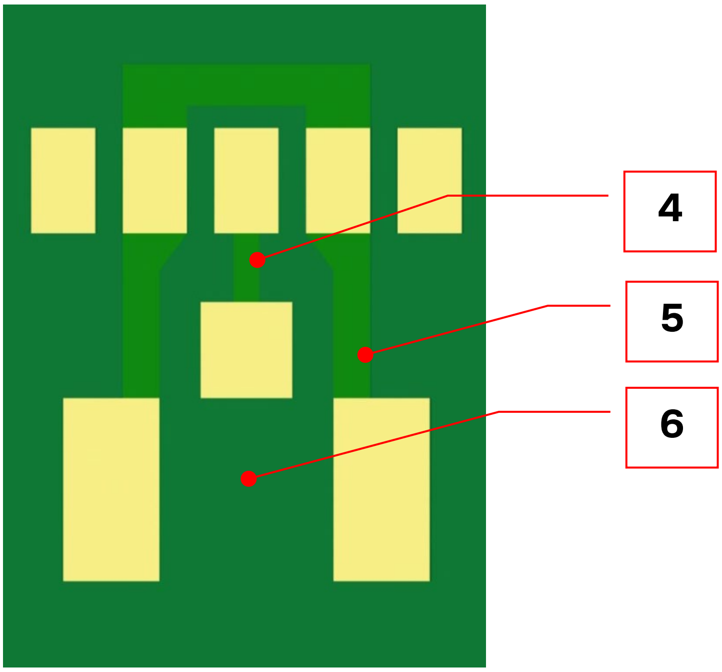


Figure 25: NINA-B501 antenna reference design

Reference	Part	Manufacturer	Description
1	NINA-B501	u-blox	NINA-B50 module with antenna pin
2	Carrier PCB		Should have a solid GND inner layer underneath and around the RF components (vias and small openings are allowed)
3	U.FL-R-SMT-1(10)	Hirose	Coaxial connector, 0 – 6 GHz, for external antenna
4	RF trace		Antenna coplanar microstrip, matched to 50 Ω
5	GND trace		Minimum required top layer GND-trace. See also Figure 27.
6	Copper keep-out		Keep this area free from any copper on the top layer

Table 12: Antenna reference design – item descriptions

B.1.2 RF trace specification

The 50 Ω coplanar micro-strip dimensions used in the reference design are shown in Figure 26 and described in Table 12. GND stitching vias should be used around the RF trace to ensure a proper GND connection. No other components are allowed within this area.

The solid GND layer beneath the "top layer" shall surround at least the entire RF trace and connector. No signal traces are allowed to be routed on the GND layer within this area but vias and small openings are allowed.

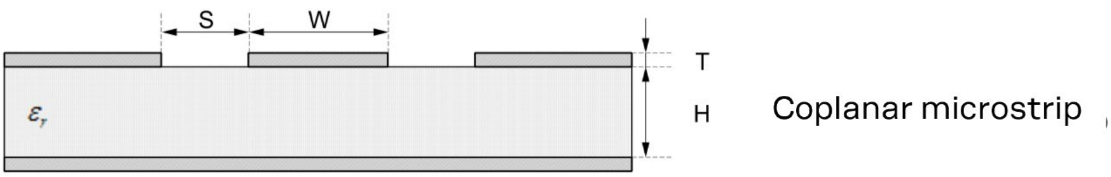


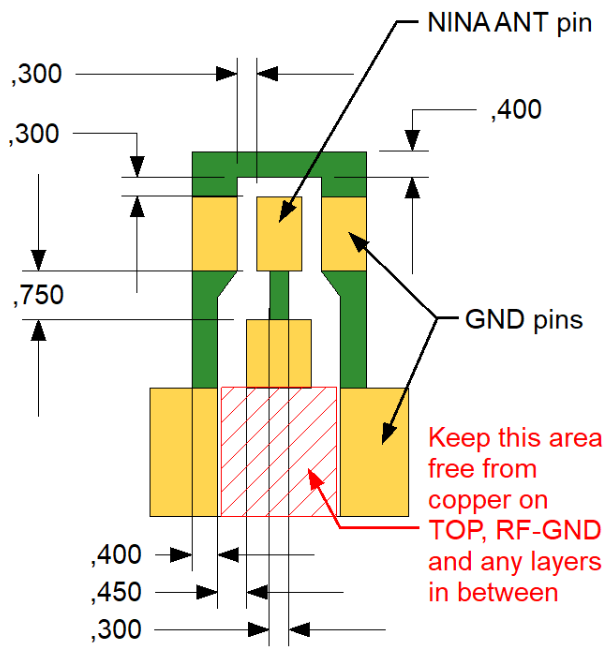
Figure 26: Coplanar micro-strip dimension specification

Reference	Item	Value
S	Spacing	200 +/- 50 µm
W	Conductor width	300 +/- 30 µm (match as close to 50 Ω as possible)
T	Copper and plating/surface coating thickness	35 +/- 15 µm
H	Conductor height	150 +/- 20 µm
ε_r	Dielectric constant (relative permittivity)	3.77 +/- 0.5 @ 2 GHz

Table 13: Coplanar micro-strip specification

☞ The GND spacing requirements of the NINA ANT and U.FL connector RF pins are greater than the spacing requirement of a 50 Ω coplanar microstrip. However, when using the conductor width and height specified in Table 12, the increased spacing to GND does not significantly affect the trace impedance for short trace lengths. Therefore, the impedance is still close to 50 Ω.

