RNBD451

RNBD451 Bluetooth® Low Energy Module Data Sheet

Introduction

The RNBD451 module is based on Microchip's PIC32CX-BZ2 Bluetooth® Low Energy System-on-Chip (SoC) that provides a complete solution to implement Bluetooth 5.2 Low Energy connectivity. These modules are interfaced via a Two-Wire or Four-Wire UART interface with Microchip's simple ASCII command set for easy integration into most of the applications. The host microcontroller can dynamically configure the RNBD451 module with a few simple ASCII commands. The RNBD451 module combined with Microchip's Bluetooth Low Energy silicon with necessary GPIO and an on-board PCB antenna creates an easy-to-use drop-in solution.

Features

- Fully-certified Bluetooth Low Energy Module
- Compact Form Factor
- On-board Bluetooth 5.2 Low Energy Stack
- ASCII Command Interface API over UART
- ASCII Commands are Backward Compatible with RN487x Family of Modules
- Definable Beacon Feature to Make Various Beacons, such as iBeacon™/Eddystone™
- Built-in Microchip Transparent Profile for UART Data Streaming
- Over-the-Air (OTA) Remote Configuration
- Embedded Enhanced Security
- 2M Uncoded PHY and Long Range (Coded PHY)
- Extended Advertising
- Data Length Extensions and Secure Connections
- Bluetooth Low Energy Privacy 1.2 with up to Eight Resolvable and Accept Lists
- UART based Device Firmware Update (DFU)
- Built-in Microchip OTA Profile with Client and Server Role for OTA DFU Execution
- Integrated 16 MHz POSC
- Supports UART
- 8 GPIOs that can be Controlled by RN Command
- 12-bit Analog-to-Digital Converters (ADC) Successive Approximation Register (SAR) Module for Analog to Digital Conversion
- Add-on up to Six 16-bit UUID GATT Services (Public Service), Four 128-bit UUID GATT Services (Private Service), and Each Service Includes up to Eight Characteristic Attributes
- Supports Bluetooth Low Energy Advertiser, Observer, Central and Peripheral Roles
- Supports Bluetooth Low Energy GATT Client and Server Roles
- Supports up to Six Concurrent Bluetooth Low Energy Connections

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Operational Conditions

- Operating Voltage: 1.9-3.6V (3.3V typical)
- Temperature Range: -40°C to +85°C
- 39-pin SMD Package with Shield CAN
  - Size: 15.5 mm x 20.7 mm x 2.8 mm

RF/Analog Features

- Industrial, Scientific and Medical (ISM) Band: 2.402-2.480 GHz Operation
- Channels: 0-39
- Up to +12 dBm Programmable Transmit Output Power
- Typical Receiver Power Sensitivity:
  - -95 dBm for Bluetooth Low Energy 1 Mbps
  - -92 dBm for Bluetooth Low Energy 2 Mbps
  - -102 dBm for Bluetooth Low Energy 125 Kbps
  - -99 dBm for Bluetooth Low Energy 500 Kbps
- Digital Received Signal Strength Indicator (RSSI)

Applications

- Health/Medical Devices
- Sports Activity/Fitness Meters
- Beacon Applications
- Internet of Things (IoT) Sensor Tag
- Remote Control
- Wearable Smart Devices and Accessories
- Smart Energy/Smart Home
- Industrial Control

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1. Quick References

1.1 Reference Documentation

For more details, refer to the following document:

- *AN233 Solder Reflow Recommendation Application Note* (DS00233)
- *RNBD451 Bluetooth® Low Energy Module User's Guide* (DS50003467)

1.2 Acronyms and Abbreviations

Table 1-1. Acronyms and Abbreviations

Acronyms and Abbreviations	Description
ADC	Analog-to-Digital Converters
API	Application Programming Interface
CDM	Charged Device Model
CTS	Clear to Send
DIS	Device Information Service
DFU	Device Firmware Update
HBM	Human Body Model
IoT	Internet of Things
ISM	Industrial, Scientific and Medical
MBD	Microchip Bluetooth Data
NVM	Nonvolatile Memory
OTA	Over-the-air
OTAPC	Over-the-air Profile Client
PDS	Persistent Data Storage
PMU	Power Management Unit
POR	Power-on Reset
RSSI	Received Signal Strength Indicator
RTS	Request to Send
SAR	Successive Approximation Register
SoC	System-on-Chip

2. Ordering Information

This chapter provides the ordering information of the RNBD451 module.

2.1 RNBD451 Module Ordering Information

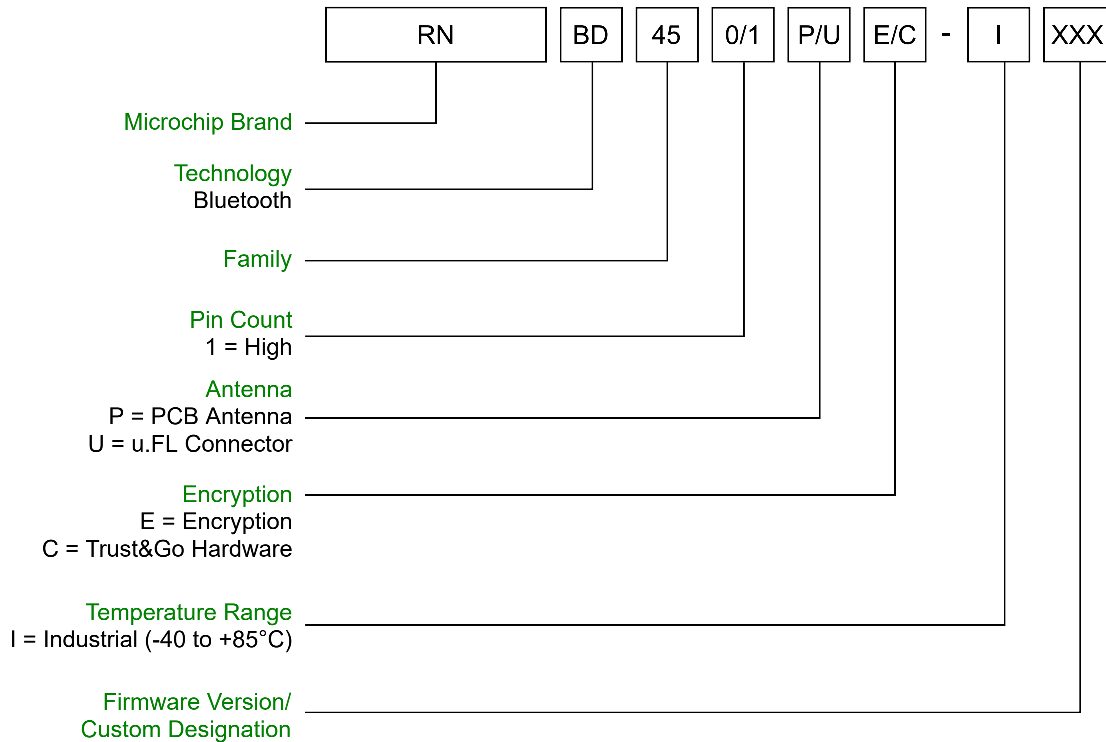
The following table describes the ordering information of the RNBD451 module.

Table 2-1. RNBD451 Module Ordering Details

Model No.	Module SoC	Description	Regulatory Certification	Ordering Code
RNBD451PE	PIC32CX1012BZ250 48-I/MYX	RNBD451 module with PCB antenna	FCC, ISED, CE	RNBD451PE-I

The following figure illustrates the details of the RNBD451 module ordering information.

Figure 2-1. RNBD451 Module Ordering Information



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3. Device Overview

3.1 Module Overview

The RNBD451 Bluetooth Low Energy module integrates Bluetooth 5.2 baseband controller, Bluetooth stack, digital and analog I/O, and RF power amplifier into one solution.

Figure 3-1. RNBD451 Module Block Diagram

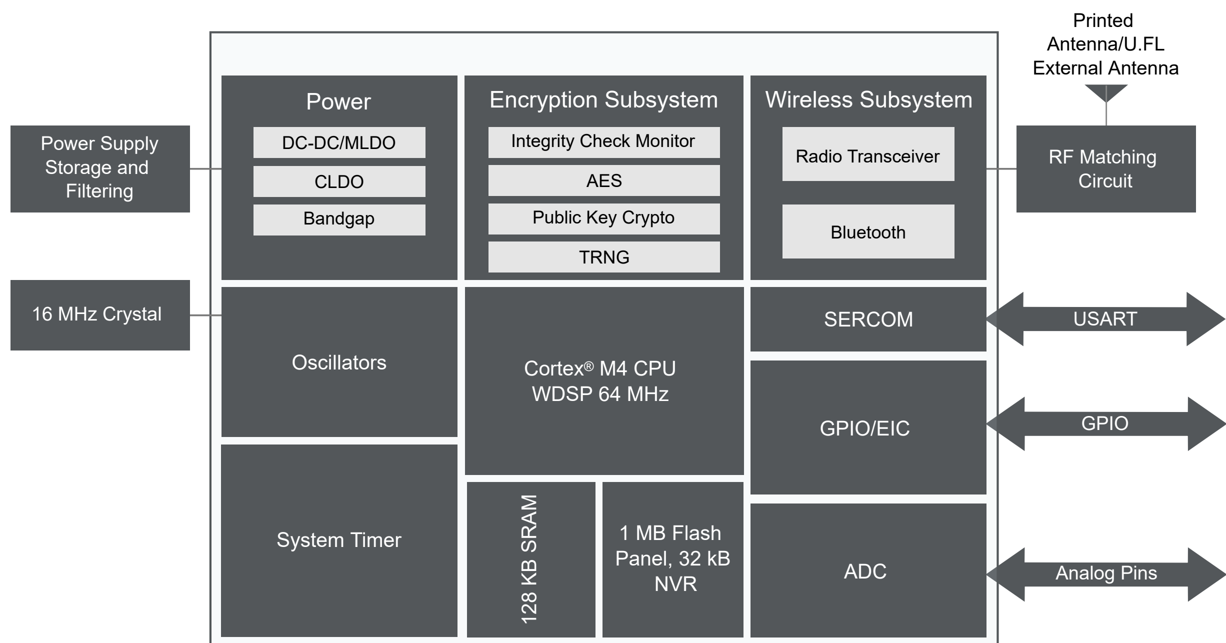
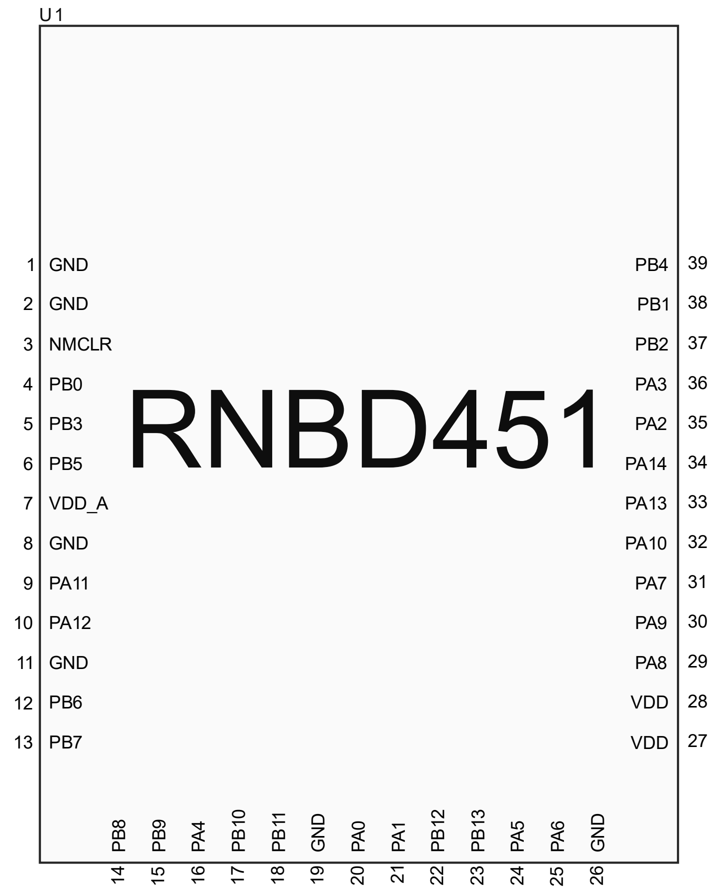


Figure 3-2. Pin Diagram – RNBD451



Note: Ensure the exposed thermal pad (TPAD_GND) on the bottom of the module is connected to ground in the PCB.

Table 3-1. Pin Description

Pin Number	Name	RNBD451 Definition
1	GND	Ground
2	GND	Ground
3	NMCLR	Reset
4	PB0	Reserved for PTA control
5	PB3	Bluetooth Low Energy status indication pin 1/2
6	PB5	Bluetooth status LED
7	VDD_A	Power source
8	GND	Ground
9	PA11	Reserved
10	PA12	Reserved
11	GND	Ground
12	PB6	UART receive data
13	PB7	Bluetooth Low Energy status indication pin 2/2

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...........continued

Pin Number	Name	RNBD451 Definition
14	PB8	I/O level control by RN command
16	PA4	UART Request to Send (RTS)
17	PB10	I/O level control by RN command
18	PB11	I/O level control by RN command
19	GND	Ground
20	PA0	I/O level control by RN command
21	PA1	I/O level control by RN command
22	PB12	I/O level control by RN command
23	PB13	I/O level control by RN command
24	PA5	UART transmit data
25	PA6	UART Clear to Send (CTS)
26	GND	Ground
27	VDD	Power source
28	VDD	Power source
29	PA8	Debug UART receive data
31	PA7	Debug UART transmit data
32	PA10	I/O level control by RN command
33	PA13	Reserved for PTA control
34	PA14	Reserved for PTA control
35	PA2	UART transmit indication pin
36	PA3	Event indication pin (RSSI indication pin)
37	PB2	UART mode switch
38	PB1	ADC
39	PB4	UART receive indication pin/RNBD451 wake-up pin Low-power mode

Note:
- Upon reset, if the PB5 pin is held low, the RNBD451 module sends out REBOOT, MAC ID and firmware version. Upon the RNBD451 module reset, the PB5 pin acts as the input for approximately 300 ms. Post this time, the PB5 pin changes to output and resumes normal functionality, which is Bluetooth status LED.

3.2 Module Configuration

Use the ASCII command interface for configuring the GPIO pins of the RNBD451 module to different functions. The following table provides the details about the various pins and functions available in the RNBD451 module that are available for configuration and their default configuration settings.

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Table 3-2. Configurable Functions and Descriptions

Pin	Function Name	Description
PB5	Bluetooth status LED	To indicate Bluetooth Low Energy connection status by a specific LED flash pattern, see the following pattern description: • Standby mode – No Bluetooth Low Energy connection. The RNBD451 module is in Advertisement or Scan state. Flash one time for every three seconds. – ON – 50 ms – OFF – 2950 ms • Linked mode – Bluetooth Low Energy ACL link is connected, regardless of whether it is in the Central or Peripheral role. Flash two times for every 1.5 seconds. – ON – 50 ms – OFF – 150 ms – ON – 50 ms – OFF – 1050 ms • MCU DFU mode – The RNBD451 module is in MCU DFU procedure. Flash 4 times for every two seconds. – ON – 100 ms – OFF – 100 ms **Note:** By default, the Bluetooth status LED is turned OFF. The user can enable this feature by using the SR,<hex16> command. For example SR,0001. For more details, refer to the *RNBD451 Bluetooth Low Energy Module User's Guide* (DS50003467).
PB1	ADC	A dedicated ADC input pin where an analog signal can be the input to the RNBD451 module. The RNBD451 module performs the ADC conversion using a fixed reference and provides the digital value that can be read using a command. For more details, refer to the *RNBD451 Bluetooth Low Energy Module User's Guide* (DS50003467).
PB8, PB10, PB11, PA0, PA1, PB12, PB13 and PA10	I/O level control	Host MCU can assert the RN command to set some GPIO pins as output pins to set their level or input pins to read their level.
PB2	UART mode switch	• When the host MCU pulls the UART mode switch pin from low to high (rising edge), the RNBD451 module switches to the Data mode. • When the host MCU pulls the UART mode switch pin from high to low (falling edge), the RNBD451 module switches to the Command mode. • When the host MCU uses the RN command to switch the mode, the host MCU keeps the UART mode switch pin to the original setting. **Note:** By default the UART mode switch functionality is not assigned on to the PB2 pin. The user can enable this feature using SR,<hex16> command. For example, SR,0002. For more details, refer to the *RNBD451 Bluetooth Low Energy Module User's Guide* (DS50003467).
PB4	UART RX indication	• If the RNBD451 module's low power is enabled, the host MCU must wake up the RNBD451 module before sending the UART data out. • Pull the UART RX indication pin low to wake up the system)

...........continued		
Pin	**Function Name**	**Description**
PA3	RSSI indication	• Use this indication pin to indicate the quality of the link based on the RSSI level. • If the RSSI level is lower than the specified threshold value, then the RSSI indication pin goes low.
PA2	UART TX indication	• UART TX indication is an output pin. Provides indication if the RNBD451 module is transmitting to host MCU over UART. • Pulled low before UART TX begins and pulled high after UART TX is over.

Table 3-3. Status Indication Pins

BT_Status_Ind1 (PB3)	BT_Status_Ind2 (PB7)	RNBD451 Status
Low	Low	Bluetooth Low Energy is disconnected
		Data transmission channel is closed
High	Low	Bluetooth Low Energy is connected
		Data transmission channel is closed
High	High	Bluetooth Low Energy is connected
		Data transmission channel is opened
Low	High	MCU DFU mode (local or Over-the-air Profile Client (OTAPC))
Note: By default the Bluetooth status indication feature is disabled in the firmware. The user can enable this feature via `SR,<hex16>` command. For example, `SR,1000`. For more details, refer to the *RNBD451 Bluetooth Low Energy Module User's Guide* (DS50003467).		

3.3 Device Power Modes

The RNBD451 module incorporates a Power Management Unit (PMU) that provides both DC-DC (Buck) and MLDO power conversion. On power-up, the RNBD451 module operates in MLDO mode. The RNBD451 module command set provides the option to set the PMU mode as MLDO mode or BUCK PWM mode via `Set PMU Mode` command. For example, `SPMU,<0,1>`.

