NM180100

LoRa® Bluetooth® 5 Low Energy Module

# Hardware Integration Manual

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# 1. Introduction

## 1.1. Overview

The successful development of a wireless product requires a system level approach where all disciplines must be taken into consideration during the planning stage. There are many approaches to product development. A typical development workflow begins with the industrial design including overall cosmetic of the product and the user interaction elements. Afterwards, an antenna floor plan is developed to identify the general locations of all the antennas that would exist in the product. This is followed by the general mechanical stack-up such as where the battery and the PCB would be located. Finally, the major electrical component placement is determined such as wireless transceiver or power management IC locations. A detailed exposition of wireless product development is beyond the scope of the present discussion. This manual focuses on the necessary requirements for a successful integration of the NM180100 and the corresponding antenna design considerations.

The NM180100 is a highly integrated device with significant signal conditioning integrated onto the module. Careful PCB layout is important to obtain the optimal performance while meeting regulatory requirements. The goal of this document is to enable designer engineers without RF or analog background to achieve the optimal performance from the NM180100 while minimizing the fabrication cost and the board layout effort.

## 1.2. NM180100 Description

The NM180100 integrates an Ambiq Apollo3 microcontroller and a Semtech SX1262 LoRa transceiver supporting the 868MHz and 915MHz ISM bands. Bluetooth 5 Low Energy is integrated with the Apollo3 microcontroller. The Apollo 3 possesses a secure interface (ISO 7816) including secure boot and secure OTA firmware upgrade over Bluetooth. The operating system, radio drivers and wireless communication protocol stacks are provided in the form of source code. This enables the system integrator to fully leverage the module's existing regulatory grants (such as IC or FCC) where applicable. Full programmability allows the module to function as a host while maintaining all RF, mixed-signals, and digital functions in a single device without the need for additional microcontrollers. A block diagram of the major components is shown in Figure 1.

# 2. Application PCB Consideration

## 2.1. PCB Stackup Recommendations

The NM180100 module is designed to be routable in a conventional PCB stackup without making use of HDI technologies such as micro or blind/buried vias. While NM180100 can be integrated into a 2-layer stack in simple applications, a 4-layer stackup is recommended. Figure 3 shows the PCB stackup used in the NM180100EVB where

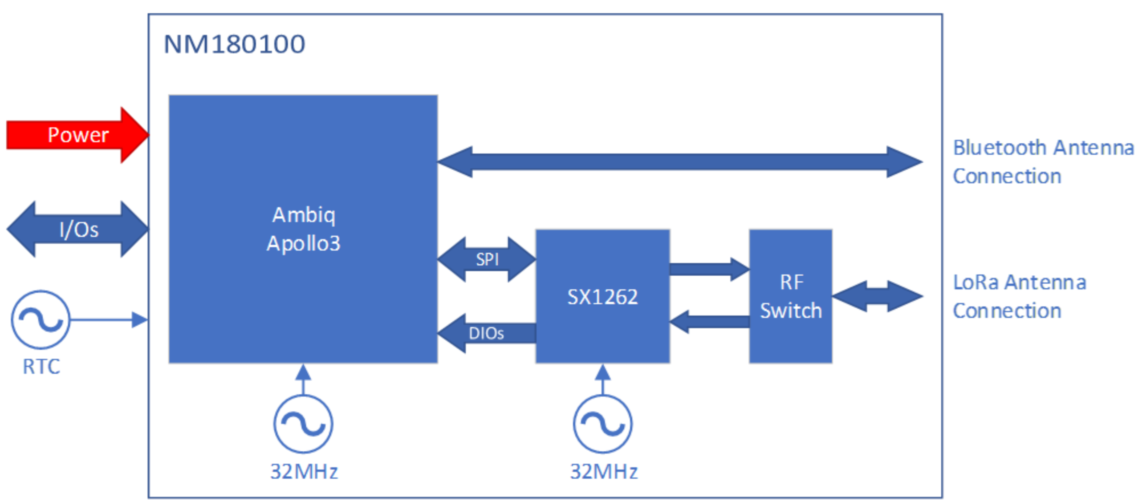


*Figure 1 NM module block diagram*

the NM180100 is mounted on Layer 1. Layer 1 and 4 are generally flooded with the ground plane. Digital/analog signals and power are routed in Layer 2 and Layer 3 whenever possible. Power traces are pulled back from the board edges to decrease the risk of shorting from the board edges and to minimize E-field emissions due to noisy power source. All the RF traces and the antenna pattern are routed on layer 1 with the transmission line reference in Layer 2. To keep the RF section isolated from the noisy transient digital section, the layer 2 ground reference beneath the RF traces are free of other signal traces. The reasons for this routing arrangement are to 1) minimize wideband emissions caused by switching digital signals and 2) facilitate applications implementing internal antennas where the entire PCB is utilized as a part of the antenna. Also shown in Figure 3 is the via stack where only through holes are used. Combining with a pad pitch of 1.35mm, this allows the application board to be fabricated with a single drilling steps without micro or blind vias.