Figure 27 shows the **ANT** and **GND** pins, with the dimensions of the U.FL connector, and the copper-free area on RF-GND.



All dimensions are shown in mm

Figure 27: RF trace and minimum required GND trace of the U.FL antenna connector reference design

Related documents

[1] Packaging information reference, UBX-14001652
[2] NINA-B50 series data sheet, UBX-22021114
[3] NINA-B50 series product summary, UBX-23007102
[4] NXP K32W148 Datasheet https://www.nxp.com/docs/en/data-sheet/K32W1480.pdf
[5] NXP K32W1480 Reference Manual https://www.nxp.com/webapp/Download?colCode=K32W1480RM
[6] NXP KW45 Datasheet https://www.nxp.com/docs/en/data-sheet/KW45.pdf
[7] NINA nested design and migration, application note, UBX-17065600
[8] EVK-NINA-B50 user guide, UBX-23007761
[9] JEDEC J-STD-020C - Moisture/Reflow Sensitivity Classification for Non Hermetic Solid State Surface Mount Devices
[10] IEC EN 61000-4-2 - Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test
[11] ETSI EN 301 489-1 - Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements
[12] IEC61340-5-1 - Protection of electronic devices from electrostatic phenomena – General requirements
[13] ETSI EN 60950-1:2006 - Information technology equipment – Safety – Part 1: General requirements
[14] JESD51 – Overview of methodology for thermal testing of single semiconductor devices
[15] NINA-B50 EU Declaration of conformity (EU DoC), UBXDOC-465451970-3248
[16] NINA-B50 UKCA Declaration of conformity (UKCA DoC), UBXDOC-465451970-3251
[17] Tag-Connect pad connector - http://www.tag-connect.com/TC2030-CTX
[18] Getting Started with MCUXpresso SDK CMSIS Packs: https://www.nxp.com/webapp/Download?colCode=MCUXSDKPACKSGSUG
[19] MCUXpresso SDK API Reference Manual: https://mcuxpresso.nxp.com/api_doc/dev/3397/
[20] Guidance on software or network configuration of Non-SDR devices, OET KDB 594280 D01
[21] Software security requirements for U-NII devices, OET KDB 594280 D02
[22] u-blox short range open CPU repository, https://github.com/u-blox/u-blox-sho-OpenCPU
[23] Managing Lifecycles on KW45 and K32W148, AN13931 (NXP login required)
[24] Programming the KW45 flash for Application and Radio firmware via Serial Wire Debug during mass production, AN14003 (NXP login required)
[25] MCUXpresso Secure Provisioning Tool User Guide, MCUXSPTUG (NXP login required)
[26] MCUXpresso SDK, https://www.nxp.com/design/designs/mcuxpresso-software-development-kit-sdk:MCUXpresso-SDK
[27] MCUXpresso IDE, https://www.nxp.com/design/software/development-software/mcuxpresso-software-and-tools-/mcuxpresso-integrated-development-environment-ide:MCUXpresso-IDE
[28] MCUXpresso SDK builder, https://mcuxpresso.nxp.com/en/welcome
[29] Debug Authentication on KW45/K32W148, AN14158 (NXP login required)

☞ For product change notifications and regular updates of u-blox documentation, register on our website, www.u-blox.com.

Revision history

Revision	Date	Name	Comments
R01	26-Jun-2023	lkis	Initial release
R02	02-Nov-2023	lkis, mape, abfa	Updated document status to “Advance information” in Document information. Added Battery section. Added figures to describe Power efficient configuration and Power switch configurations in Power supply configuration section. Updated Power modes section. Revised sections describing Data interfaces, Other Digital interfaces, Analog interfaces, and Debug interfaces. Removed content duplicated in the data sheet and included related references. Updated Open CPU software. Included minor updates and documentation improvements throughout the document.
R03	15-Mar-2024	lkis	Changed document status to Early production information. Removed previously duplicated NINA-B50 block diagram (maintained in the data sheet). Updated antenna list in Antennas. Added automotive grade variant information in Table 1. Updated power supply connections for Power efficient and Power switch configurations in Figure 3 and Figure 4. Added 2.4.6 FlexCAN and 2.4.7 LIN sections. Added Output power limitation section and Antenna reference designs. Updated country approvals in Regulatory compliance. Included minor updates and documentation improvements throughout the document.

Contact

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