The RNBD451 module supports the following device power modes:

- Run mode – In the Run mode, the CPU is actively executing code. Run mode provides normal operation of the processor. All the features and configurations are available to be controlled.
- Sleep/Standby mode – In this mode, the RNBD451 module operates with minimum power consumption.
  Upon entering this mode, the RNBD451 module enters into minimal power consumption state in between the advertisement interval. After establishing the connection, then in between the connection interval, the RNBD451 module enters into minimal power consumption state and only consumes less power. Every connection/advertising interval, the RNBD451 module wakes up from Sleep/Standby Sleep mode, performs the Bluetooth low energy activity and goes back to sleep. In this mode, the overall average power consumption of the system is always less in comparison to the module in Run mode.
  Use the `Low Power Control` command to configure the RNBD451 module into Sleep mode or Low-power Control mode. For example, `SO,<0,1>`.

  Pull the UART_RX_IND (PB4) pin to low from Host MCU to enable the UART before the Host MCU transmits data to the RNBD451 module. The UART_RX_IND must be active prior to UART data more than two ms to make the RNBD451 module ready to receive data.
- Deep Sleep mode – In this mode, configure the RNBD451 module to operate with less power consumption compared to Sleep/Standby mode. The Deep Sleep mode feature is incorporated only for advertisement. After

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every advertising interval, the RNBD451 module wakes up from Deep Sleep mode, performs the advertisement and goes back to Deep Sleep mode. The RNBD451 module continues this pattern of advertisement until a connection is established.
Enable the deep sleep advertisement in the RNBD451 module using `Set Deep Sleep Advertising` command. For example, `SDO,<0,1>,<hex16>`.

Pull the UART_RX_IND (PB4) pin to low from host MCU to enable the UART before Host MCU transmits data to the RNBD451 module. The UART_RX_IND must be active prior to UART data more than 25 ms to make the RNBD451 module ready to receive data.

- Extreme Deep Sleep mode – In this mode, configure the module to operate in Shutdown state. In this state, the system stays in the Extreme Deep Sleep (XDS) mode and it consumes extreme low power. Hard reset or pull UART_RX_IND pin low can bring the system back to Run mode. For more details on the commands for different Low-power mode configurations, refer to the *RNBD451 Bluetooth Low Energy Module User's Guide* (DS50003467).

3.4 Device Programming

The RNBD451 device is available for purchase with a pre-programmed firmware. Microchip periodically releases the firmware for fixing previously reported issues or to implement latest feature support. There are two ways to perform regular firmware update:

1. Serial DFU command based update over UART
2. Over-the-air (OTA) update of firmware using Microchip Bluetooth Data (MBD) mobile application or module to module OTA update (OTAPC mode commands)
3. Advanced programming

For advanced programming option (SWD), go to support.microchip.com.
Note: For the serial DFU and OTA programming guidance, refer to the *RNBD451 Bluetooth Low Energy Module User's Guide* (DS50003467).

4. Electrical Characteristics

4.1 Absolute Maximum Electrical Characteristics

Exposure to these maximum rating conditions for extended periods may affect device reliability. Functional operation of the device at these or any other conditions above the parameters indicated in the operation listings of this specification is not implied.

Table 4-1. Absolute Maximum Ratings

Parameter	Value
Ambient temperature under bias[1, 2]	-40°C to +85°C
Storage temperature	-65°C to +150°C
Voltage on V_{DD} / V_{DDIO} with respect to GND	-0.3V to +4.0V
Voltage on pins, with respect to GND	-0.3V to (V_{DD} + 0.3V)
Maximum current out of GND pins	300 mA
Maximum current into V_{DD} pins[2]	300 mA
Maximum output current sourced/sunk by any Low Current Mode I/O pin (4x drive strength)	10 mA
Maximum output current sourced/sunk by any High Current Mode I/O pin (8x drive strength)	15 mA
Maximum current sink by all ports	120 mA
Maximum current sourced by all ports[2]	120 mA
ESD Qualification	
Human Body Model (HBM) per JESD22-A114	2000V
Charged Device Model (CDM) (ANSI/ESD STM 5.3.1)…(All pins/Corner pins)	+500V/-500V

Notes:
1. Stresses above those listed under “Absolute Maximum Ratings” can cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.
2. Maximum allowable current is a function of device maximum power dissipation (See the *Thermal Operating Conditions* table in the *Thermal Specifications* from Related Links).

4.2 DC Electrical Characteristics

Table 4-2. Operating Frequency VS. Voltage

Param. No.	V_{DDIO}, V_{DDANA} Range	Temp. Range (in °C)	Max. MCU Frequency	Comments
DC_5	1.9V to 3.6V	-40°C to +85°C	64 MHz	Industrial

Note: The same voltage must be applied to V_{DDIN} and V_{DDANA}.

4.3 Active Current Consumption DC Electrical Specifications

Table 4-3. Active Current Consumption DC Electrical Specifications

DC Characteristics				Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9V to 3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp			
Param. No.	Symbol	Characteristics	Clock/Freq	Typ [1]	Max.	Units	Conditions
APWR_1	I_{DD_ACTIVE} (2,3)	MCU I_{DD} in Active mode w/LDO mode selected	PLL 64 MHz	131	—	µA/MHz	V_{DD} = V_{DDANA} = 3.3V
APWR_2			FRC 8 MHz	443			
APWR_3		MCU I_{DD} in Active mode w/ BUCK mode selected	PLL 64 MHz	76.8			
APWR_4			FRC 8 MHz	300			

Figure 4-1. Run Mode Current Consumption in Buck Mode at PLL 64 MHz

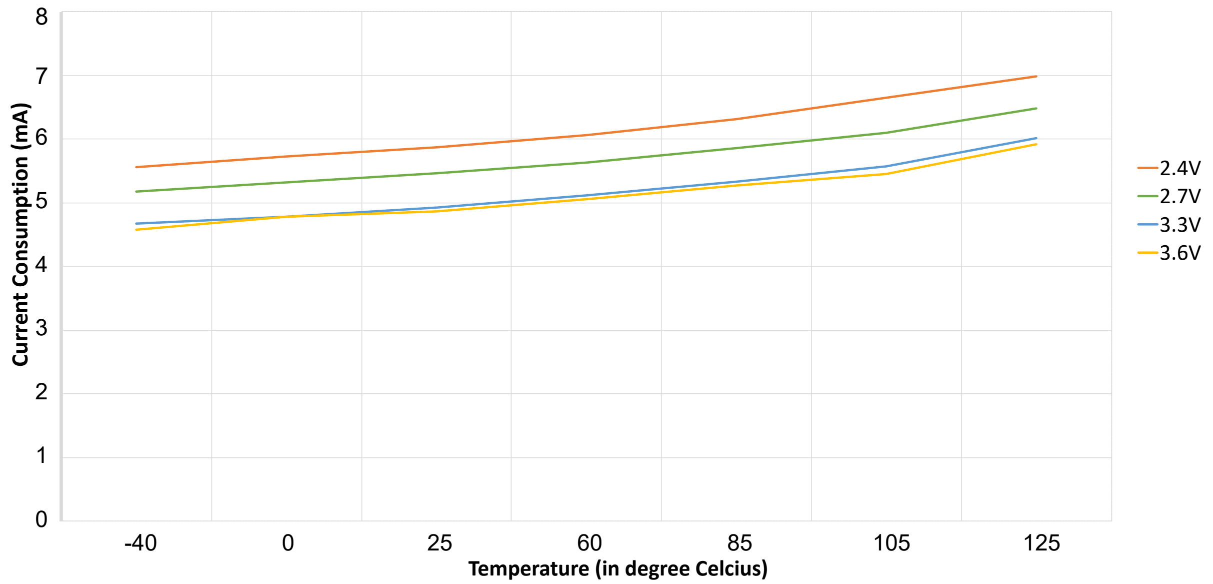

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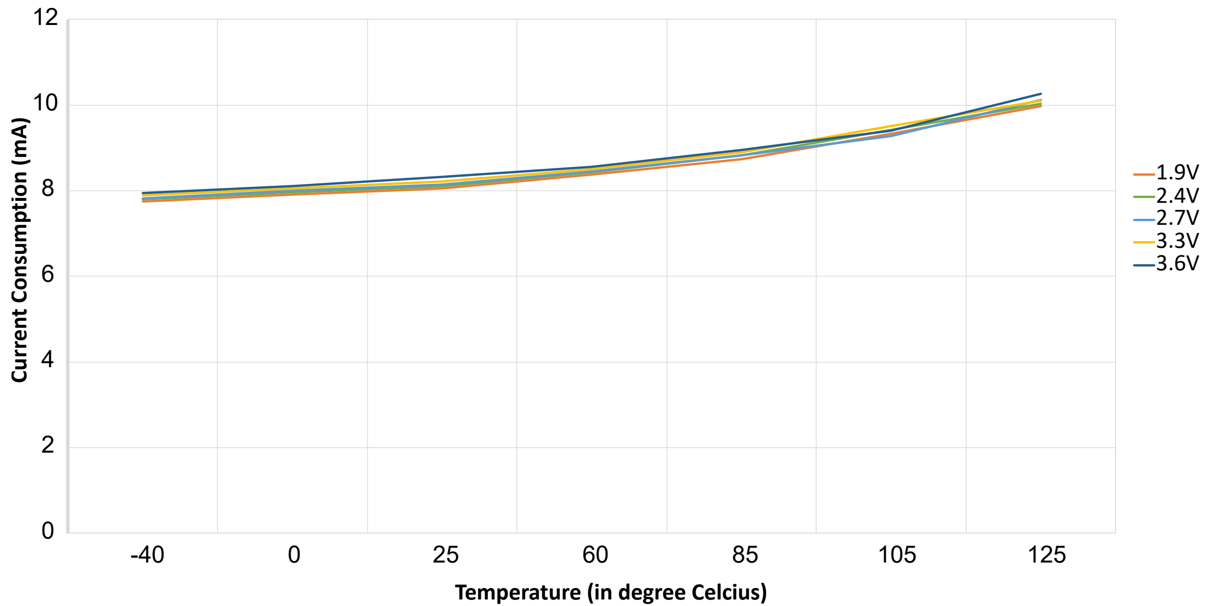
Figure 4-2. Run Mode Current Consumption in MLDO Mode at PLL 64 MHz



Notes:

1. Typical value measured at 3.3V and 25℃.
2. The test conditions are as follows:
   - All GPIO except RPA3 pulled up. RPA3 is pulled down.
   - RF system in IDLE state. Not transmitting or receiving packets.
   - All peripherals are disabled.
   - All PB clocks are divided by 16.
   - LPRC is set as LPCLK.
   - SOSC is disabled.
   - PMU 1 MHz clock is derived from FRC. FRC is divided by 8.
   - Cache is enabled and configured to wait states PFMWS[3:0] as 0xF.
   - Backup RAM in the Retention mode.
   - DSU is disconnected.
3. MCU running while(1) loop with 50 NOP instructions.

4.4 Sleep Current Consumption DC Electrical Specifications

Table 4-4. Sleep Current Consumption DC Electrical Specifications

DC Characteristics			Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9V to 3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	Symbol	Characteristics	V_{DDIO}	Typ[1]	Max.	Units	Conditions
SPWR_1	I_{DD_SLEEP}	MCU I_{DD} in Sleep mode w/LDO mode selected	3.3V	950	—	µA	XTAL ON
			3.3V	620	—	µA	XTAL OFF
SPWR_29		MCU I_{DD} in Sleep mode w/ BUCK mode selected	3.3V	470	—	µA	XTAL ON
			3.3V	450	—	µA	XTAL OFF

Figure 4-3. Sleep Current with XTAL_OFF_MLDO

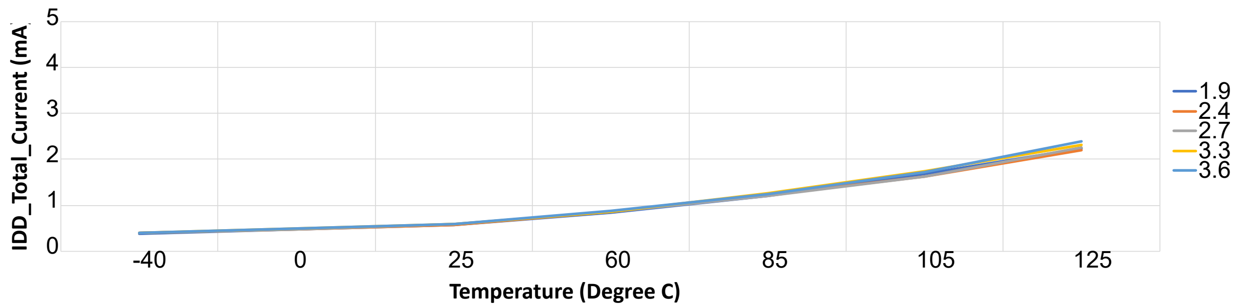


Figure 4-4. Sleep Current with XTAL_OFF_DC_DC

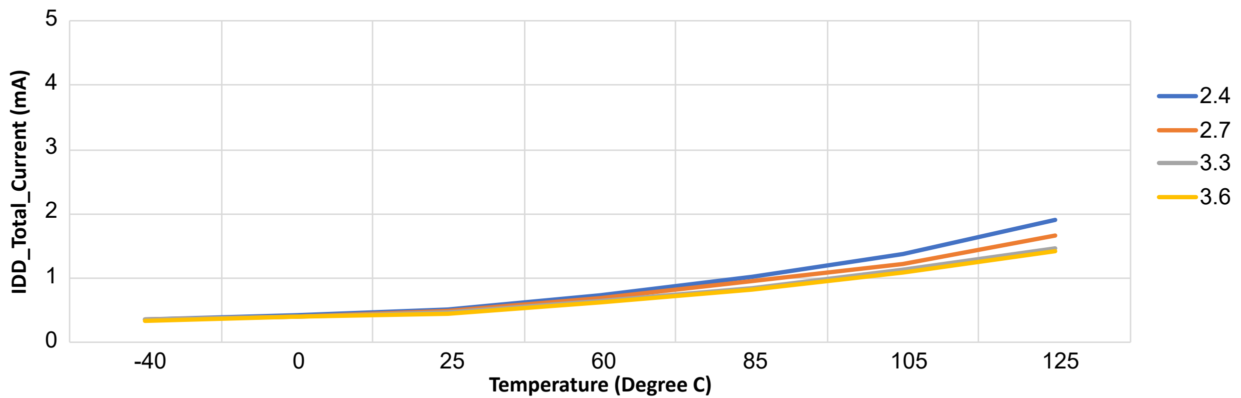


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Figure 4-5. Sleep Current with XTAL_ON_MLDO

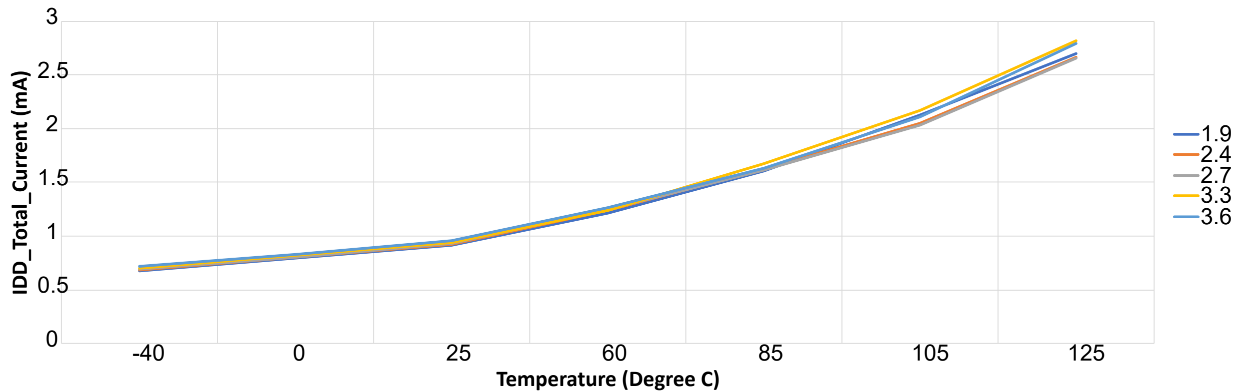
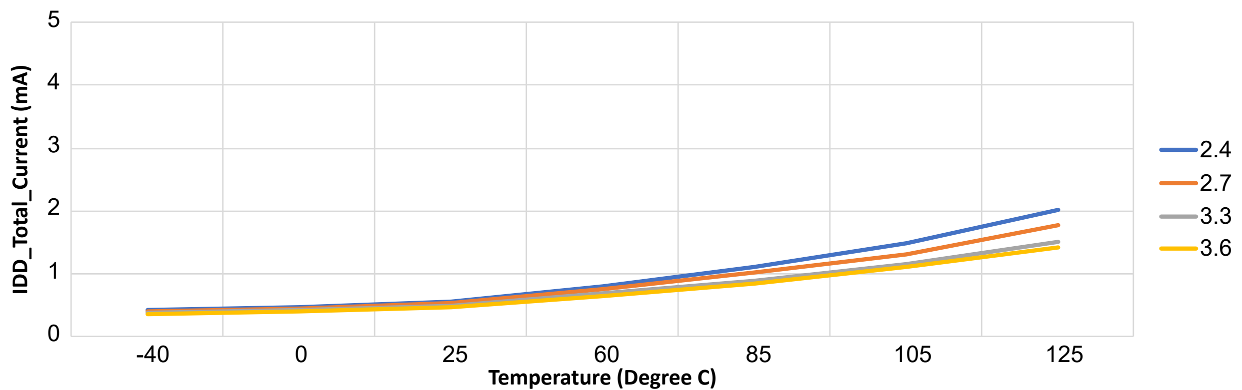


Figure 4-6. Sleep Current with XTAL_ON_DC_DC



Notes:

1. Typical value measured during characterization at 3.3V and 25℃.
2. The test conditions are as follows:
   - All GPIO except RPA3 are pulled up. RPA3 is pulled down.
   - All peripherals are disabled (except EIC).
   - All PB clocks are divided by 16.
   - LPRC is set as LPCLK.
   - SOSC is disabled.
   - CLDO is configured at lowest possible voltage (VREG Trim = 0x07).
   - PMU is configured to the Buck PSM mode on the Sleep Mode Entry with current sense is disabled.
   - Cache is enabled and configured to wait states PFMWS[3:0] as 0xF.
   - Backup RAM in the Retention mode.
   - DSU is disconnected.
   - RF system is in low power configuration.
   - Entry to the Sleep mode is enabled and WFI instruction is executed.
   - In XTAL ON mode - PMU Buck clock is derived from POSC 16 MHz and scaled to 1 MHz. FRC is OFF.
   - In XTAL OFF mode - PMU is clocked from FRC and XTAL 16 MHz clock is disabled and clock configuration in CRU changed to FRC.