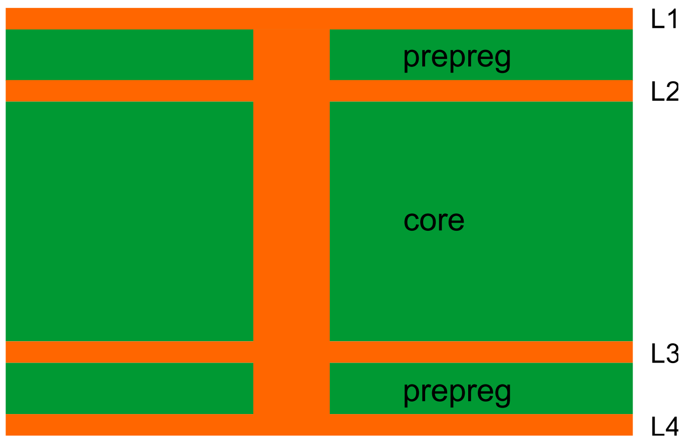


*Figure 3 PCB stack-up used in the evaluation board.*

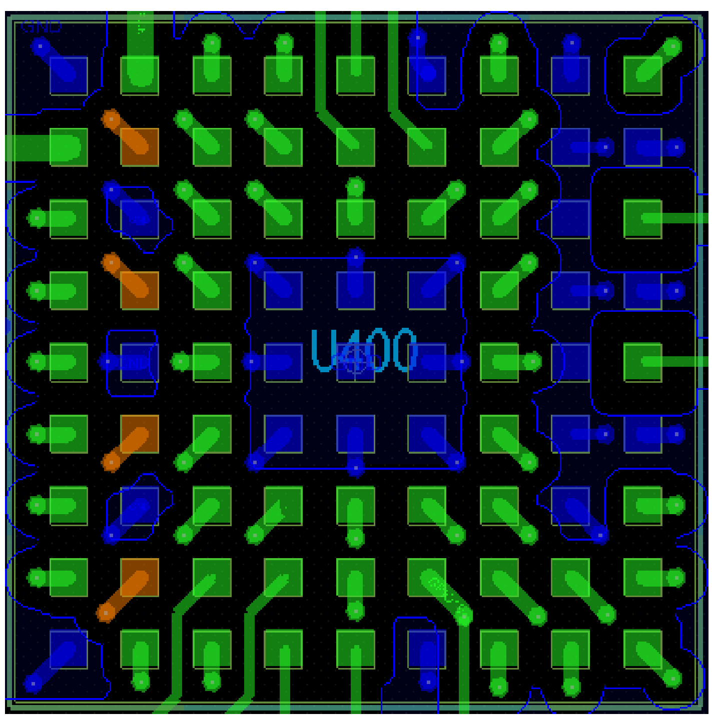


*Figure 2 NM180100 fanout in the evaluation board.*

## 2.2. Fanout and Trace Spacing Guidelines

The NM180100 uses an 81-pad land grid array, 12.8mm x 12.8mm package. The pitch in between the pins is 1.35mm. There are nine ground pads in the center of the package. This means only three rows of fanout is required. Since the spacing in between adjacent pads is 0.7mm, two rows of pads could be fanout in a single layer. In other words, the entire module can be fanout with two layers. The antenna pads are placed on the outer edges of the NM180100 package such that critical signals can be routed without transitioning to different layers.

Figure 2 shows the fanout scheme of the NM180100EVB where fanout vias are used. In the NM180100EVB, all the signals and power rails are completely routed in three layers. The top and bottom layer are used as both an EMI shield. Signal routing in the top layer are minimized and there are no signal traces in the bottom layer.

## 2.3. Placement and Routing Recommendations

This section provides a guideline on the proper placement of the NM180100 and routing strategy in order to achieve the best possible performance. Figure 4 shows the general placement of the NM180100 in an application PCB. The diagram assumes that the antenna trace is located on the PCB as this scenario has the highest placement and routing constraints compared to an external off-board antenna. As shown in Figure 4, the antenna trace is located in a keepout zone near the top edge of the PCB. The keepout zone should be freed from all other traces and metallic objects, such as batteries or metal housings, as they introduce significant antenna performance degradation. If metal objects are unavoidable in the keepout zone, they must be electrically disconnected from the system ground and must be smaller than the occupied area of the antenna trace.

The antenna feed point should be located near one of the corners of the ground plane on the PCB as shown in Figure 5. At low frequency of operation such as 800MHz to 1GHz, a corner excitation generally maximizes the antenna bandwidth. In general, the antenna would not be connected directly to the NM180100 and additional matching networks would be placed between the antenna and the NM180100. The NM180100 should be placed in such a way that the antenna pads are located close to the antenna feed point in order to minimize the insertion loss introduced by long RF traces.

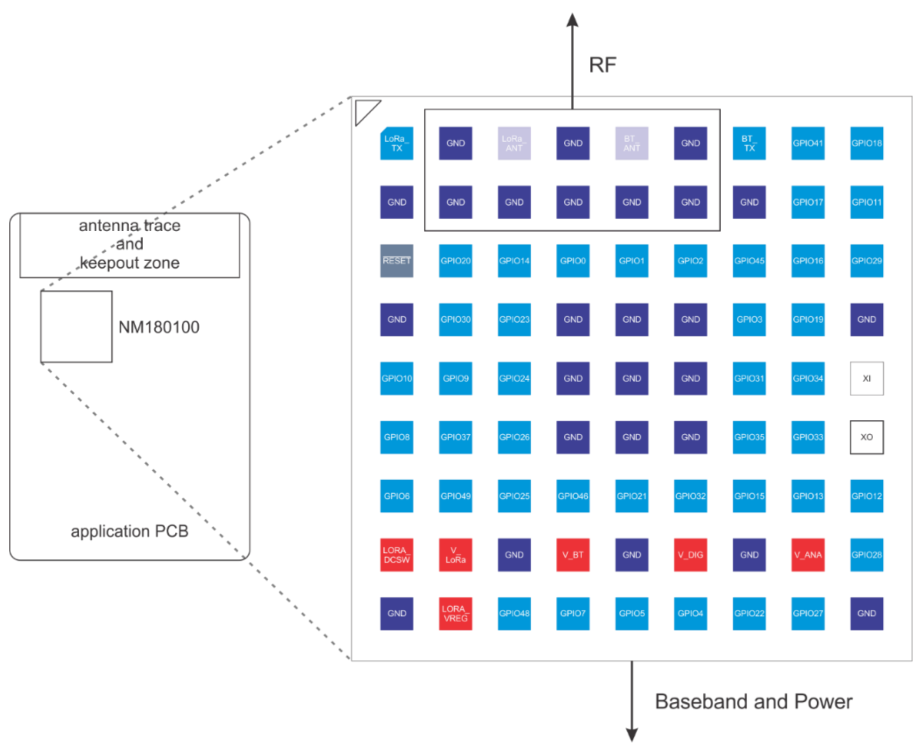


*Figure 4 NM180100 placement and signal routing guidelines*

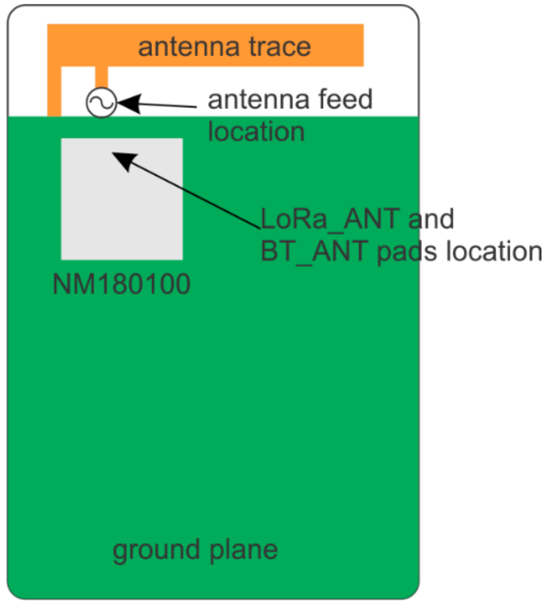


*Figure 5 Antenna feed point and the relative placement of the NM180100.*

The RF traces are the most critical and must be routed with the highest priority. In the NM180100EVB, the RF traces are routed as microstrips in the top layer with the ground reference in layer 2. The ground reference must remain continuous from the antenna pads of the module to the antenna launch point. Non-RF signal/power routing on the outer layers and near the antenna or the RF section are discouraged. This is because any disruption in the ground plane will introduce discontinuity of the antenna ground currents which may lead to degradation in antenna performance.

# 3. Application Hardware Implementation

## 3.1. Minimal Implementation

NM180100 is highly integrated and minimal amount of support circuitry is required to bring up an application. Figure 6 shows the minimal component requirement for a typical IoT sensor application. The example assumes both LoRa and BLE functionalities. For LoRa only application, the component count can be further reduced. In this context, the BLE DC decoupling capacitor and the diplexer can be removed.

## 3.2. Power Supplies

The NM180100 exposes four power supply rails for digital (V_DIG), analog (V_ANA), BLE (V_BT), and LoRa (V_LORA). The four rails can be supplied from either a single source or multiple sources. The NM180100 possesses on-module bypass capacitors. No external capacitors are needed for the power supply rails. When using multiple power sources for each rail, the voltage of each rail must be identical. This is to ensure that the digital I/O voltage level is compatible among the various components in the NM180100. The only power up sequence when using multiple power sources is that both the digital (V_DIG) and the analog (V_ANA) must be powered up together.

The flexibility of having different sources for each rail provides the designer the ability to completely shut down a section if there is prolong inactivity. For example, if a LoRa application requires only one transmission per day, the entire LoRa radio circuit can be powered off.

The NM180100 also exposes the inductor connections (LORA_DCSW and LORA_VREG) to the Semtech SX1262 on-chip DC-DC switcher for the LoRa transceiver. In applications where cost is less sensitivity, the designer can connect an external inductor across the two terminals that further minimizes power dissipation.