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4.5 Deep Sleep Current Consumption DC Electrical Specifications

Table 4-5. Deep Sleep Current Consumption DC Electrical Specifications

DC Characteristics			Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9V to 3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	Symbol	Characteristics	V_{DDIO}	Typ[1]	Max.	Units	Conditions
BPWR_1	I_{DD_BACKUP}[2]	MCU I_{DD} in Deep Sleep mode powered from V_{DDIO}	3.3V	1.2	—	µA	No backup RAM retained
BPWR_2			3.3V	1.5	—	µA	8 KB backup RAM retained

Figure 4-7. Deep Sleep Current RAM ON

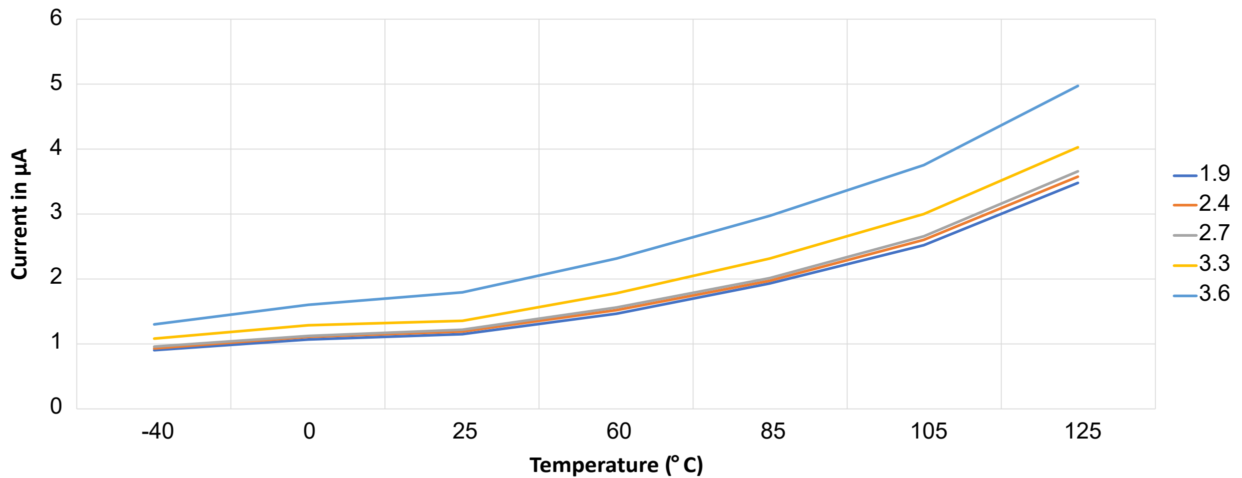
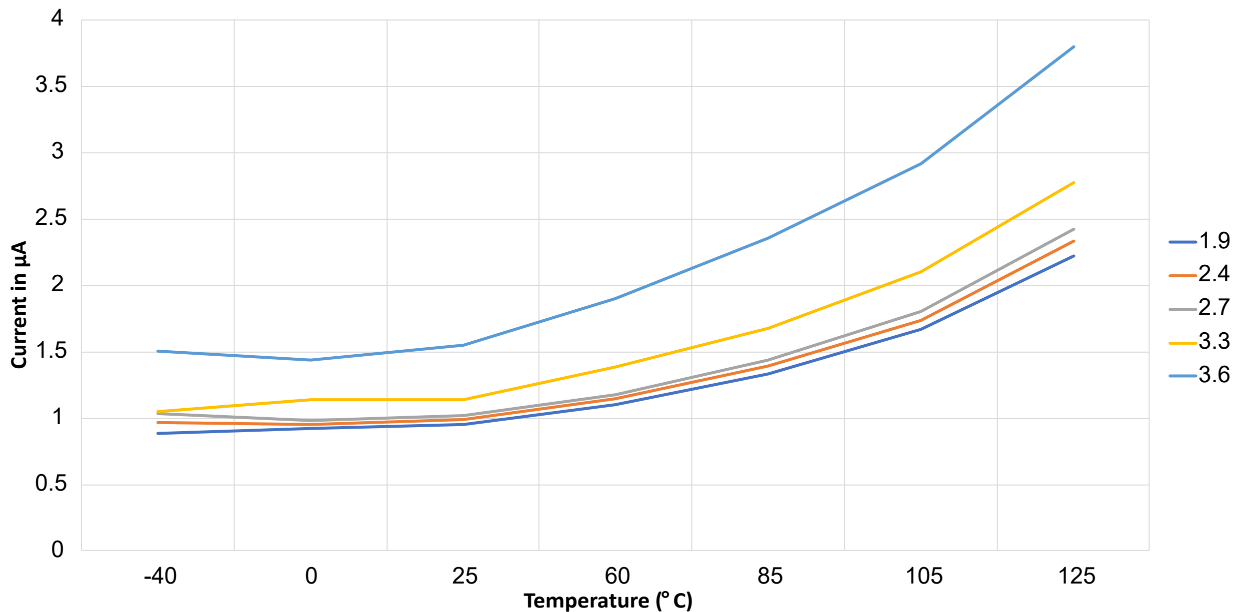


Figure 4-8. Deep Sleep Current RAM OFF



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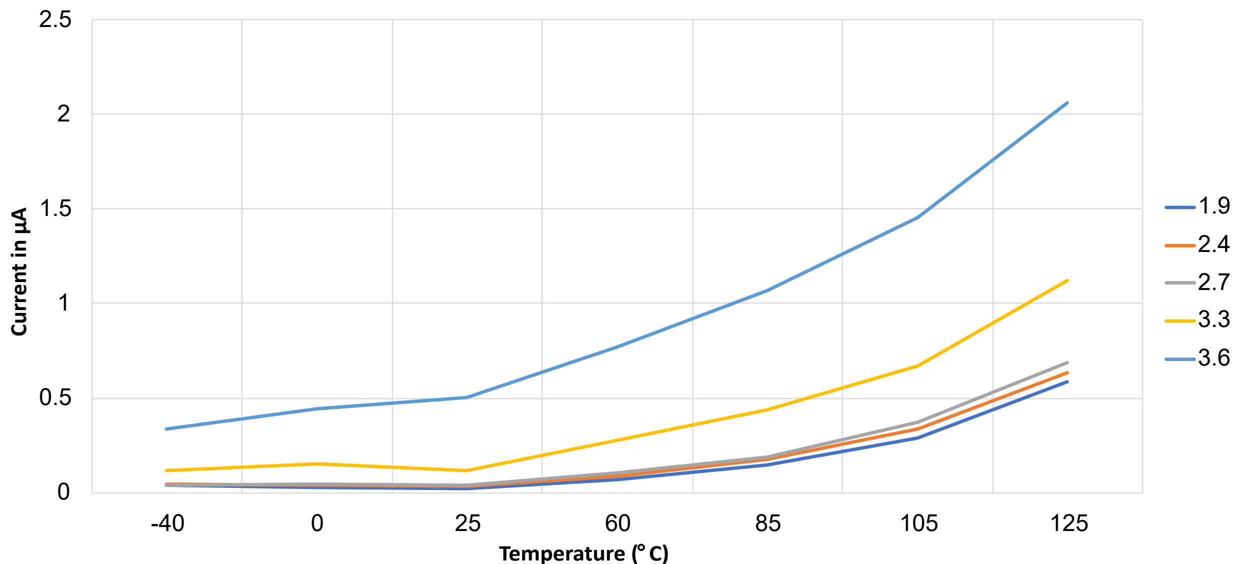
Notes:
1. Typical value measured during characterization at 3.3V and 25℃.
2. The test conditions are as follows:
   – All GPIO except RPA3 are pulled up. RPA3 is pulled down.
   – All peripherals are disabled.
   – All PB clocks are divided by 16.
   – LPRC is set as LPCLK.
   – SOSC and POSC is disabled.
   – DSU is disconnected.
   – RF system is in low power configuration.
   – DSWDT is enabled and configured for wake-up.
   – Deep sleep entry is configured and WFI instruction is executed.

4.6 XDS (Extreme Deep Sleep) Current Consumption DC Electrical Specifications

Table 4-6. XDS (Extreme Deep Sleep) Current Consumption DC Electrical Specifications

DC Characteristics			Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9V to 3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	Symbol	Characteristics	V_{DDIO}	Typ(1)	Max.	Units	Conditions
OPWR_1	I_{DD_OFF}(2)	MCU I_{DD} in OFF mode powered from V_{DDIOx}	3.3V	0.12	—	µA	In OFF mode, the device is entirely powered-off. **Note:** This mode is left by pulling the RESET pin low, or when a power Reset is done.

Figure 4-9. Extreme Deep Sleep Current



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Notes:

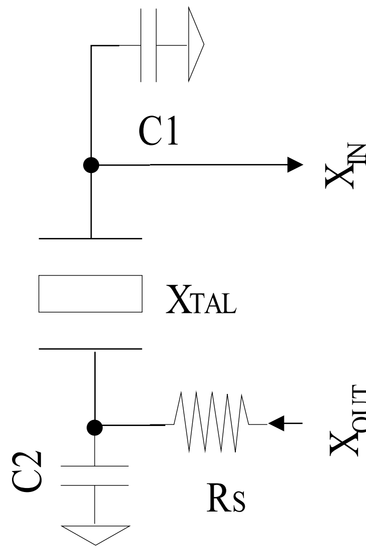
1. Typical value measured during characterization at 3.3V and 25℃.
2. The test conditions are as follows:
   - All GPIO except RPA3 are pulled up. RPA3 is pulled down.
   - All peripherals are disabled.
   - DSU is disconnected.
   - RF system is in low power configuration.
   - DSWDT is disabled.
   - RTCC and POSC is disabled.
   - Deep sleep entry is configured and WFI instruction is executed.

4.7 XOSC32 AC Electrical Specifications

Table 4-7. XOSC32 AC Electrical Specifications

AC Characteristics			Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9V to 3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	**Symbol**	**Characteristics**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**(1)
XOSC32_1	FOSC_XOSC32	XOSC32 oscillator crystal frequency	—	32.768	—	kHz	XIN32, XOUT32 secondary oscillator
XOSC32_3	CXIN32	XOSC32 XIN32 parasitic pin capacitance	—	0.4 2.4	—	pF	At the SOC pins on the Module
XOSC32_5	CXOUT32	XOSC32 XOUT32 parasitic pin capacitance on PIC32CX-BZ2	—	0.4 2.4	—	pF	At the SOC pins on the Module
XOSC32_11	CLOAD_X32(3)	32.768 kHz crystal load capacitance	—	11	—	pF	—
XOSC32_13	ESR_X32	32.768 kHz crystal ESR	—	75	—	KΩ	—
XOSC32_15	TOSC32	TOSC32 = 1/ FOSC_XOSC32	—	30.518	—	µs	See parameter XOSC32_1 for FOSC_XOSC32 value
XOSC32_17	XOSC32_ST(2)	XOSC32 crystal start-up time	—	23	—	ms	This includes system delay and cannot be considered as the exact start-up time of SOSC clock as it is brought out on REFOx

Figure 4-10. XOSC32 Block Diagram



Notes:

1. $V_{DDIO} = V_{DDANA} = 3.3V$.
2. This is for guidance only. A major component of crystal start-up time is based on the second party crystal MFG parasitic that is outside the scope of this specification. If this is a major concern, the customer might need to characterize this based on their design choices.
3. The test conditions for crystal load capacitor calculation are as follows:
   – Standard PCB trace capacitance = 1.5 pF per 12.5 mm (0.5 inches) (in other words, PCB STD TRACE W = 0.175 mm, H = 36 µm, T = 113 µm)
   – Xtal PCB capacitance typical; therefore, ~= 2.5 pF for a tight PCB xtal layout
   – For CXIN and CXOUT within 4 pF of each other, assume CXTAL_EFF = ((CXIN / 2)
   – **Note:** Averaging CXIN and CXOUT will affect the final calculated CLOAD value by less than the tolerance of the capacitor selection.
4. **Equation 4-1. Equation 1:**

   $$MFG\ \ CLOAD\ Spec = \{([CXIN + C1] * [CXOUT + C2])/[CXIN + C1 + C2 + CXOUT]\} + estimated\ oscillator\ PCB\ stray\ capacitance$$

   Assuming C1 = C2 and CXin ~= CXout, the formula can be further simplified and restated to solve for C1 and C2 by:

   Equation 4-2. Equation 2 (In other words: Simplified Equation 1)

   $$C1 = C2 = ((2 * MFG\ \ CLOAD\ Spec) - CXTAL_EFF - (2 * PCB\ \ capacitance))$$

   Example:

   - XTAL Mfg CLOAD Data Sheet Spec = 12 pF
   - PCB XTAL trace Capacitance = 2.5 pF
   - CXIN pin = 6.5 pF, CXOUT pin = 4.5 pF therefore CXTAL_EFF = ((CXIN / 2)

   CXTAL_EFF = ((6.5 + 4.5)/2) = 5.5 pF

   C1 = C2 = ((2 * MFG Cload spec) - CXTAL_EFF - (2 * PCB capacitance))

   C1 = C2 = (24 - 5.5 - (2 * 2.5))

   C1 = C2 = (24 - 5.5 - 5)

   C1 = C2 = 13.5 pF (Always rounded down)

   C1 = C2 = 13 pF (in other words, for hypothetical example crystal external load capacitors)

   User C1 = C2 = 13 pF ≤ CLOAD_X32 (max.) spec

4.8 Power Supply DC Module Electrical Specifications

Table 4-8. Power Supply DC Electrical Specifications

AC Characteristics			Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	**Symbol**	**Characteristics**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
REG_36	VDDCORE	VDDCORE voltage range	—	1.2	—	V	MCU Active, cache and prefetch disabled while executing from Flash[1]
REG_37	VDD33[4]	VDD33 input voltage range	1.9	3.3	3.6	V	—
REG_39	VDDANA[4]	VDDANA input voltage range	1.9	3.3	3.6	V	—
REG_40	VDDREG	VDDREG input voltage range	—	1.35	—	V	PMU output voltage
REG_43	SVDDIO_R	VDDIO rise ramp rate to ensure internal Power-on Reset signal	—	0.1	—	V/µs	Failure to meet this specification may lead to start-up or unexpected behaviors
REG_44	SVDDIO_F	VDDIO falling ramp rate to ensure internal Power-on Reset signal	—	—	—	V/µs	Failure to meet this specification may cause the device to not detect reset
REG_45	VP0R+	Power-on Reset	—	1.5	—	V	VDDIO power up/Down (See Param REG43, VDDIO Ramp Rate)
REG_45_A	VP0R-	Power-on Reset	—	1.5	—	V	VDDIO Power up/Down (See Param REG43, VDDIO Ramp Rate)
REG_47	VBOR33[4]	VDDIO BOD (All modes)[4]	—	1.7	—	V	—
REG_48	VBOR12	BOR of the 1.2V regulator	—	1.0	—	V	—
REG_48A	VZBPOR33	Zero power BOR	—	1.8	—	V	—
REG_53	TRST[6]	External RESET valid active pulse width	—	11	—	µs	Minimum Reset active time to guarantee MCU Reset for the module. Reset filter circuit inside Module
REG_54	MLDO_DELAY	PMU MLDO and CLDO power-up delay	—	260	—	µs	—
REG_55	SYS_DELAY	System delay before fetching first instruction	—	—	—	µs	—

...........continued							
AC Characteristics			Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	Symbol	Characteristics	Min.	Typ.	Max.	Units	Conditions
REG_56	CLK_DELAY	Crystal start-up delay	—	XOSC_2	—	µs	Refer to XOSC_2 parameter from the crystal oscillator section
REG_57	POWER_ON_DELAY	Power-up period	—	—	—	µs	—
REG_58	BOR_DELAY	Width of the BOR event	—	488	—	µs	Includes system delay since this is measured with a CPU event

Notes:

1. Ferrite Bead ISAT(min) ≥ (IDDANA(max) * 1.15).
2. Buck Inductor ISAT(min) ≥ ((ICAPACITOR + IVDDCORE_MAX) * 1.2) when the BUCK mode is enabled (shielded inductor only).
3. User must select either LDO or BUCK Mode. The modes are exclusive to each other.
4. VDD33 and VDDANA must be at the same voltage level.
5. All bypass caps must be located immediately adjacent to pin(s) and on the same side of the PCB as the MCU. Each primary power supply group VDDIO, VDDANA, VDDCORE must have one bulk capacitor and all power pins with a 100 nF bypass cap.
6. The RESET pulse width is the minimum pulse width required on the I/O pin after any filtering on the NMCLR pin.
7. Keep the DCR as low as possible to improve efficiency.