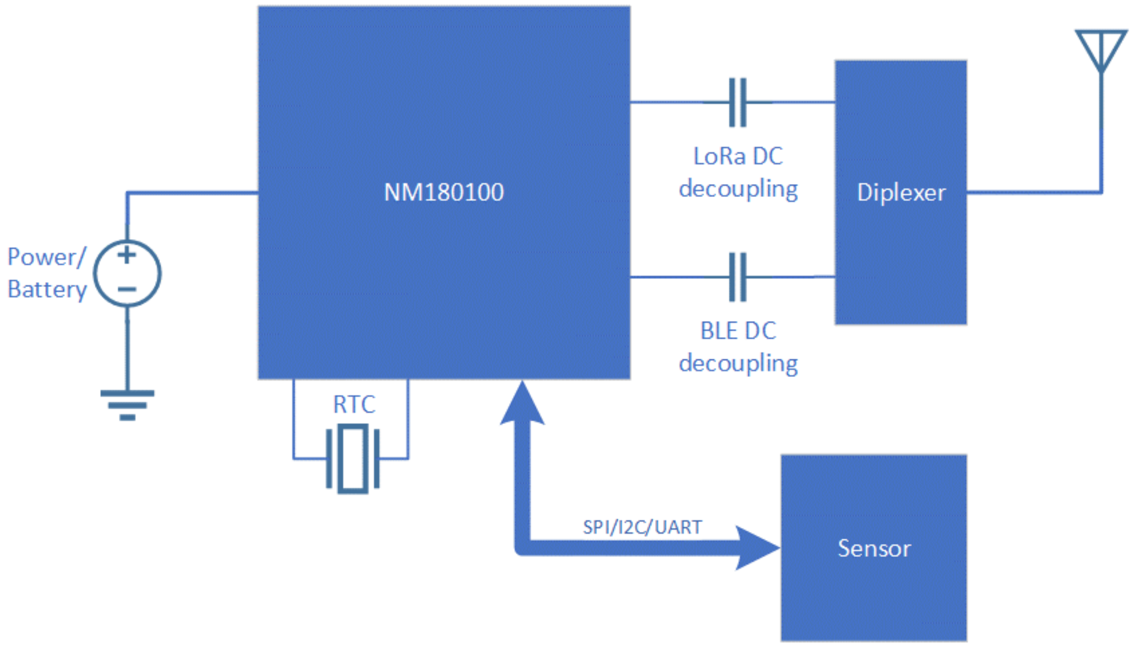


*Figure 6 An example IoT sensor application implementation.*

### 3.3. Real-Time Clock

For BLE application, the current ARM Cordio BLE stack requires an external tuning fork crystal to be connected across the XI and XO pins. A crystal-less implementation is currently being developed and until further notice by ARM or Ambiq, it is mandatory that the RTC crystal be present in order to use the BLE transceiver. The crystal specifications are listed in both the NM180100 datasheet [1] and the Ambiq Apollo 3 datasheet [2].

### 3.4. Analog to Digital Converter

The analog voltage reference of the Apollo 3 are limited to either 1.5V or 2.0V and can be configured to use an external or the internal voltage reference. The reference voltage determines the ceiling of what the ADC can convert. Therefore, the resolution of the ADC is defined by dividing the reference voltage by the total number of possible conversion values which in turns is determined by the ADC precision expressed in bits. The ADC precision can be configured to 8, 10, 12, and 14-bit.

The NM180100 uses the Apollo 3 on-chip bandgap voltage reference to simplify integration. This is because a bandgap voltage reference is temperature independent and produces a constant voltage regardless of power supply variations, temperature changes, and loading changes. These characteristics simplify the burden on the designer on designing a stable voltage reference across the operating conditions of the application. Application making use of the ADC should therefore configure the reference to make use of either the 1.5V or 2.0V internal analog voltage reference.

At 14-bit precision and a 1.5V reference, the smallest voltage quanta that the ADC could resolve is

$$\Delta V = \frac{V_{REF}}{2^{14}} = \frac{1.5}{16384} = 9.155 \times 10^{-5}$$

or approximately 92uV. This voltage level is sufficiently small that it can be easily perturbed by external EMI emissions. Applications requiring this kind of resolution should route the analog input in an inner layer and surround the trace by ground.

### 3.5. Serial Wire Debug

The NM180100 exposes the Apollo 3 Serial Wire Debug port externally through the GPIOs. The default boot-up SWD port is mapped to GPIO20 (SWDCK) and GPIO21 (SWDIO). Although the SWD port can be re-mapped to other pins, GPIO20 and GPIO21 should always be accessible during boot-up for first time factory programming.

If the SWD port is the only means of programming the NM180100 and the default mapping of GPIO20 and GPIO21 is not used during run-time, then sufficient amount of time should be left for the programmer to attach to Apollo 3 for firmware upgrade before the default mapping is re-configured. Failure to observe this could potentially prevent programming of the NM180100.

### 3.6. Sleep Mode

To achieve the lowest power consumption during sleep, the entire LoRa section should be power off. This can be achieved by connecting a load switch in series with V_LoRa allowing the SX1262 and the RF switch to be shut off completely when they are not in used for extended period of time.

To achieve the lowest power consumption, all peripherals such as the FPU, UART, SPI/I2C, ADC, SWD, clock have individual enable and disable bits. When going to deep sleep, any of these peripherals that is not active should be powered down to minimize the deep sleep current. Further power savings could be achieved by disabling the cache and individual flash and RAM pages.

As an example, consider an application that wakes up every 10ms from deep sleep to perform 100us of processing. The Apollo 3 has a deep sleep current of 2.7uA and a transition current of 2.9uA (consisting of wake-up energy and power consumption used during branching to and from ISR). At a nominal clock speed of 48MHz, the current consumption during active processing is

$$6\mu\text{A}/\text{MHz} \times 48\ \text{MHz} = 288\mu\text{A}$$

Simplifying the calculation and assuming that the average aggregated deep sleep current and transition current to be 2.8uA, the total charge consumed during this period is

$$\frac{2.8\mu\text{C}}{\text{s}}\frac{1\text{s}}{1 \times 10^{6}\mu\text{s}}10000\mu\text{s} + \frac{288\mu\text{A}}{\text{s}}\frac{1\text{s}}{1 \times 10^{6}\mu\text{s}}100\mu\text{s} = 0.057\mu\text{C}$$

Finally, the average current consumed during this period is therefore

$$\frac{0.057\mu\text{C}}{10.1\text{ms}} = 5.63\mu\text{A}$$

As a comparison, competing processors having similar specifications as the Apollo 3 have deep sleep current in excess of 5uA with RAM retention and a running RTC.

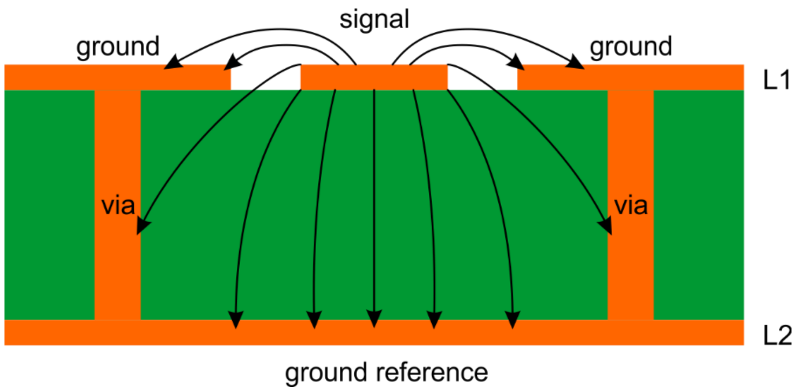


*Figure 7 Grounded co-planar wave guide with via stitching and the electric field distribution.*

# 4. RF Guidelines

## 4.1. RF Routing Guidelines

The NM180100EVB uses grounded co-planar wave guides for the RF traces, LoRa_ANT and BLE_ANT, as shown in Figure 7. A grounded co-planar wave guide is similar to a conventional microstrip wave guide in that the presence of the ground planes beside the signal trace is utilized to minimize the spread of the parasitic electric field. It has better noise immunity and lower emissions than a microstrip waveguide.

In general, it is not recommended to use any number of vias to route the RF traces unless a direct route in a single layer is not possible. Also, the length of these two traces should be made as short as possible. These two traces are the most critical when optimizing for performance and therefore have the highest priority if compromises are needed.

All the aforementioned RF traces must have a solid ground reference beneath each trace. Do not route any of the critical traces over a section of ground reference with discontinuity. The ground reference should remain continuous all the way to the antenna launch point.

## 4.2. DC Decoupling

The NM180100 incorporates an ultra-low insertion loss RF switch that enable greater than 21dBm of output at the LoRa_ANT pad. A DC de-coupling capacitor is required in series with the RF LoRa_ANT trace to ensure proper performance.

## 4.3. Antenna Consideration

The NM180100EVB provides an example of a triple band antenna implementation covering the EU and NA ISM bands at 862MHz and 915MHz as well as 2.4GHz for BLE. Although, the NM180100 can operate with two antennas, a single multi-band antenna is recommended to minimize the intermodulation products generated from simultaneous transmits between the LoRa and the BLE radios that may interfere with other wireless systems in the end application.

When a system transmits multiple frequencies, not only does it generate harmonics of the carrier frequencies, spurious tones could occur at the sum and/or difference of integer multiples of the carrier frequencies. These spurious tones are called intermodulation distortion. For a system with two transmitters transmitting at different frequencies $f_1$ and $f_2$, the distortion products can be expressed in general as

$$af_1 \pm bf_2$$

where a and b are whole numbers.

Consider the scenario where the LoRa radio is transmitting at 902.3MHz and the BLE radio is transmitting at 2478MHz; and each radio has a dedicated antenna that are in close proximity to each other. The carrier frequency of each radio can potentially leak into each other and generate a second order intermodulation

$$f_2 - f_1 = 2478\text{MHz} - 902.3\text{MHz} = 1575.7\text{MHz}$$

This intermodulation frequency is within the GPS band and could de-sensitize applications having a GPS receiver in close proximity.

## 4.4. Reference Antenna

The reference antenna on the NM180100EVB is a PIFA having a ground connection. The topology and the dimensions are shown in Figure 8. This topology has the benefit of improved ESD immunity without an ESD diode as it provides a return path to ground during an ESD strike. For the complete RF characteristics and fabrication details of the reference antenna, please refer to the evaluation board user guide [3] and the manufacturing package are available for download at https://www.northernmechatronics.com. The manufacturing package contains all the information (including the gerber, PCB stackup, fabrication drawings, and BOM) needed to reproduce the reference antenna.