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Figure 4-11. Power-On Reset Timing Characteristics

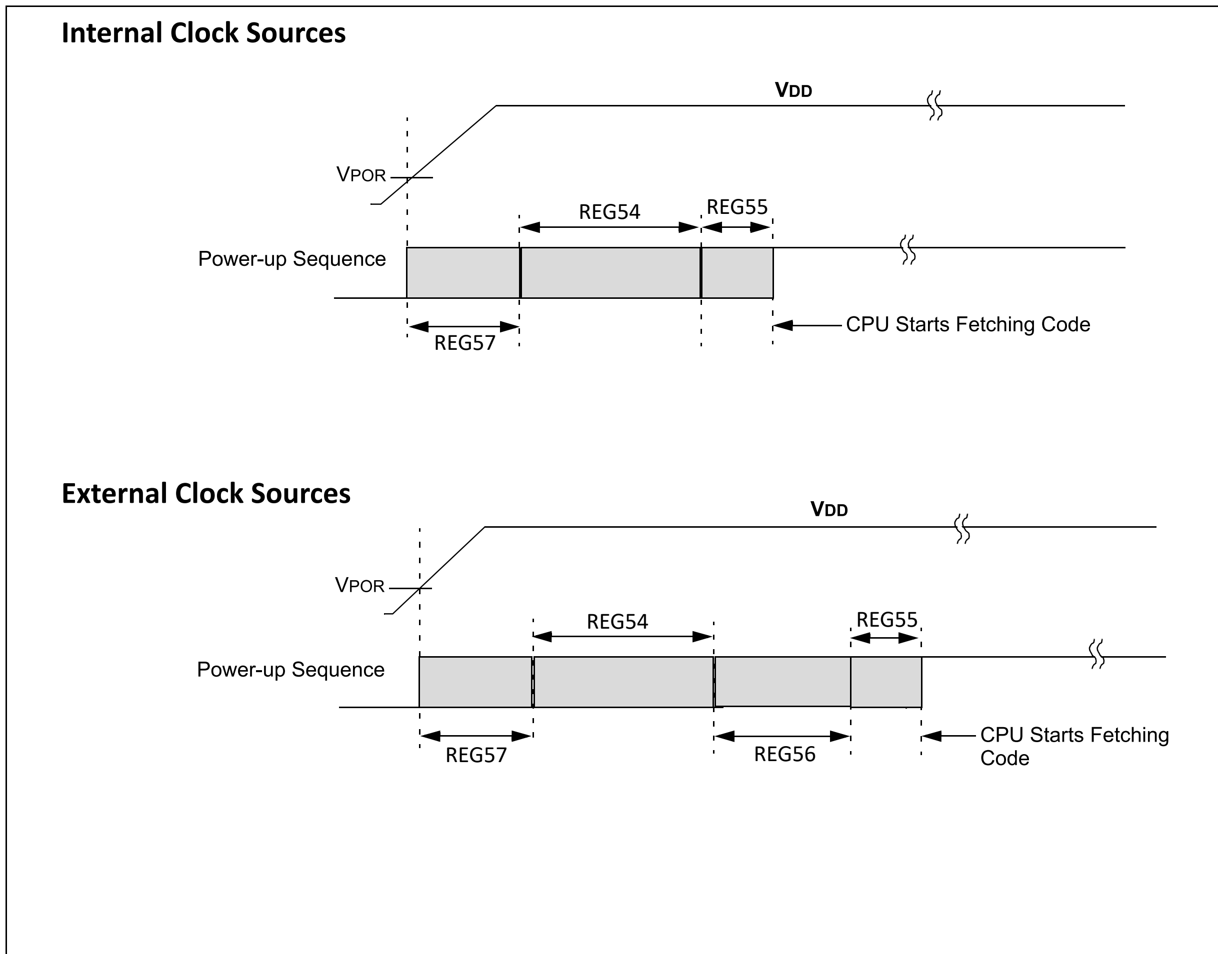
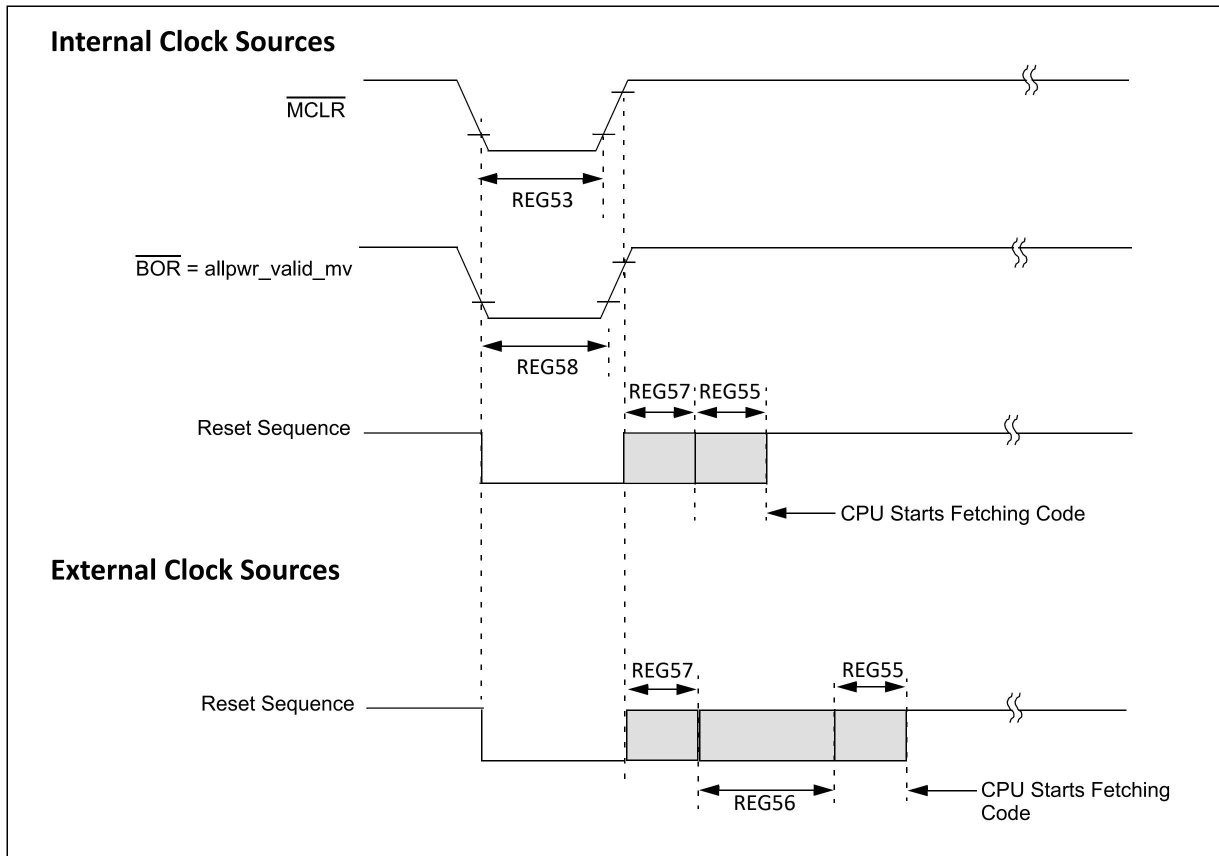


Figure 4-12. External Reset Timing Characteristics



4.9 I/O PIN AC/DC Electrical Specifications

Table 4-9. I/O PIN AC/DC Electrical Specifications

AC Characteristics			Standard Operating Conditions: $V_{DDIO} = V_{DDANA}$ 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	Symbol	Characteristics	Min.	Typ.(1)	Max.	Units	Conditions
DI_1	VOL	Output voltage low (Drive strength, 8x)	—	0.1	—	V	VDDIO = 3.3V at IOL= 10 mA
		Output voltage low (Drive strength, 4x)		0.2	—		VDDIO = 3.3V at IOL= 10 mA
DI_2	VOL	Output voltage low (Drive strength, 8x)	—	0.2	—	V	VDDIO = 3.3V at IOL= 13 mA
		Output voltage low (Drive strength, 4x)		0.3	—		VDDIO = 3.3V at IOL= 13 mA

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...........continued

AC Characteristics			Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	Symbol	Characteristics	Min.	Typ.[1]	Max.	Units	Conditions
DI_3	VOL	Output voltage low (Drive strength, 8x)	—	0.2	—	V	VDDIO = 3.3V at IOL= 15 mA
DI_4	VOH	Output voltage low (Drive strength, 8x)	—	2.3	—	V	VDDIO = 3.3V at IOH= 5 mA
		Output voltage low (Drive strength, 4x)	—	2.1	—		VDDIO = 3.3V at IOH= 5 mA
DI_5	VOH	Output voltage low (Drive strength, 8x)	—	2.2	—	V	VDDIO = 3.3V at IOH= 7 mA
		Output voltage low (Drive strength, 4x)	—	2.0	—		VDDIO = 3.3V at IOH= 7 mA
DI_6	VOH	Output voltage High (Drive strength, 8x)	—	2.1	—	V	VDDIO = 3.3V at IOH= 10 mA
DI_7	VIL	Input voltage low (Drive strength, 8x)	—	0.7	—	V	VDDIO = 3.3V
		Input voltage low (Drive strength, 4x)	—	0.5	—		VDDIO = 3.3V
DI_8	VIH	Input voltage high (Drive strength, 8x)	—	2.9	—	V	VDDIO = 3.3V
		Input voltage high (Drive strength, 4x)	—	2.9	—		VDDIO = 3.3V
DI_13	IIL	Input pin leakage current	—	71.8	—	nA	—

...........continued

AC Characteristics			Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	Symbol	Characteristics	Min.	Typ.[1]	Max.	Units	Conditions
DI_15[5]	RPDWN	Internal pull-down (Drive strength, 8x)	—	21.4	—	kΩ	VDDIO = 3.3V
		Internal pull-down (Drive strength, 4x)	—	3.9	—	kΩ	
DI_17	RPUP	Internal pull-up (Drive strength, 8x)	—	18.6	—	kΩ	
		Internal pull-up (Drive strength, 4x)	—	3.3	—	kΩ	
DI_25	TRISE	I/O pin rise time (High drive strength, high load)	—	1.97	—	ns	VDDIO = 3.3V
		I/O pin rise time (Low drive strength, high load)	—	10.7	—	ns	—
		I/O pin rise time (High drive strength, standard load)	—	2.0	—	ns	—
		I/O pin rise time (Low drive strength, standard load)	—	7.6	—	ns	—
DI_27	TFALL	I/O pin fall time (High drive strength, high load)	—	1.6	—	ns	—
		I/O pin fall time (Low drive strength, high load)	—	8.1	—	ns	—
		I/O pin fall time (High drive strength, standard load)	—	1.6	—	ns	—
		I/O pin fall time (Low drive strength, standard load)	—	5.1	—	ns	—

Notes:

1. All measurements done at 3.3V at 25℃.
2. VIL source < (GND – 0.3). Characterized but not tested.
3. Any number and/or combination of I/O pins not excluded under IICL or IICH conditions are permitted provided the absolute instantaneous sum of the input injection currents from all pins do not exceed the specified ∑IICT limit. To limit the injection current, the user must insert a resistor in series RSERIES (in other words, RS), between the input source voltage and device pin. The resistor value is calculated according to:
   – For negative Input voltages less than (GND – 0.3): RS ≥ absolute value of | ((VIL source – (GND – 0.3)) / IICL) |
   – For positive input voltages greater than (VDDIO + 0.3): RS ≥ ((VIH source – (VDDIO +0.3))/ IICH)
   – For Vpin voltages greater than VDDIO + 0.3 and less than GND – 0.3: RS = the larger of the values calculated above
4. High load = 50 pF and Standard load = 30 pF.
5. The drive strength of pads are as follows:
   – 8x pads - PA0, PA1, PA3, PA4, PA5, PA6, PA7, PA8, PA9, PA10, PA13, PA14, PB10, PB11, PB12, PB13
   – 4x pads - PA2, PB0, PB1, PB2, PB3, PB4, PB5, PB6, PB7, PB8, PB9

4.10 ADC Electrical Specifications

Table 4-10. ADC AC Electrical Specifications

AC Characteristics			Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	Symbol	Characteristics	Min.	Typ.	Max.	Units	Conditions
Device Supply							
ADC_1	V_{DDANA}	ADC supply	$V_{DDANA(min)}$	—	$V_{DDANA(max)}$	V	V_{DDIO} = V_{DDANA}
Reference Inputs							
ADC_3	V_{REF}(6)	ADC reference voltage(4)	—	—	V_{DDANA}	V	External reference voltage
Analog Input Range							
ADC_7	AFS	Full-scale analog input signal range (Single-ended)	0	—	V_{DDANA}	V	V_{REF} = $V_{DDANA(max)}$
ADC_9		Full-scale analog input signal range (Differential)	V_{DDANA}/2	—	V_{DDANA}/2	V	

Table 4-11. ADC Single-Ended Mode AC Electrical Specifications

AC Characteristics			Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	Symbol	Characteristics	Min.	Typ.	Max.	Units	Conditions
Single-Ended Mode ADC Accuracy							

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...........continued							
AC Characteristics			**Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp**				
Param. No.	**Symbol**	**Characteristics**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
SADC_11	Res	Resolution	6	—	12	bits	Selectable 6, 8, 10, 12 bit resolution ranges
SADC_13	EN0B(3)	Effective number of bits	—	9.3	—	bits	1.6 Msps, Internal V_{REF}, V_{DDANA} = V_{DDIO} = 3.3V
SADC_19	INL(3)	Integral non linearity	—	-5.2 2.7	—	LSb	1.6 Msps, Internal V_{REF}, V_{DDANA} = V_{DDIO} = 3.3V
SADC_25	DNL(3)	Differential non linearity	—	-1 1.8	—	LSb	1.6 Msps, Internal V_{REF}, V_{DDANA} = V_{DDIO} = 3.3V
SADC_31	GERR(3)	Gain error	—	-0.7	—	LSb	1.6 Msps, Internal V_{REF}, V_{DDANA} = V_{DDIO} = 3.3V
SADC_37	E0FF(3)	Offset error	—	3.2	—	LSb	Internal V_{REF}, V_{DDANA} = V_{DDIO} = 3.3V
Single-Ended Mode ADC Dynamic Performance							
SADC_49	SINAD(1,2,3)	Signal to noise and distortion	—	57.8	—	dB	V_{REF} = V_{DDANA} = V_{DDIO} = 3.3V at 12-bit resolution, max sampling rate(1,2)
SADC_51	SNR(1,2,3))	Signal to noise ratio	—	58.2	—		
SADC_53	SFDR(1,2,3)	Spurious free dynamic range	—	66.2	—		
SADC_55	THD(1,2,3,5)	Total harmonic distortion	—	-71.3	—		

Notes:

1. Characterized with an analog input sine wave = (FTP(maximum)/100). Example: FTP(maxium) = 1 Msps/100 = 10 KHz sine wave.
2. Sinewave peak amplitude = 96% ADC_ Full Scale amplitude input with 12-bit resolution.
3. Spec values collected under the following additional conditions:
   a. 12-bit resolution mode.
   b. All registers at reset default value otherwise not mentioned.
4. ADC Measurements done with 3.3V V_{REF} Voltage.
5. Value taken over 7 harmonics.
6. Referred to as AVDD in the pinout.

Table 4-12. ADC Conversion AC Electrical Requirements

AC Characteristics			**Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp**				
Param. No.	**Symbol**	**Characteristics**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
ADC_ Clock Requirements							

...........continued							
AC Characteristics			**Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp**				
Param. No.	**Symbol**	**Characteristics**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
ADC_57	TAD	ADC clock period	—	20.8	—	ns	V_{REF} = V_{DDANA} = 3.3V
ADC Single-Ended Throughput Rates							
ADC_59	FTPR (Single-ended Mode)	Throughput rate[2] (Single-ended)	—	2	—	Msps	12-bit resolution, DIV_SHR = 2
			—	0.7	—		12-bit resolution, DIV_SHR = 4

Notes:
1. Conversion_time = (SAMC_SHR+15)*TAD.
2. FTPR = 1/((SAMC_SHR + Resolution + 1) * (1/(ControlClk/DIV_SHR))).

Table 4-13. ADC Sample AC Electrical Requirements

AC Characteristics			**Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp**				
Param. No.	**Symbol**	**Characteristics**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
ADC_65	TCNV	Conversion time[1] (Single-ended Mode)	14			TAD	12-bit resolution
			12				10-bit resolution
			10				8-bit resolution
ADC_67		Conversion time[1] (Differential Mode)	14			TAD	12-bit resolution
			12				10-bit resolution
			10				8-bit resolution
ADC_69	CSAMPLE	ADC internal sample cap	—	5	—	pf	—
ADC_71	RSAMPLE	ADC internal impedance	—	—	200	Ω	—

Note:
1. ADC Throughput Rate FTP = ((1/((TSAMP + TCNV) * TAD))/(# of user active analog inputs in use on specific target ADC module)).

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4.11 Bluetooth Low Energy RF Characteristics

Table 4-14. Bluetooth Low Energy RF Characteristics

AC Characteristics			Standard Operating Conditions: $V_{DDIO} = V_{DDANA}$ 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	Symbol	Characteristics	Min.	Typ[1]	Max.	Units	Conditions
BTG1	FREQ	Frequency range of operation	2400	—	2480	MHz	—
BTTX1	TXPWR:MPA	Bluetooth transmit power MPA	—	11.5	—	dBm	—
BTTX2	TXPWR:LPA	Bluetooth transmit power LPA	—	4.0	—	dBm	—
BTX3	TXIB:1MBPS	In-band emission for FTX ± -2 MHz	—	-32	—	dBm	—
		In-band emission for FTX ± -(3+N) MHz	—	-45	—	dBm	—
BTX4	TXIB:2MBPS	In-band emission for FTX ± -4 MHz	—	-43	—	dBm	—
		In-band emission for FTX ± -5 MHz	—	-48	—	dBm	—
		In-band emission for FTX ± -(6+N) MHz	—	-51	—	dBm	—
BTRX1	RXSENSE	Receiver sensitivity at 1 Mbps	—	-95.5	—	dBm	[1]
		Receiver sensitivity at 2 Mbps	—	-92.5	—	dBm	[5]
		Receiver sensitivity at 500 kbps	—	-98.5	—	dBm	[5]
		Receiver sensitivity at 125 kbps	—	-102	—	dBm	[5]
BTRX2	MAXINSIG	Maximum input signal level at 1 Mbps	—	0	—	dBm	—
		Maximum input signal level at 2 Mbps	—	0	—	dBm	
		Maximum input signal level at 500 kbps	—	0	—	dBm	
		Maximum input signal level at 125 kbps	—	0	—	dBm	

...........continued							
AC Characteristics			Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	Symbol	Characteristics	Min.	Typ[(1)]	Max.	Units	Conditions
BTRX3[(4)]	CI1M:COCH	C/I Co channel rejection	—	13	—	dB	—
	CI1M: ± -1 MHz	C/I adjacent channel rejection	—	13	—	dB	—
	CI1M: ± -2 MHz	C/I adjacent channel rejection	—	13	—	dB	—
	CI1M:ADJ(3+n)	C/I alternate channel rejection	—	15	—	dB	—
	CI1M:IMG	C/I image frequency rejection	—	15	—	dB	—
	CI1M:IMG ± -1 MHz	C/I adjacent channel to image freq rejection	—	14	—	dB	—
BTRX4[(4)]	CIS2:COCH	C/I Co channel rejection	—	11	—	dB	—
	CIS2: ± -1 MHz	C/I adjacent channel rejection	—	17	—	dB	—
	CIS2: ± -2 MHz	C/I adjacent channel rejection	—	18	—	dB	—
	CIS2:ADJ(3+n)	C/I alternate channel rejection	—	17	—	dB	—
	CIS2:IMG	C/I image frequency rejection	—	14	—	dB	—
	CIS2:IMG ± -1 MHz	C/I adjacent channel to image freq rejection	—	18	—	dB	—
BTRX5[(4)]	CIS8:COCH	C/I Co channel rejection	—	6	—	dB	—
	CIS8: ± -1 MHz	C/I adjacent channel rejection	—	13	—	dB	—
	CIS8: ± -2 MHz	C/I adjacent channel rejection	—	13	—	dB	—
	CIS8:ADJ(3+n)	C/I alternate channel rejection	—	14	—	dB	—
	CIS8:IMG	C/I image frequency rejection	—	8	—	dB	—
	CIS2:IMG ± -1 MHz	C/I adjacent channel to image freq rejection	—	16	—	dB	—

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...........continued							
AC Characteristics			**Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp**				
Param. No.	**Symbol**	**Characteristics**	**Min.**	**Typ[1]**	**Max.**	**Units**	**Conditions**
BTRX6[4]	CI2M:COCH	C/I Co channel rejection	—	13	—	dB	—
	CI2M: ± -2 MHz	C/I adjacent channel rejection	—	16	—	dB	—
	CI2M: ± -4 MHz	C/I adjacent channel rejection	—	19	—	dB	—
	CI2M:ADJ(6+2n)	C/I alternate channel rejection	—	16	—	dB	—
	CI2M:IMG	C/I image frequency rejection	—	13	—	dB	—
	CI2M:IMG ± -2 MHz	C/I adjacent channel to image freq rejection	—	19	—	dB	—
BTRX7[4]	BLOCK1M:<2 GHZ	Blocking performance from 30-2 GHz	—	20	—	dB	—
	BLOCK1M:2 GHZ<SIG<2399 MHz	Blocking performance from 2003-2399 MHz	—	14	—	dB	—
	BLOCK1M:2484 MHZ<SIG<2977 MHz	Blocking performance between 2484-2997 MHz	—	20	—	dB	—
	BLOCK1M:3 GHZ<SIG<12.75 GHz	Blocking performance between 3-12.5 GHz	—	20	—	dB	—
BTRX8[4]	BLE1M:INTERMOD	Inter modulation performance for BLEM	—	13.5	—	dB	—
	BLE2M:INTERMOD	Inter modulation performance for BLEM	—	19.5	—	dB	—

Notes:

1. Measured at 25℃, averaged across all voltages and channels.
2. Measured on a board with the reference schematic.
3. All measurement across voltage based on the SIG specifications.
4. The specified value is the limit above the SIG specifications.
5. PDU length = 37, channels = 2402/2426/2440/2480 MHz.