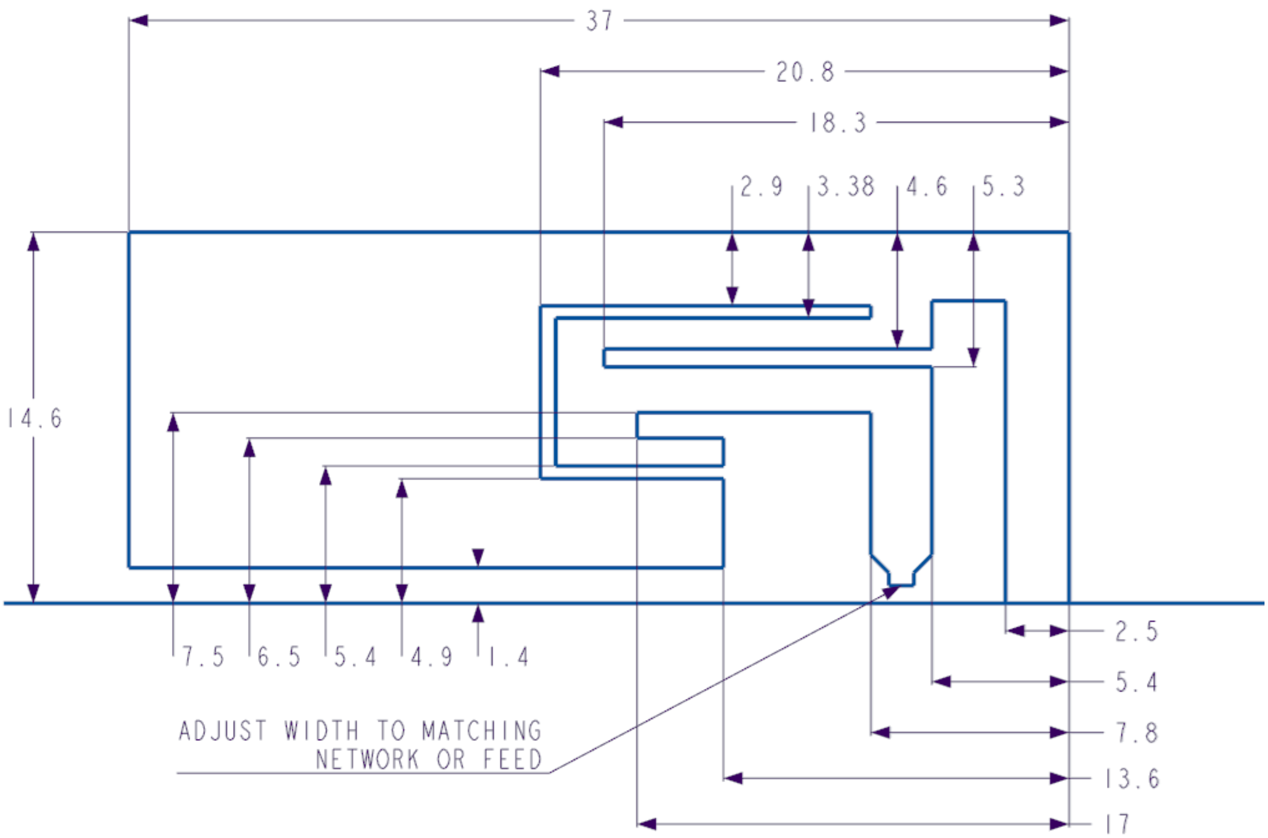


*Figure 8 Reference antenna dimensions. Units are in mm unless otherwise stated.*

## 4.1. Wireless Activity Indicator

The NM180100 exposes two signals, LoRa_Tx and BLE_Tx, to indicate when the LoRa or the BLE radio is transmitting. This could be useful in applications where simultaneous transmission is not desirable such as the above example where the LoRa, BLE, and GPS radios all have separate antennas and are near each other.

# 5. Regulatory Compliance Consideration

Depending on the region where the end-product will be operating in, both CE and FCC are necessary for system level products.

If the end-product has a custom antenna, it is the integrator’s responsibility to make sure that the antenna being used is in compliance with all the laws for the country, frequency, and power levels in which the device is used. Additionally, some countries regulate reception in certain frequency bands. It is the end integrator’s responsibility to maintain compliance with all local laws and regulations. To facilitate compliance testing, the certification test instruction [4] is available for download at https://www.northernmechatronics.com/nm180100.

In order to leverage the NM180100 modular certification, the peak and average gain of the antenna must be equal to or less than the reference antenna as shown in the table below.

| Band | Peak Gain (dBi) |
|---|---|
| 915 ISM | 2.27 |
| BLE | 2.26 |

# 6. Production Testing Consideration

End product production testing is highly recommended to ensure regulatory compliance. Since each module is completely characterized during manufacturing, end-product RF testing of the NM180100 is straight forward. In order to measure the RF performance, a switched RF coaxial connector can be placed in-line with the RF path such as a Murata MM8430-2610RA1 used in the NM180100EVB. Figure 8 and Figure 9 show example implementations on where the connector would be placed for a single or a dual antenna implementation respectively.

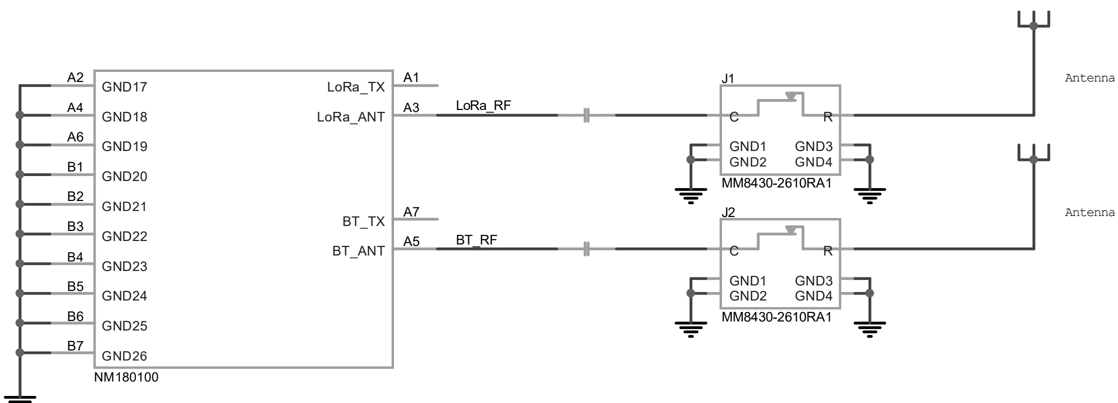


*Figure 9 Dual antenna switched RF coaxial connectors (J1 and J2) placement.*

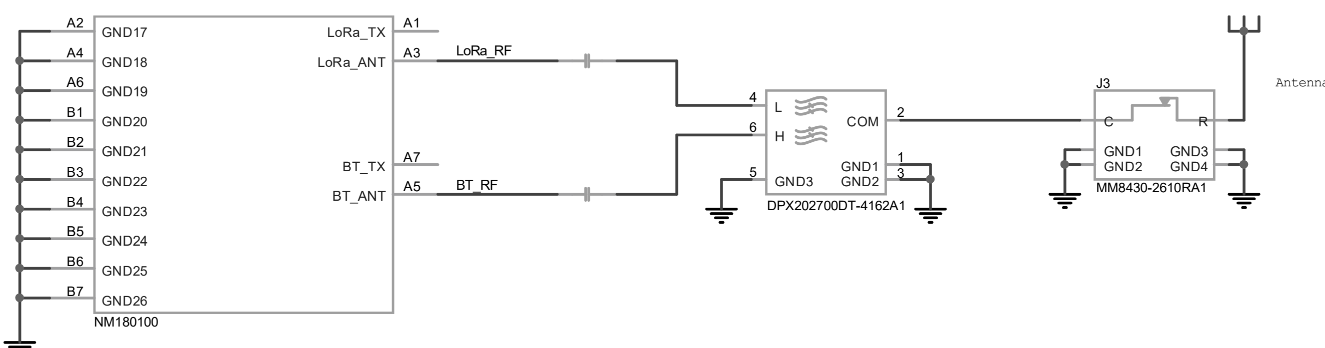


*Figure 10 Single antenna switched RF coaxial connector (J3) placement.*

## 7. Regulatory and Compliance Notice

In the United States, the NM180100 has obtained modular approval under Federal Communications Commission (FCC) CFR47 Telecommunications, Part §15 Subpart C "Intentional Radiators" in accordance with Part §15.212 "Modular Transmitter".

FCC ID: 2AL5J-180100

In Canada, the NM180100 has obtained modular approval under Innovation, Science and Economic Development Canada (ISED) Radio Standards Specification (RSS) RSS-247 and RSS-Gen.

ISED: 22729-180100

### 7.1. Note to Module Integrators

This modular approval allows the integration of the NM180100 module into an end product without the module integrator obtaining separate approvals for intentional radiation, provided no changes or modifications are made that would violate the modular approval grant.

The module integrator must comply with all of the instructions provided by Northern Mechatronics Inc., which indicate installation and/or operating conditions necessary for compliance.

An end product, which integrates the NM180100, is required to comply with all applicable FCC/ISED equipment authorization regulations, requirements and equipment functions not associated with the transmitter module portion.

For example, compliance must be demonstrated to regulations for other transmitter components within the end product, such as requirements for unintentional radiators (Part §15 Subpart B "Unintentional Radiators" and ICES-003 "Information Technology Equipment – Limits and Methods of Measurement"), such as digital devices, computer peripherals, radio receivers, etc.; and compliance to additional authorization requirements for the non-transmitter functions on the transmitter module (i.e., Verification, or Declaration of Conformity), as appropriate.

## 7.2. United States: Federal Communications Commission (FCC) Notice

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.