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Table 4-15. Bluetooth Low Energy RF Current Characteristics

AC Characteristics					Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp				
Param. No.	**Symbol**	**Characteristics**	**RF Power**	**CPU Frequency**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
IBLETX1	IDDTXMPA	Current consumption with output power in DC-DC mode 1 Mbps	+12 dBm	64 MHz	—	42.8	—	mA	—
IBLETX2			+12 dBm	32 MHz	—	40.5	—	mA	—
IBLETX3			+12 dBm	8 MHz	—	39.0	—	mA	—
IBLETX4		Current consumption at +12 dBm output power in MLDO mode	+12 dBm	64 MHz	—	96.7	—	mA	—
IBLETX5			+12 dBm	32 MHz	—	91.8	—	mA	—
IBLETX6			+12 dBm	8 MHz	—	88.1	—	mA	—
IBLETX7	IDDTXLPA	Current consumption at +4 dBm output power in DC-DC mode 1 Mbps	4 dBm	64 MHz	—	24.9	—	mA	—
IBLETX8			4 dBm	32 MHz	—	22.9	—	mA	—
IBLETX9			4 dBm	8 MHz	—	21.1	—	mA	—
IBLETX10		Current consumption at +4 dBm output power in MLDO mode	4 dBm	64 MHz	—	55.5	—	mA	—
IBLETX11			4 dBm	32 MHz	—	48.7	—	mA	—
IBLETX12			4 dBm	8 MHz	—	45.8	—	mA	—
IBLETX7	IDDTXLPA0	Current consumption at +0 dBm output power in DC-DC mode 1 Mbps	0 dBm	64 MHz	—	22.7	—	mA	—
IBLETX8			0 dBm	32 MHz	—	20.9	—	mA	—
IBLETX9			0 dBm	8 MHz	—	18.2	—	mA	—
IBLETX10		Current consumption at 0 dBm output power in MLDO mode	0 dBm	64 MHz	—	47.6	—	mA	—
IBLETX11			0 dBm	32 MHz	—	43.0	—	mA	—
IBLETX12			0 dBm	8 MHz	—	39.7	—	mA	—

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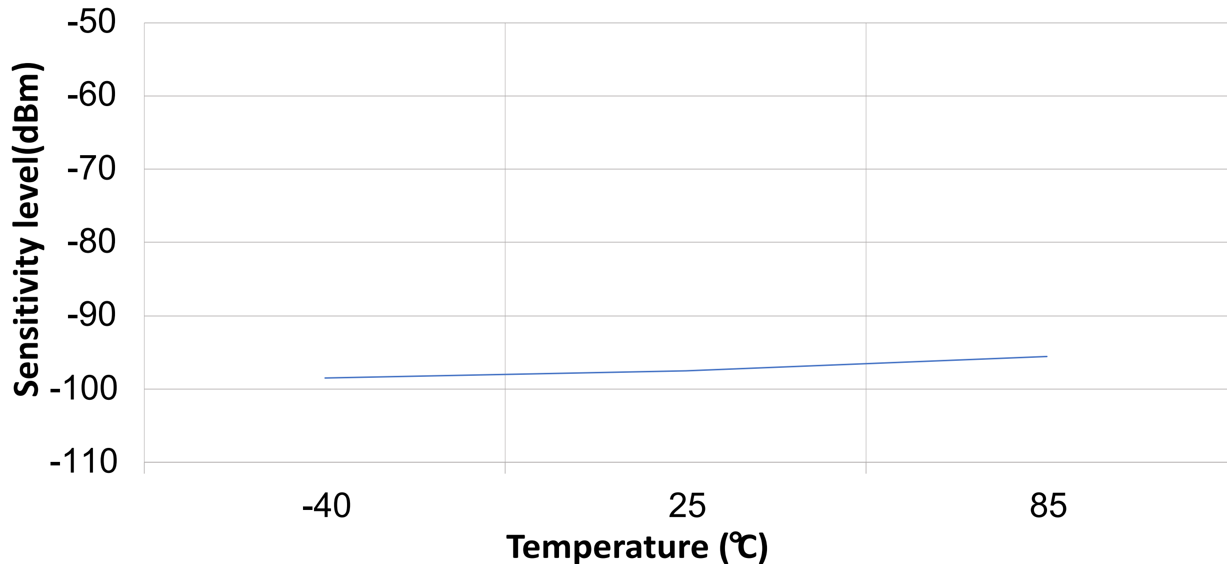
...........continued									
AC Characteristics					**Standard Operating Conditions: V_{DDIO} = V_{DDANA} 1.9-3.6V (unless otherwise stated) Operating Temperature: -40°C ≤ T_A ≤ +85°C for Industrial Temp**				
Param. No.	**Symbol**	**Characteristics**	**RF Power**	**CPU Frequency**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
IBLERX1	IDDRXBLE1M	Current consumption at RX signal level -80 dBm in DC-DC mode	-80 dBm	64 MHz	—	20.6	—	mA	—
IBLERX2			-80 dBm	32 MHz	—	18.2	—	mA	—
IBLERX3			-80 dBm	8 MHz	—	16.5	—	mA	—
IBLERX4		Current consumption at RX signal level -80 dBm in MLDO mode	-80 dBm	64 MHz	—	40.6	—	mA	—
IBLERX5			-80 dBm	32 MHz	—	35.1	—	mA	—
IBLERX6			-80 dBm	8 MHz	—	30.9	—	mA	—

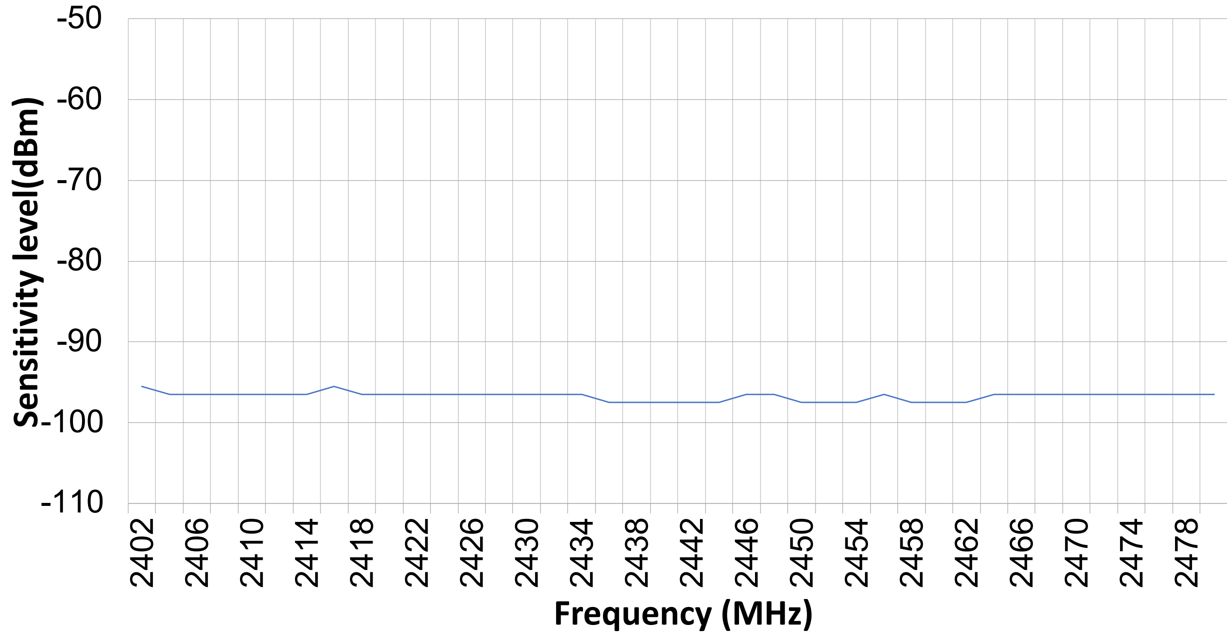
Notes:
- Current consumption is measured on a board based upon the Microchip Technology Reference Design.
- Current consumption is for the entire SoC (including the MCU), measured at the input power rail.
- Current consumption is measured using HUT code.
- Current reported is the average of the current during the transmit or receive burst (exclude off cycle of the transmit/receive operation).

Figure 4-13. Module Bluetooth Low Energy Receive Sensitivity vs Temperature



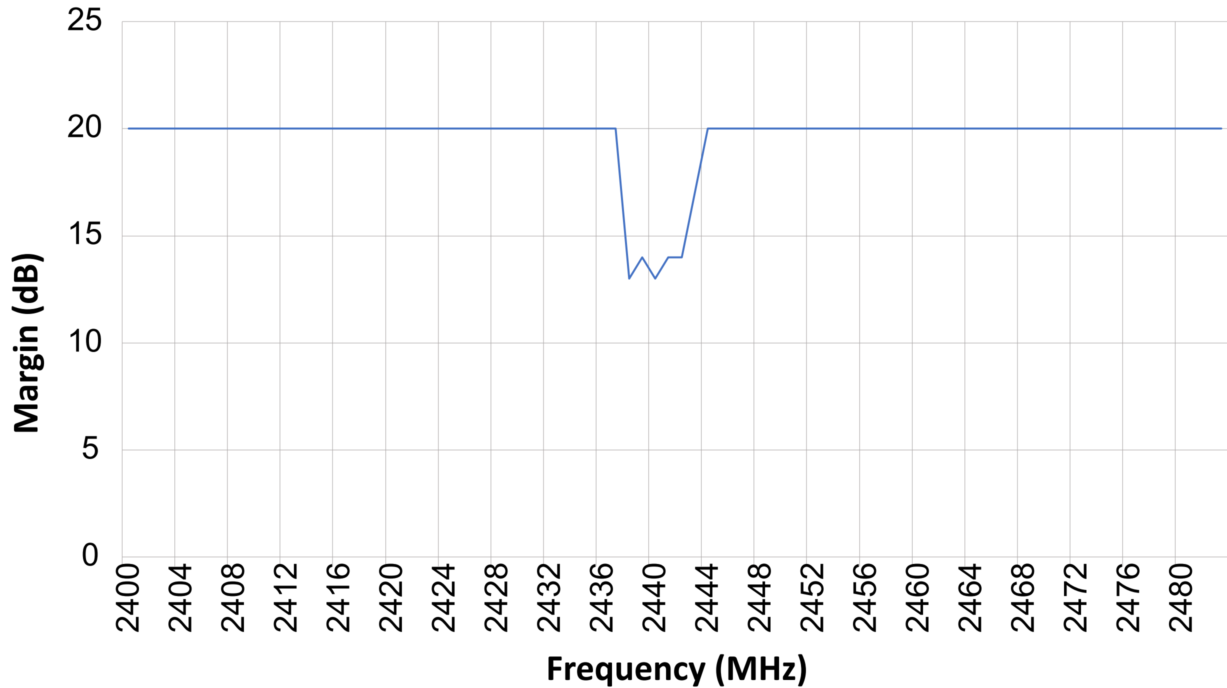
Notes:
- Bluetooth Low Energy receive sensitivity is measured across temperature at 3.6V, 2440 MHz, uncoded data at 1 Ms/s.
- PDU length = 37.
- Sensitivity is measured according to the SIG specifications.

Figure 4-14. Module Bluetooth Low Energy Receive Sensitivity vs Frequency



Notes:
- Bluetooth Low Energy sensitivity is measured across channels at 3.6V at 25℃, uncoded data at 1 Ms/s.
- PDU length = 37.
- Sensitivity is measured according to the SIG specifications.

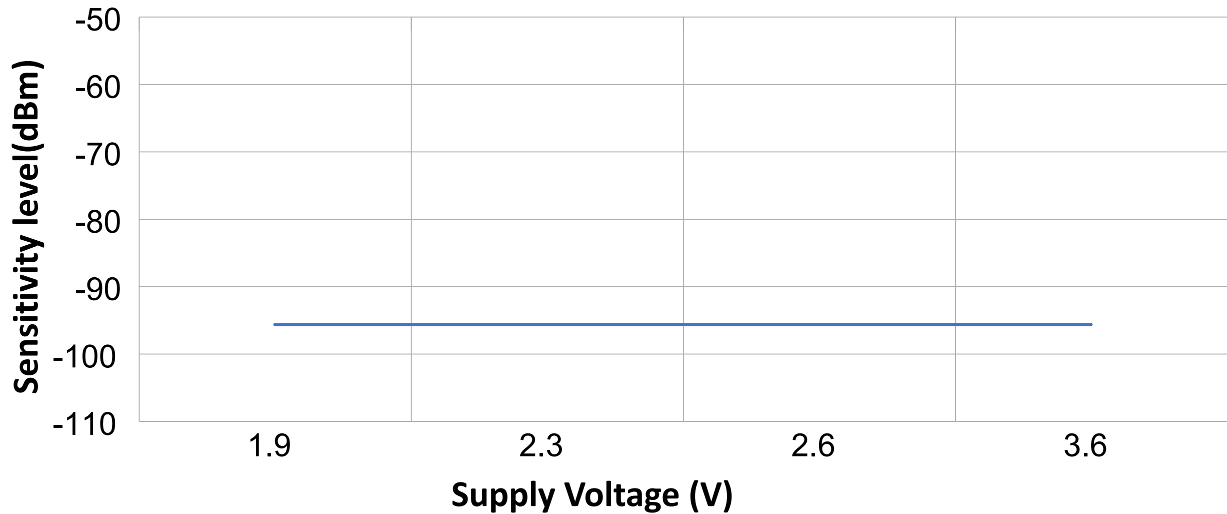
Figure 4-15. Bluetooth Low Energy 1M CI Margin



Notes:

- Bluetooth Low Energy 1M C/I Margin is measured at 2440 MHz at 25℃, 3.6V, uncoded data at 1 Ms/s.
- C/I test is done with HUT code based on the SIG specifications.
- Reported C/I margin is the margin above the C/I specifications from SIG.

Figure 4-16. Bluetooth Low Energy Receive Sensitivity vs Voltage



Notes:

- Bluetooth Low Energy receive sensitivity is measured at 2440 MHz at 25℃, uncoded data at 1 Ms/s.
- PDU length = 37.
- Sensitivity is measured according to the SIG specifications.