### *Warning: RF Exposure Compliance*

⚠ **The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons.**

⚠ **This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter except in accordance with FCC procedures and as authorized in the module certification filing.**

⚠ **The gain of the antenna(s) used for NM180100 must not exceed 2.27 dBi in the frequency range 902– 928 MHz and must not exceed 2.26 dBi in the frequency range 2402 – 2480 MHz.**

### *Module Usage Conditions*

⚠ **Changes or modifications not expressly approved by Northern Mechatronics Inc. may void the user's authority to operate the equipment.**

⚠ **Manufacturers of mobile or fixed devices incorporating the NM180100 module are authorized to use the FCC Grant of the NM180100 module for their own final products according to the conditions referenced in the grants.**

⚠ **The FCC label shall, in the above case, be visible from the outside, or the host device shall bear a second label stating:**

**"Contains FCC ID: 2AL5J-180100"**

⚠ **The end user is to be notified that any changes or modifications made to the equipment, that are not expressly approved by Northern Mechatronics Inc. could void the user's authority to operate the equipment.**

⚠ **IMPORTANT: Manufacturers of portable applications incorporating the NM180100 module are required to have their final product certified and apply for their own FCC Grant related to the specific portable device. This is mandatory to meet the SAR requirements for portable devices.**

## 7.3. Canada: Innovation, Science and Economic Development (ISED) Notice

This device complies with Innovation, Science and Economic Development Canada (ISED) Radio Standards Specification (RSS) RSS-247 and RSS-Gen. Operation is subject to the following two conditions:

(1) This device may not cause interference; and

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

*Warning: RF Exposure Compliance*

⚠ **The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons.**

⚠ **This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter except in accordance with ISED procedures and as authorized in the module certification filing.**

⚠ **The gain of the antenna(s) used for NM180100 must not exceed 2.27 dBi in the frequency range 902– 928 MHz and must not exceed 2.26 dBi in the frequency range 2402 – 2480 MHz.**

*Module Usage Conditions*

⚠ **Changes or modifications not expressly approved by Northern Mechatronics Inc. may void the user's authority to operate the equipment.**

⚠ **Manufacturers of mobile or fixed devices incorporating the NM180100 module are authorized to use the ISED certificate of the NM180100 module for their own end products according to the conditions referenced in the certificates.**

⚠ **The user is to be notified that any changes or modifications made to this device, that are not expressly approved by Northern Mechatronics Inc. could void the user's authority to operate the equipment.**

⚠ **The ISED label shall, in the above case, be visible from the outside, or the host device shall bear a second label stating:**

**"Contains ISED: 22729-180100"**

⚠ **IMPORTANT: Manufacturers of portable applications incorporating the NM180100 module are required to have their final product certified and apply for their own ISED Certificate related to the specific portable device. This is mandatory to meet the SAR requirements for portable devices.**

## 7.4. Canada: Avis d’Innovation, Sciences et Développement économique Canada (ISDE)

Cet appareil est conforme à cahiers des charges sur les normes radioélectriques (CNR) CNR-210 et CNR-Gen d’Innovation, Sciences et Développement économique Canada (ISDE). L'exploitation est autorisée aux deux conditions suivantes:

(1) L’appareil ne doit pas produire de brouillage, et

(2) L’utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

*Attention: Conformité d'exposition aux radiofréquences*

⚠ **L’antenne ou les antennes utilisées pour cet émetteur doivent être installées de façon à fournir une distance de séparation d'au moins 20 cm de toutes personnes.**

⚠ **Le transmetteur ne doit pas être placées au même endroit qu'une autre antenne ou transmetteur sauf conformément aux procédures ISDE et autorisé dans le dépôt de certification du module.**

⚠ **Le gain d'antenne utilisé pour NM180100 ne doit pas dépasser 2.27 dBi dans la gamme de fréquences 902–928 MHz et ne doit pas dépasser 2.26 dBi dans la gamme de fréquences 2402 – 2480 MHz.**

*Conditions d’utilisation modulaire*

⚠ **Tous les changements ou modifications non expressément approuvées par Northern Mechatronics Inc. pourraient annuler l'autorisation de l'utilisateur pour utiliser l'équipement.**

⚠ **Les fabricants d'appareils mobiles ou fixes incorporant le module NM180100 sont autorisés à utiliser le certificat ISDE du module NM180100 pour leurs propres produits finaux selon les conditions référencées dans les certificats.**

⚠ **L'utilisateur doit être informé que tout les changements ou modifications non expressément approuvées par Northern Mechatronics Inc. pourraient annuler l'autorisation de l'utilisateur pour utiliser l'équipement.**

⚠ **L'étiquette ISDE doit, dans le cas ci-dessus, être visible de l'extérieur, ou le dispositif hôte doit porter une deuxième étiquette indiquant:**

**“Contains ISED: 22729-180100”**

**IMPORTANT: Les fabricants d'applications portables intégrant le module NM180100 sont tenus d'avoir leur produit final certifié et d'appliquer leur propre certificat ISDE relatif à l'appareil portable spécifique. Ceci est obligatoire pour satisfaire aux exigences DAS pour les appareils portables.**

# 8. References

[1] Northern Mechatronics Inc., "NM180100 Datasheet," November 2019. [Online]. Available: https://www.northernmechatronics.com/nm180100.

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# 10. Revision History

| Revision | Date | Description |
|---|---|---|
| A.1 | January 24, 2020 | Initial release |

# 11.Document Details

| Parameter | Value |
|---|---|
| **Name** | NM180100 Hardware Integration Manual |
| **Number** | 2000002 |
| **Revision** | -0.9 |
| **Life Cycle State** | In Work |