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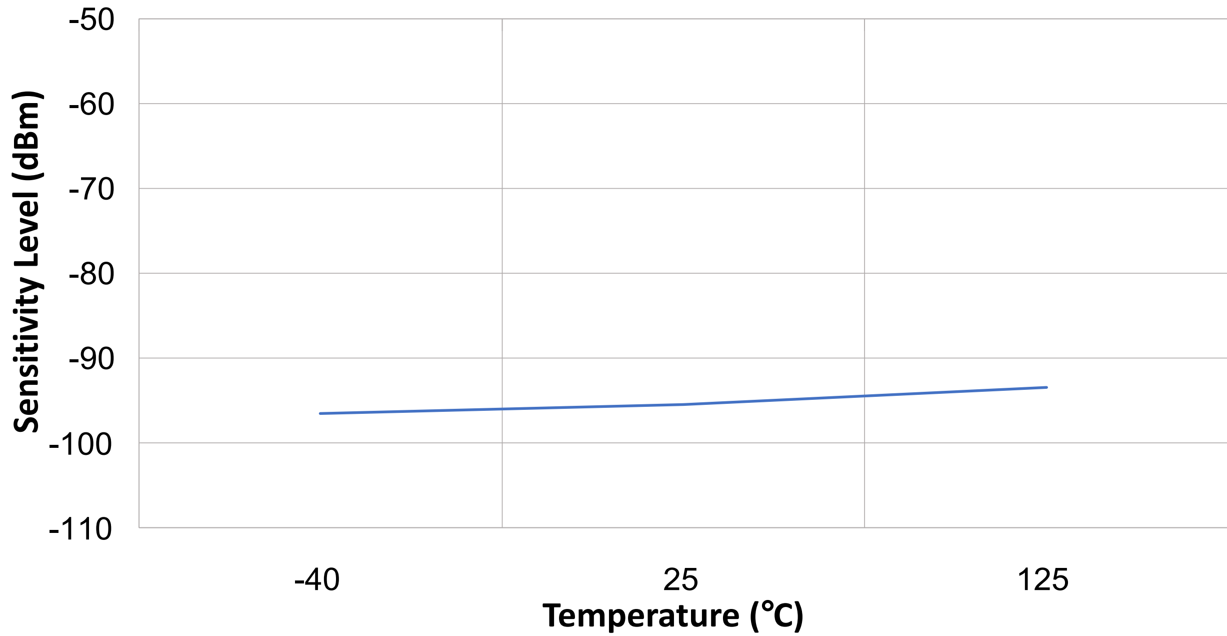
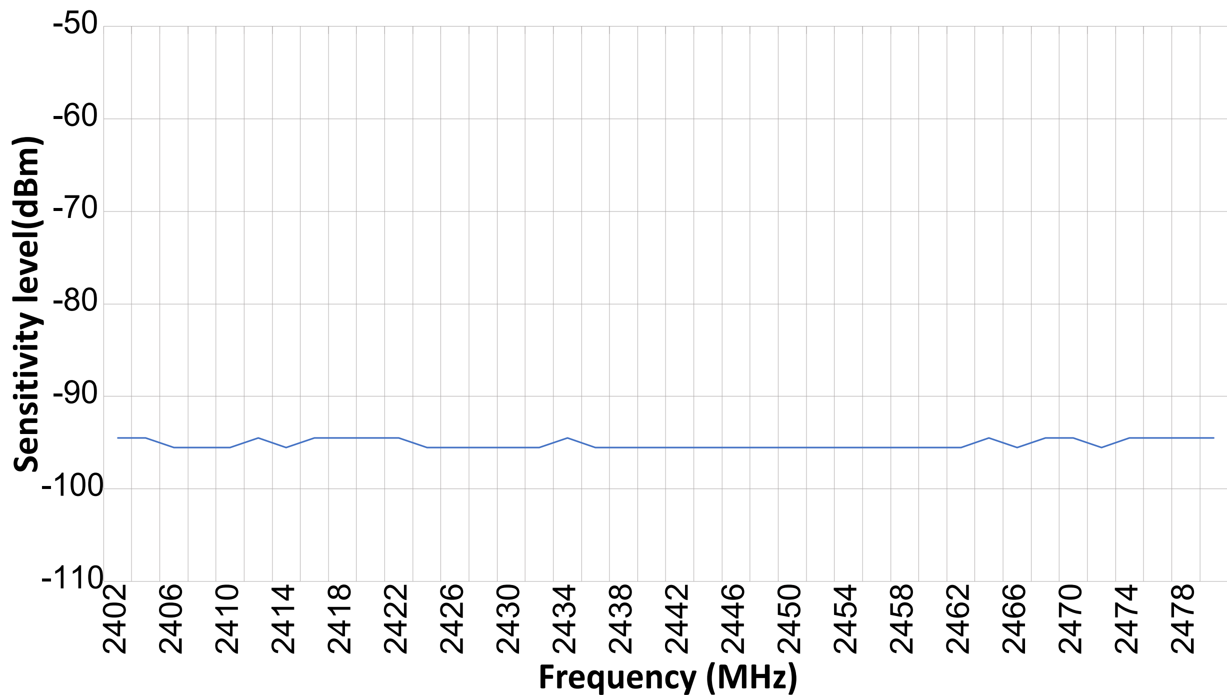
Figure 4-17. Bluetooth Low Energy Receive Sensitivity vs Temperature



Notes:

- Bluetooth Low Energy receive sensitivity is measured across channels at 3.6V, 2440 MHz, uncoded data at 1 Ms/s.
- PDU length = 37.
- Sensitivity is measured according to the SIG specifications.

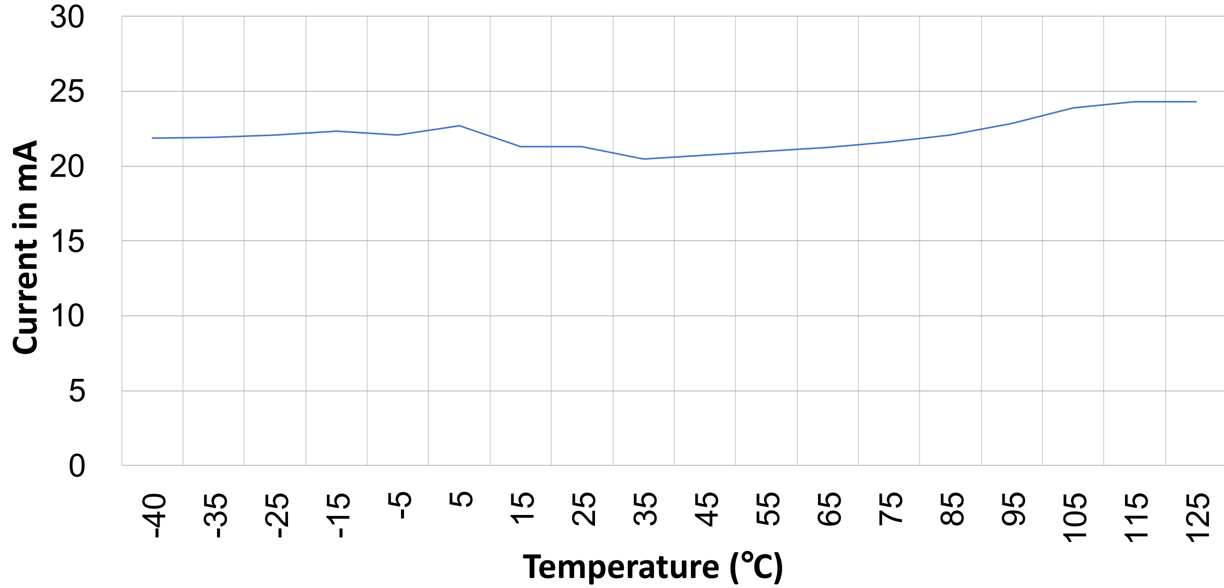
Figure 4-18. Bluetooth Low Energy Receive Sensitivity vs Frequency



Notes:

- Bluetooth Low Energy receiver sensitivity is measured across channels at 3.6V at 25℃, uncoded data at 1 Ms/s.
- PDU length = 37.
- Sensitivity is measured according to the SIG specifications.

Figure 4-19. Bluetooth Low Energy Receive Current vs Temperature



Notes:

- Bluetooth Low Energy receive current is measured at 3.3V (Buck mode), uncoded data at 1 Ms/s with LNA configured at maximum gain.
- PDU length = 37.
- Current is measured on input power rail to SoC (includes processor current as well).
- Current is measured with HUT code.

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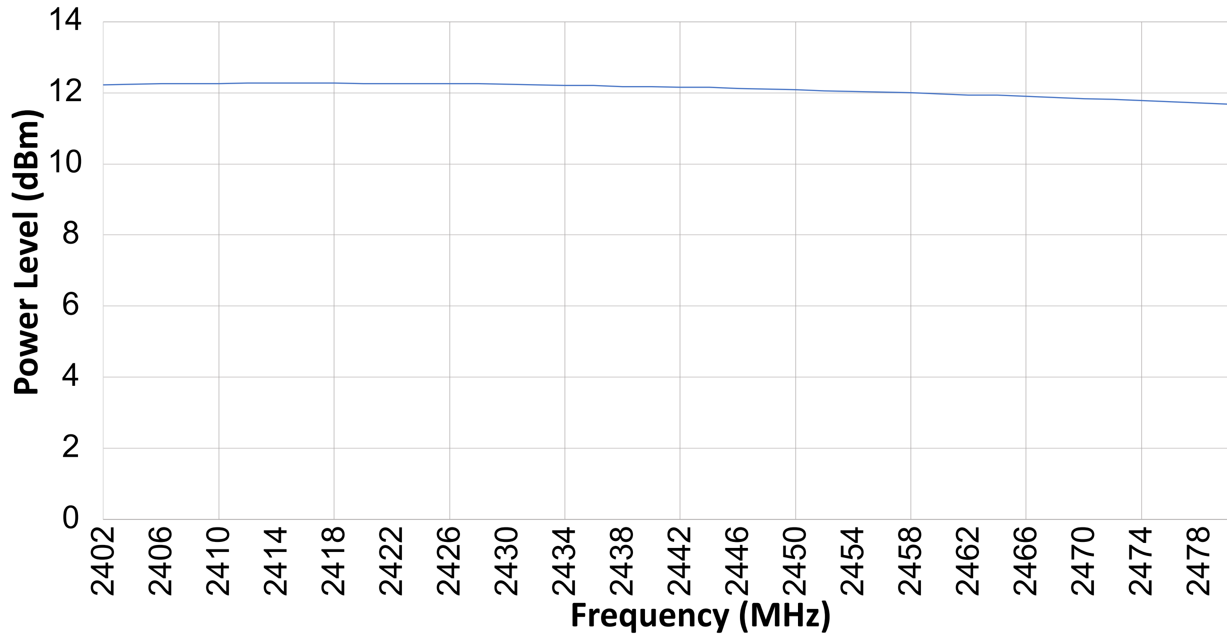
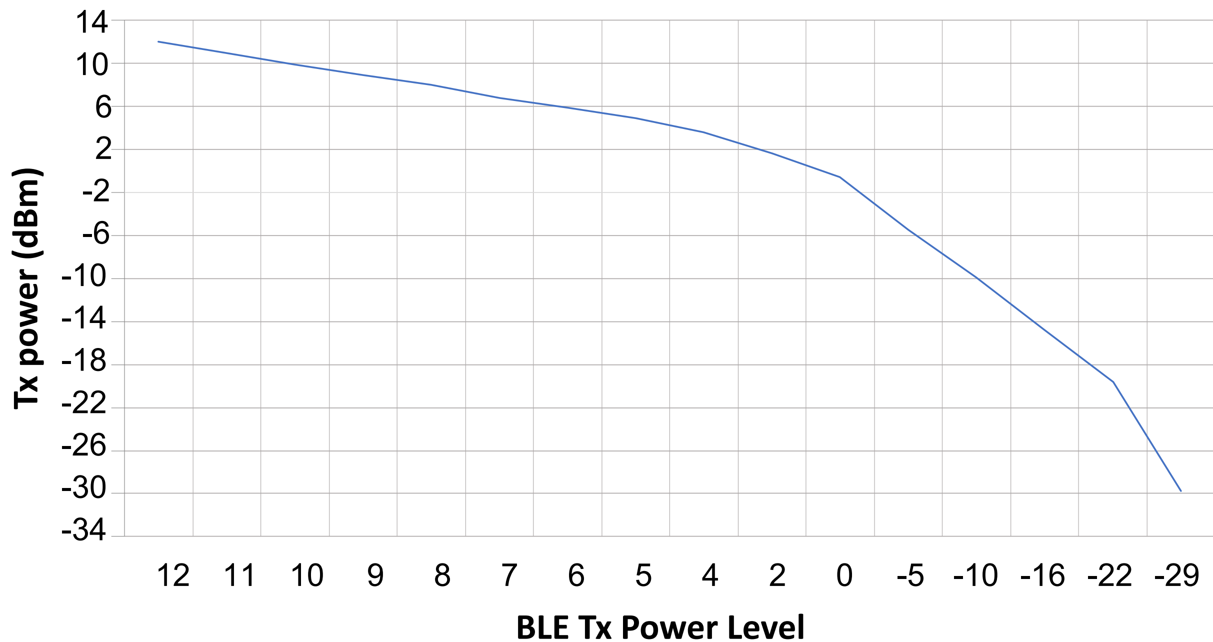
Figure 4-20. Bluetooth Low Energy Transmit Power vs Frequency



Notes:

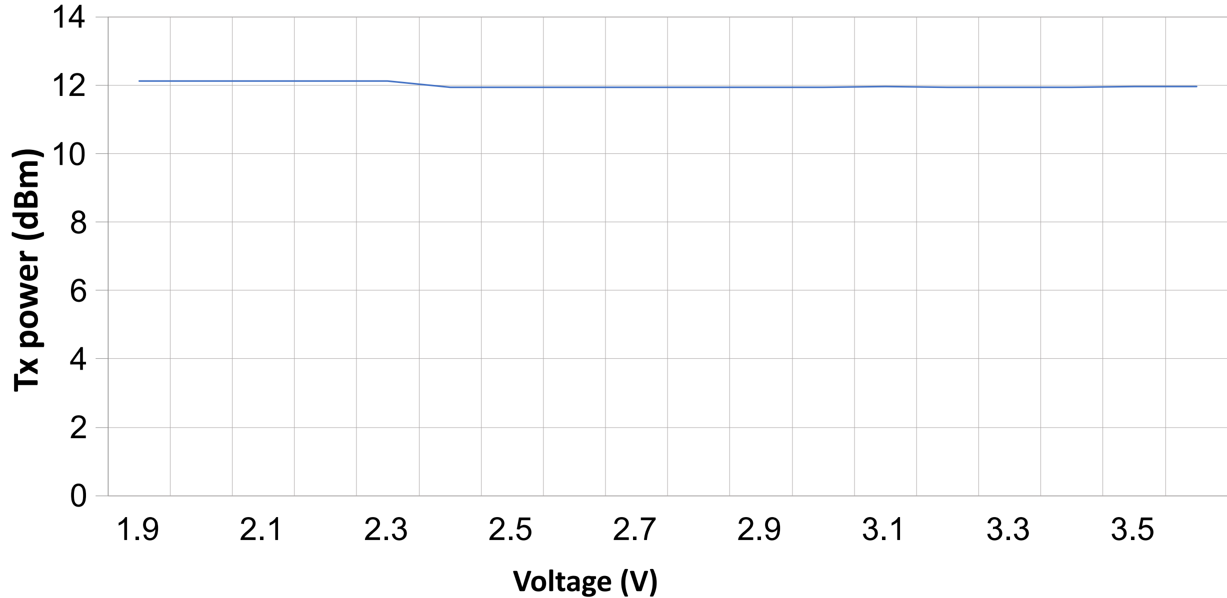
- Bluetooth Low Energy transmit power is measured across frequency after transmit power calibration at 3.3V (Buck mode).
- Transmit power is measured with HUT code.
- Transmit power is measured after the PA matching and LPF.

Figure 4-21. Bluetooth Low Energy Transmit Power vs Transmit Power Level



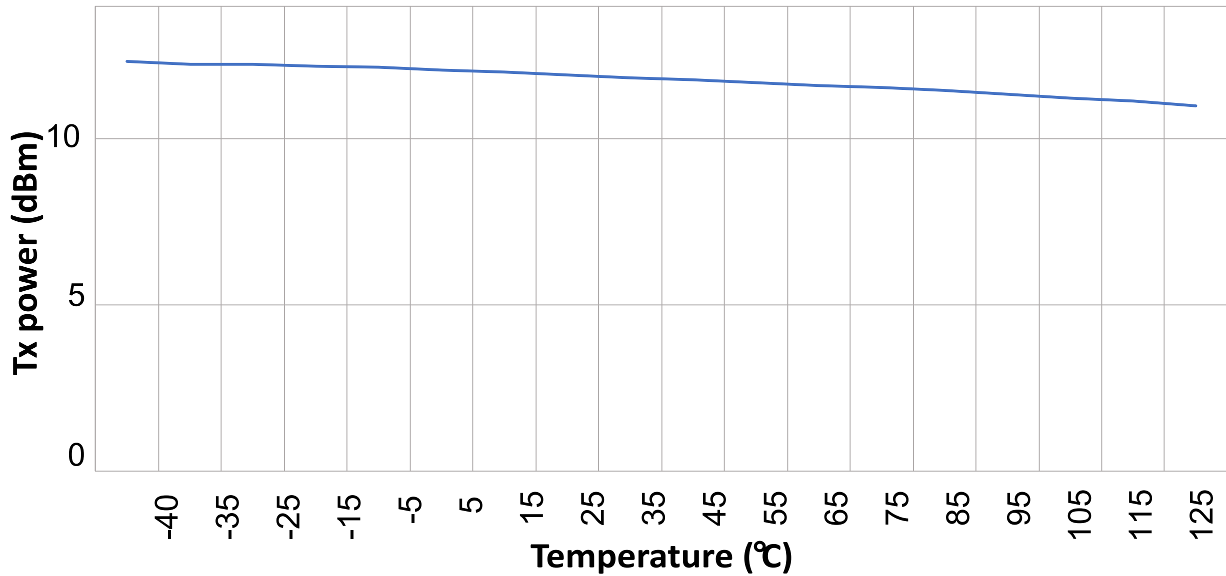
Notes:
- Bluetooth Low Energy transmit power is measured at 2440 MHz after transmit power calibration.
- Transmit power is measured on board based on Microchip Technology Reference Design.
- Transmit power is measured after PA match and LPF.
- Transmit power is measured with HUT code.
- Transmit power is controlled by transmit power settings on HUT code for measurement.

Figure 4-22. Bluetooth Low Energy Transmit Power vs VDD Supply Voltage



Notes:
- Bluetooth Low Energy transmit power is measured across voltage after transmit power calibration.
- Transmit power is measured after calibration at +12 dBm (± 0.5 dBm).
- Transmit power is measured on board based on the Microchip Reference Design.
- Transmit power is measured after the LPA and PA match section.
- Transmit power is measured with HUT code.

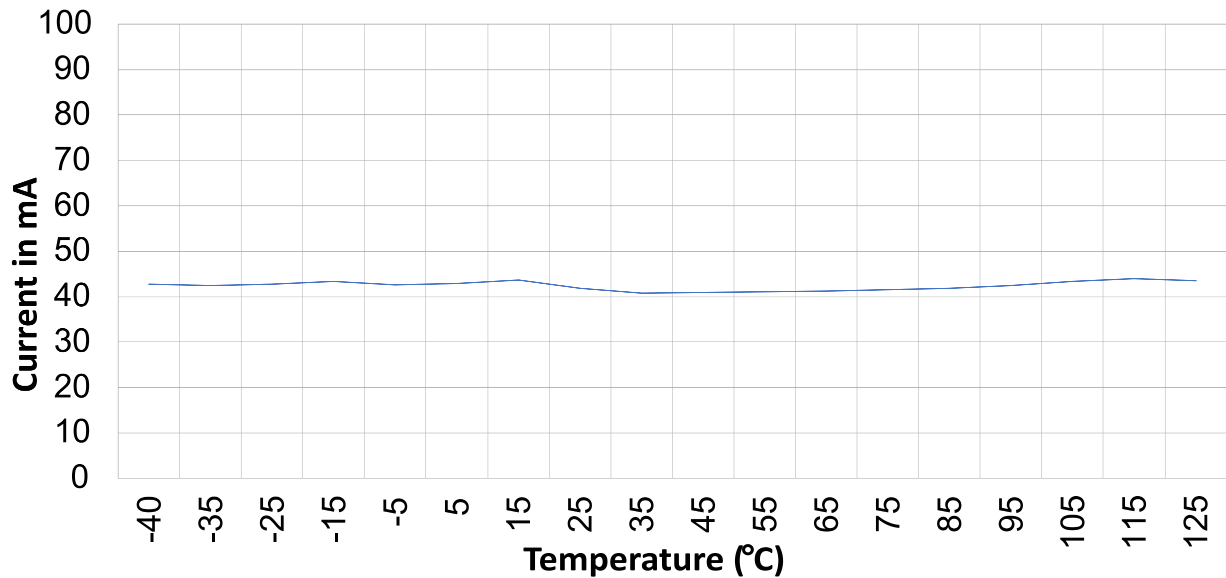
Figure 4-23. Bluetooth Low Energy Transmit Power vs. Temperature



Notes:

- Bluetooth Low Energy transmit power is measured across temperature after transmit power calibration at 3.6V and 2440 MHz.
- Transmit power is measured with HUT code.
- Temperature power compensation is triggered before power measurement.
- Transmit power is measured after the PA matching and LPF.

Figure 4-24. Bluetooth Low Energy Transmit Current vs Temperature



Notes:

- Bluetooth Low Energy transmit current is measured at 3.3V (Buck mode) at 2440 MHz across temperature.
- Transmit current is measured after calibration at +12 dBm (± 0.5 dBm).
- Current is measured on input power rail to SoC.
- Current is measured with HUT code.

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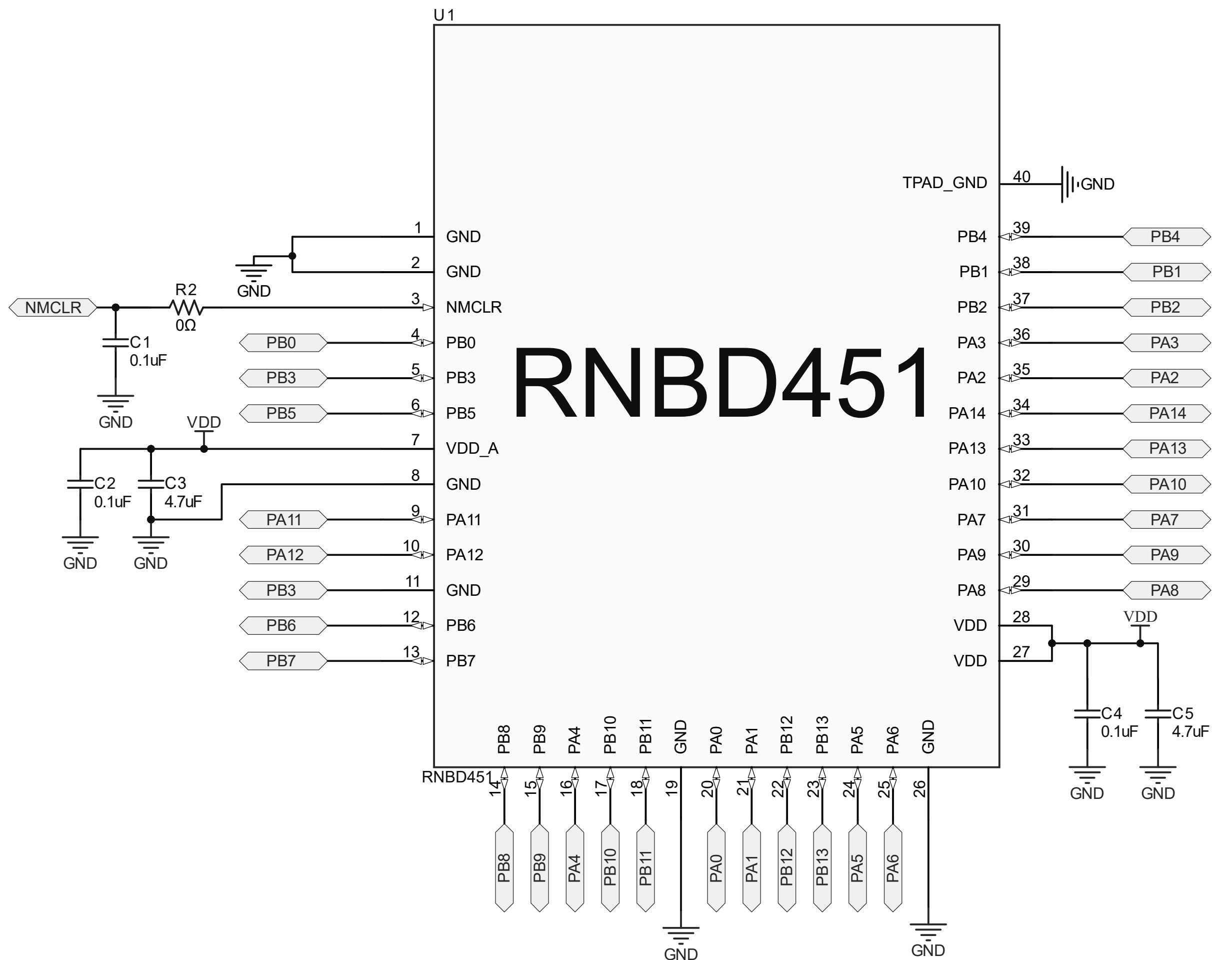
5. Basic Connection Requirement

The RNBD451 module requires attention to a minimal set of device pin connections before proceeding with development.

Figure 5-1. RNBD451 Module Basic Connection and Interface Diagram



5.1 Power Pins

It is recommended that a bulk and a decoupling capacitor be added at the input supply pin (VDD, VDD_A and GND pins) of the RNBD451 module.

- It is recommended that 4.7 µF be on the VDD_A pin and 4.7 µF and a 0.1 µF be on the VDD pin.
- The value of the capacitors are based on typical application requirements and are the minimum recommended values. Depending on the application requirement (in other words, a noisy power line or other known noise sources), the values of capacitors can be adjusted to provide a clean supply to the module.
- All capacitors must be placed close to the Module Power supply pins.

5.2 Master Clear (NMCLR) Pin

The NMCLR pin provides for two specific device functions:

- Device Reset

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- Device programming and debugging

Pulling the NMCLR pin low generates a device Reset. For more details on the typical NMCLR circuit, see Figure 5-1.

The module has sufficient filtering (0.1 µF) and pull-up (10k) on the Reset line. On a typical application, no extra filtering is required on this pin.

5.3 Unused I/O Pins

The recommendation is not to allow the unused I/O pins to float as inputs. The user can configure them as inputs and pulled up. Alternatively, depending on the application, they can be pulled down as well.

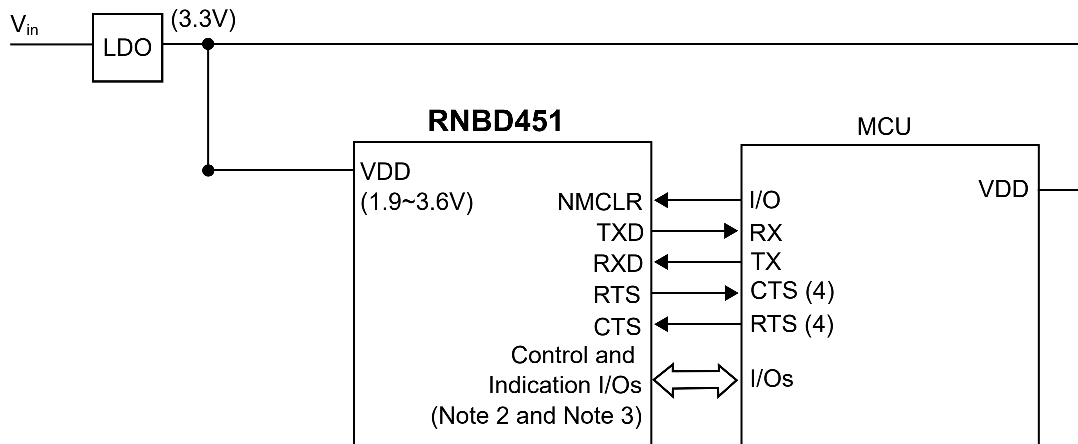
5.3.1 GPIO Pins Functions

Most of the RNBD451 module pins can be configured as GPIOs pins. To find the functionality supported by each of these GPIOs, see Table 3-1. It is recommended to add a series resistor on the host board for all critical, high frequency pins and clocks for EMI considerations GPIOs. The value of the series resistor depends on the actual pin configuration. These resistors must be placed close to the module. For the placement of the series resistor, see Figure 6-2.

5.4 Interface Pins

The following illustrates the power scheme using a 3.3V low-dropout regulator to the RNBD451 module and a host MCU. This scheme ensures using the same voltage for both the module and the MCU.

Figure 5-2. Power Scheme



Notes:

1. Ensure VDD_IO and MCU VDD voltages are compatible.
2. Control and indication ports are configurable.
3. To implement low-power operation, enable the UART RX indication pin, connect to host MCU and control.
4. These connectivities are optional and needed only when there is a need for UART flow control.

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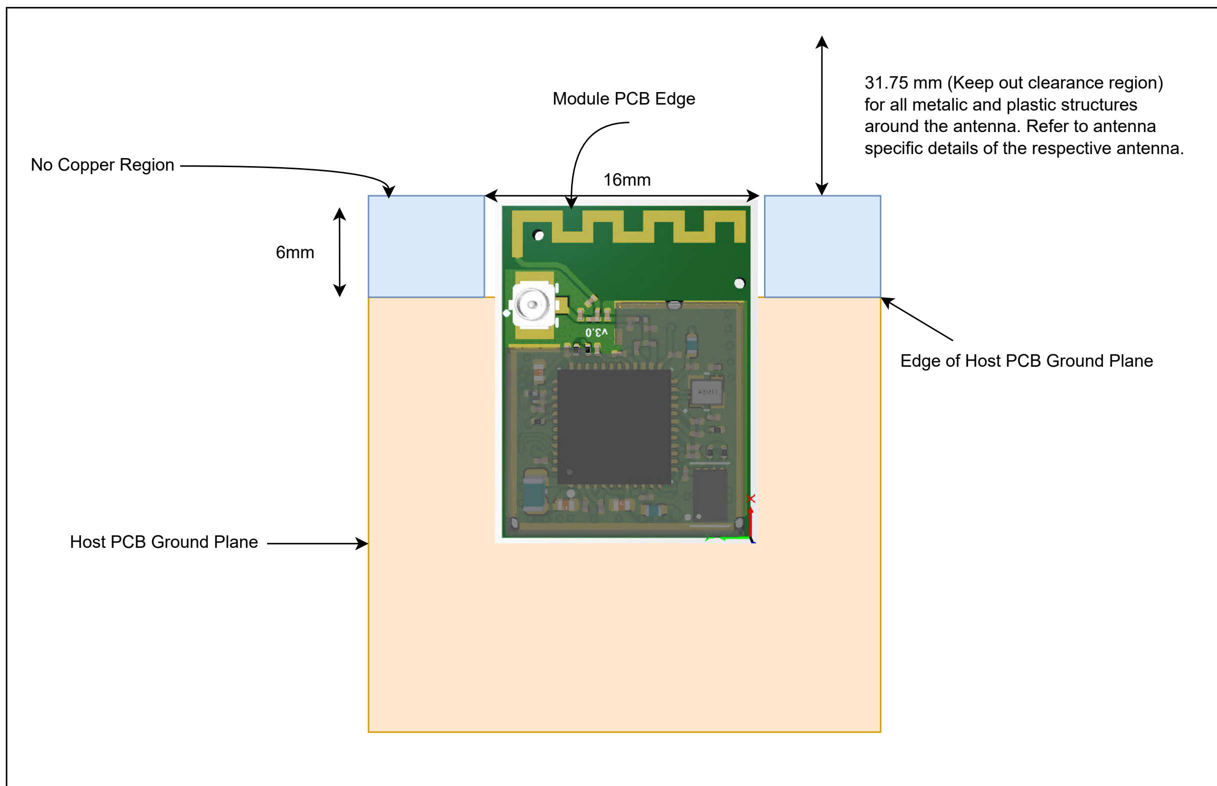
6. Physical Dimensions and Attributes

6.1 RNBD451 Module Placement Guidelines

- For any Bluetooth Low Energy product, the antenna placement affects the performance of the whole system. The antenna requires free space to radiate RF signals, and it must not be surrounded by the ground plane. Thus, for the best PCB antenna performance, the RNBD451 module must be placed at the edge of the host board.
- Align the RNBD451 module ground outline edge with the edge of the host board ground plane (see the following figure).
- A low-impedance ground plane for the RNBD451 module ensures the best radio performance (best range and lowest noise). As per the requirement, extend the ground plane beyond the minimum recommendation for the host board EMC and noise reduction.
- For best performance, keep metal structures and components (such as mechanical spacers, bump-on and so on) at least 31.75 mm away from the PCB trace antenna (see the following figure).
- Do not place the antenna on the RNBD451 module in direct contact with or close proximity to plastic casing or objects. Keep a minimum clearance of 10 mm in all directions around the PCB antenna (see the following figure). Keeping metallic and plastic objects close to the antenna can detune the antenna and reduce the performance of the device.
- Solder the exposed GND pads on the bottom of the RNBD451 module to the host board (see Figure 6-2).
- A PCB cutout or a copper keep-out is required under the RF test point. For more details, refer to 6.3. RNBD451 Module Packaging Information .
- Copper keep-out areas are required on the top layer under voltage test points. For more details, refer to 6.3. RNBD451 Module Packaging Information .
- On the other hand, the entire region except the exposed ground paddle can be solder-masked.

The following figure illustrates the examples of the RNBD451 module placement on a host board with a ground plane.

Figure 6-1. Module Placement Guidelines



6.2 RNBD451 Module Routing Guidelines

- Use the multi-layer host board for routing signals on the inner layer and the bottom layer.
- The top layer (underneath the module) of the host board must be ground with as many GND vias as possible (see the following figure).
- Avoid fan-out of the signals under the module or antenna area. Use a via to fan-out signals to the edge of the RNBD451 module.
- For a better GND connection to the RNBD451 module, solder the exposed GND pads of the RNBD451 module on the host board.
- For the module GND pad, use a GND via of a minimum 10 mil (hole diameter) for good ground to all the layers and thermal conduction path.
- Having a series resistor on the host board for all GPIOs is recommended. Place these resistors close to the RNBD451 module. The following figure illustrates the placement of the series resistor.

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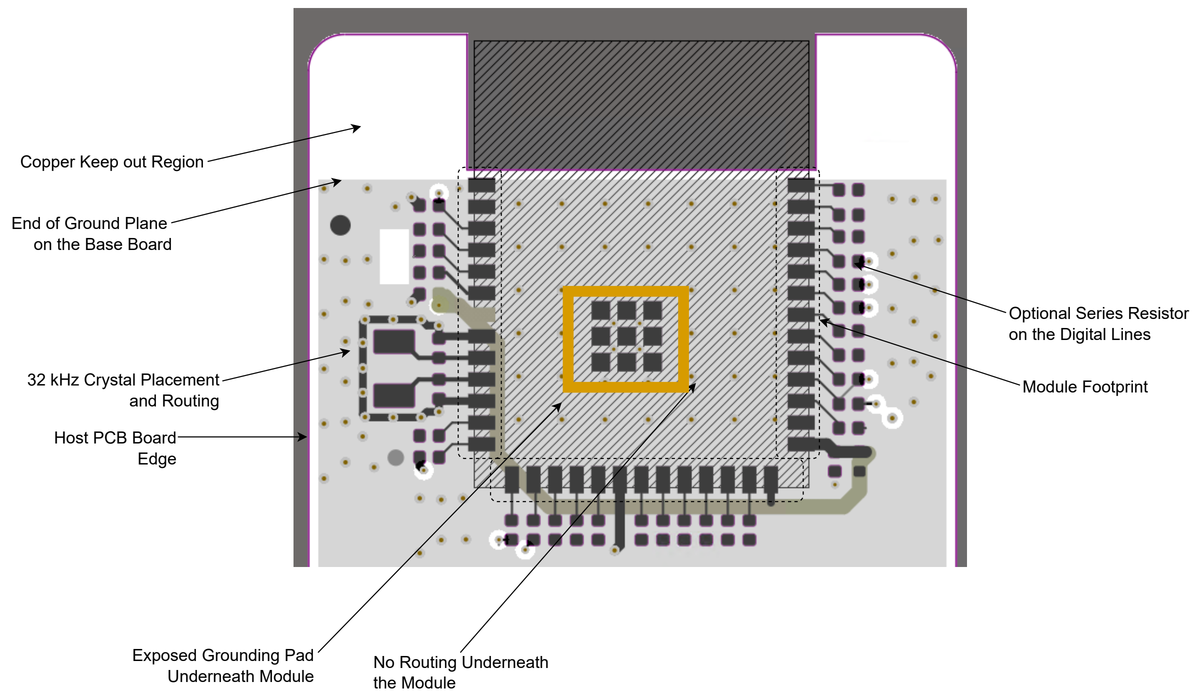
Figure 6-2. Example of Host Board on Top Layer



6.3 RNBD451 Module Packaging Information

For the most current package drawings, please see the Microchip Packaging Specification located at www.microchip.com/en-us/support/package-drawings.

The following images illustrate the packaging information of the RNBD451, which has 39-lead PCB module (ZSX) – 15.5 mm x 20.7 mm x 2.8 mm body (module) with metal shield and coaxial connector.

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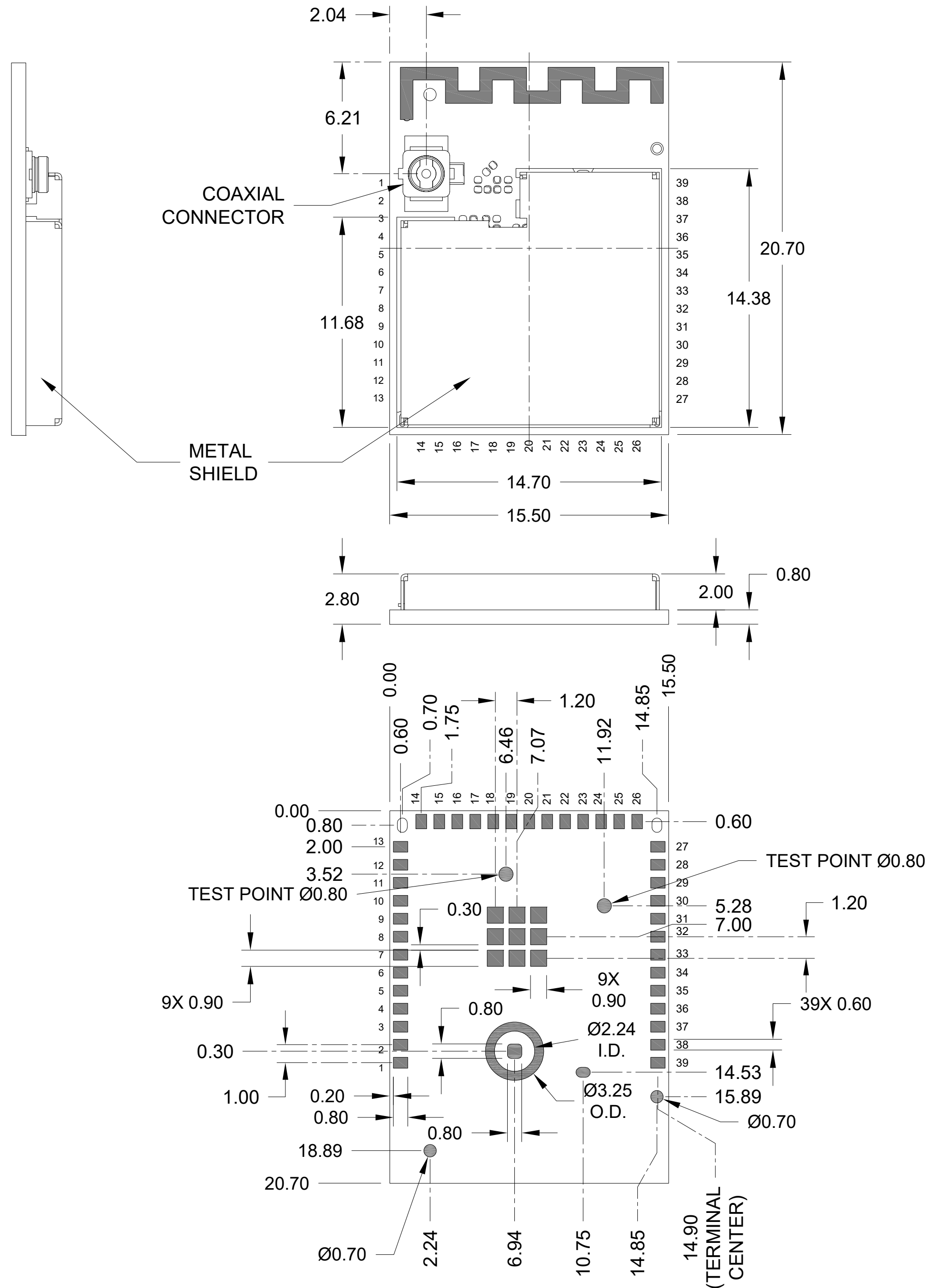
39-Lead PCB Module (ZSX) - 15.5x20.7x2.8 mm Body [MODULE] With Metal Shield and Coaxial Connector

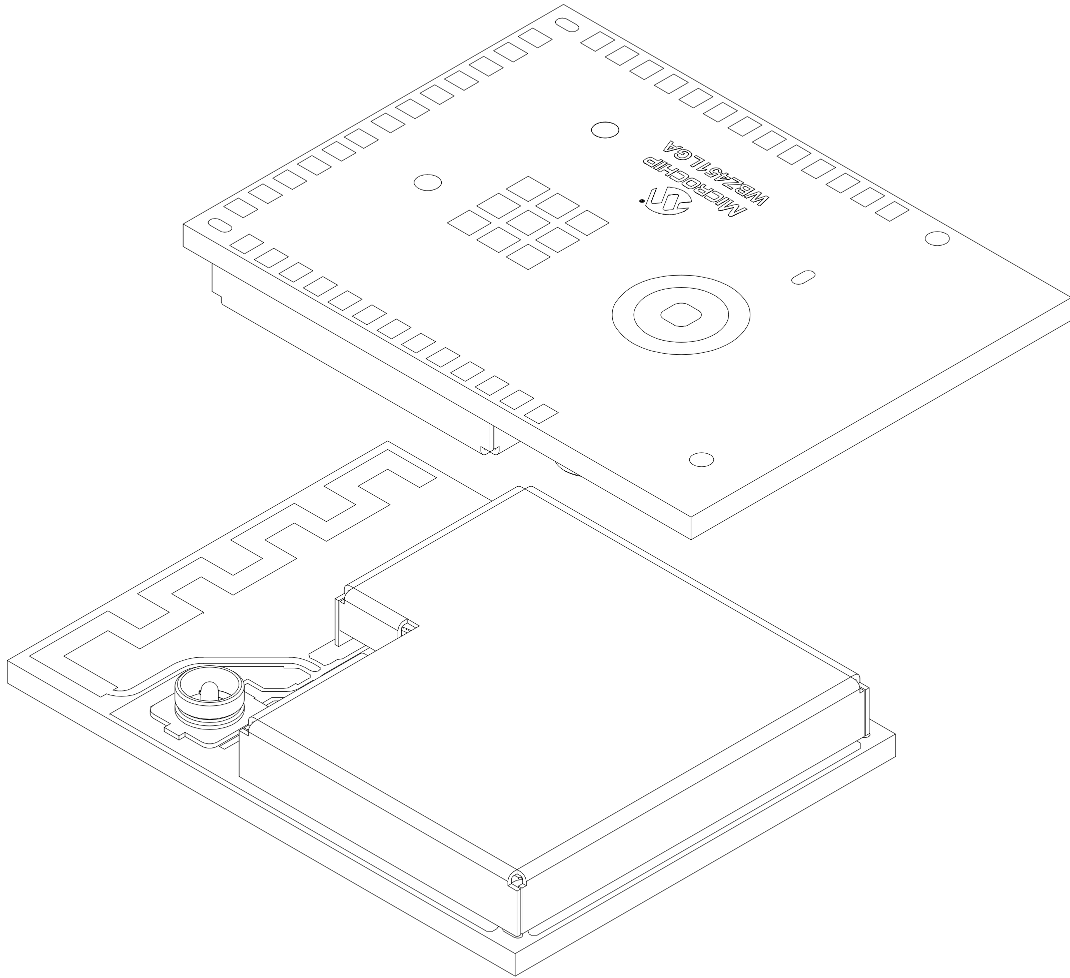
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-10052 Rev B Sheet 1 of 2

39-Lead PCB Module (ZSX) - 15.5x20.7x2.8 mm Body [MODULE] With Metal Shield and Coaxial Connector

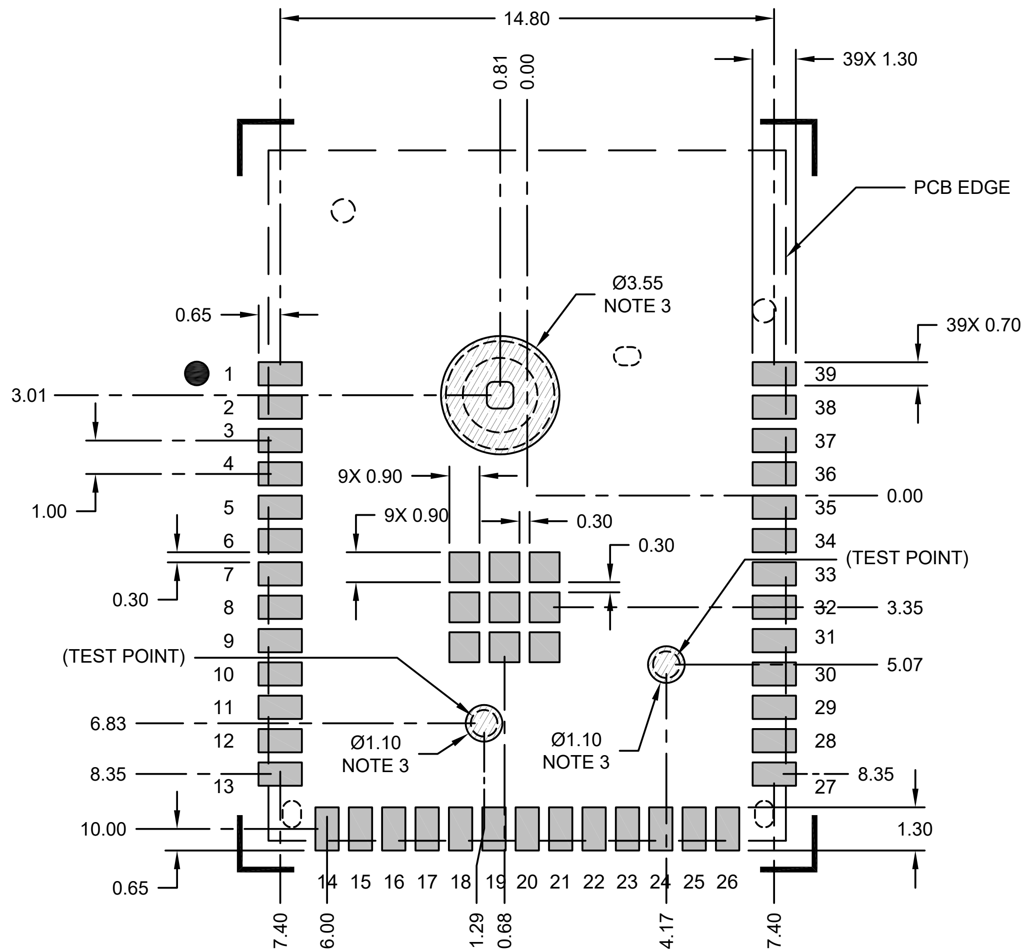
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-10052 Rev B Sheet 2 of 2

39-Lead PCB Module (ZSX) - 15.5x20.7x2.8 mm Body [MODULE] With Metal Shield and Coaxial Connector

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

Notes:

1. All dimensions are in millimeters.
2. Keep this area free from all metal, including ground fill.
3. Keep these areas free from routes and exposed copper. Ground fill with solder mask may be placed here.

Microchip Technology Drawing C04-12052 Rev B

6.4 RNBD451 Module RF Considerations

The overall performance of the system is significantly affected by the product design, environment and application. The product designer must ensure system-level shielding (if required) and verify the performance of the product features and applications.

Consider the following guidelines for optimal RF performance:

- The RNBD451 module must be positioned in a noise-free RF environment and must be kept far away from high-frequency clock signals and any other sources of RF energy.
- The antenna must not be shielded by any metal objects.
- The power supply must be clean and noise-free.
- Make sure that the width of the traces routed to GND, VDD rails are sufficiently large for handling peak TX current consumption.
  Note: The RNBD451 module includes RF shielding on top of the board as a standard feature.

6.5 RNBD451 Module Antenna Considerations

6.5.1 PCB Antenna

For the RNBD451 module, the PCB antenna is fabricated on the top copper layer and covered in a solder mask. The layers below the antenna do not have copper trace. It is recommended that the module be mounted on the edge of the host board and to have no PCB material below the antenna structure of the module and no copper traces or planes on the host board in that area.

The following table lists the technical specification of the PCB antenna when tested with the RNBD451 module mounted on an Evaluation Board.

Table 6-1. PCB Antenna Specification for RNBD451

Parameter	Specification
Operating frequency	2400 to 2480 MHz
Peak gain	2.36 dBi at 2420 MHz
Efficiency	50%

6.6 RNBD451 Module Reflow Profile Information

The RNBD451 module was assembled using the IPC/JEDEC J-STD-020 Standard lead free reflow profile. Solder the RNBD451 module to the host board using standard leaded or lead-free solder reflow profiles. To avoid damaging the module, adhere to the following recommendations:

- For Solder Reflow Recommendations, refer to the *AN233 Solder Reflow Recommendation Application Note* (DS00233).
- Do not exceed a peak temperature (TP) of 250°C.
- For specific reflow profile recommendations from the vendor, refer to the *AN233 Solder Reflow Recommendation Application Note* (DS00233).
- Use no-clean flux solder paste.
- Do not wash as moisture can be trapped under the shield.
- Use only one flow. If the PCB requires multiple flows, apply the module on the final flow.

6.6.1 Cleaning

The exposed GND pad helps to self-align the module, avoiding pad misalignment. The recommendation is to use the no clean solder pastes. Ensure full drying of no-clean paste fluxes as a result of the reflow process. As per the recommendation by the solder paste vendor, this requires longer reflow profiles and/or peak temperatures toward the high end of the process window. The uncured flux residues can lead to corrosion and/or shorting in accelerated testing and possibly the field.

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6.7 RNBD451 Module Assembly Considerations

The RNBD451 module is assembled with an EMI shield to ensure compliance with EMI emission and immunity rules. The EMI shield is made of a tin-plated steel (SPTE) and is not hermetically sealed. Use the solutions such as IPA and similar solvents to clean this module. Cleaning solutions containing acid must never be used on the module.

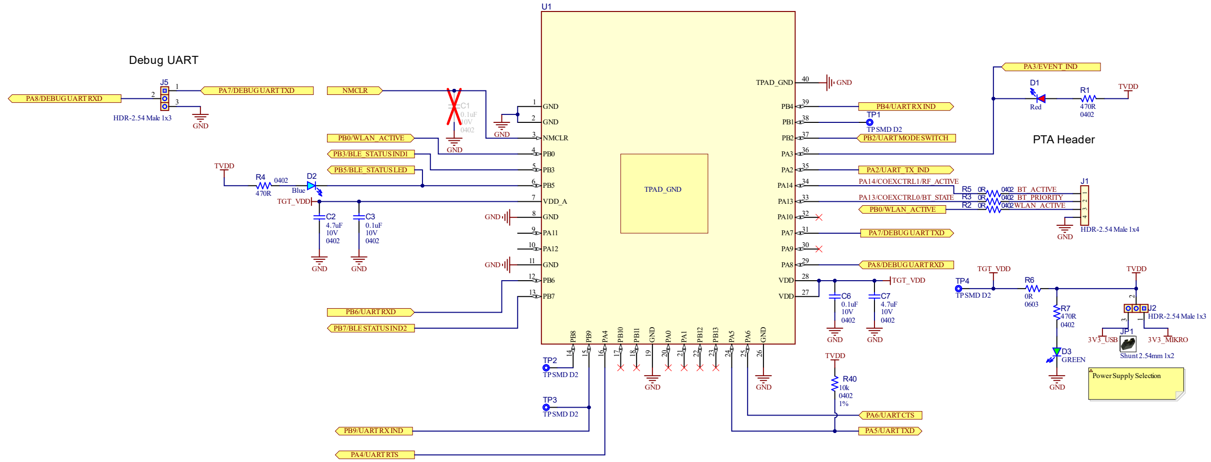
6.7.1 Conformal Coating

The modules are not intended for use with a conformal coating, and the customer assumes all risks (such as the module reliability, performance degradation and so on) if a conformal coating is applied to the modules.

7. Application Reference

This chapter provides the application reference circuits of the RNBD451 module.

Figure 7-1. RNBD451 Add On Board



8. ASCII Command API

For more details on the RNBD451 module command Application Programming Interfaces (APIs), refer to the *RNBD451 Bluetooth® Low Energy Module User's Guide* (DS50003467).

- System Configuration Commands
  - `Default Service Configure`
  - `Get Connection Status`
  - `Echo`
  - `Enter Command Mode`
  - `Exit Command Mode`
  - `Set Enter Command Character`
  - `Set Status Delimiter`
  - `Get Configuration`
  - `Query Firmware Version`
  - `Get Local Information`
  - `Remote Command Mode Control`
  - `Factory Reset`
  - `Shutdown`
  - `Reboot`
  - `Set Application Options`
  - `Set Debug Log`
  - `Get Debug Log Setting`
  - `Get Silicon Version`
  - `Set Vendor Data`
  - `Get Vendor Data`
- GAP Commands
  - General
    - `Set Device Name With Address`
    - `Set Device Name`
    - `Get Remote Device Name`
    - `Set RF Output Power`
    - `Get Signal Strength`
    - `Low Power Control`
    - `Read Local TX Power`
    - `Read Remote TX Power`
- Advertising
  - `Start Advertising`
  - `Set Advertisement Data`
  - `Set Extended Advertisement Data`
  - `Set Extended Advertisement Parameter`
  - `Get Local Advertisement Address`
  - `Stop Advertising`
  - `Set Deep Sleep Advertising`
  - `Get Deep Sleep Advertising Parameters`
- Scan
  - `Start BLE Scanning`

- `Start Extended BLE Scanning`
- `Stop BLE Scanning`

- Connection
  - `Set Central Initial Connection Parameter`
  - `Request Connection Parameter Update`
  - `Connect Last Bonded Device`
  - `Connect Device By Address`
  - `Connect Specific Bonded Device`
  - `Connect Device With Extended Parameter`
  - `Disconnect Link`
  - `Set Phy Preference`
  - `Get Phy Preference`
  - `Cancel Create Connection`
- Security
  - `Set Pairing Mode`
  - `Set Fixed Pin Code`
  - `Start Bonding Process`
  - `Add One Device Into Accept List`
  - `Add Bonded List Into Accept List`
  - `Clear Accept List`
  - `Display Accept List`
  - `Unbond Device`
  - `List All Bonded Devices`
  - `Enable Local Privacy`
  - `Get Local Privacy`
- BLE GATT/Profile Commands
  - Generic Access Service Setting
    - `Set Appearance`
  - Device Information Service Setting
    - `Set Firmware Version`
    - `Set Hardware Version`
    - `Set Model Name`
    - `Set Manufacturer Name`
    - `Set Software Revision`
    - `Set Serial Number`
- GATT Operation on Server Role
  - `Define Service Characteristic`
  - `Define Service UUID`
  - `Clear Customized Services`
  - `List Customized Service`
  - `Service Changed Indication`
  - `Read Local Characteristic Value`
  - `Write Local Characteristic Value`
- GATT Operation on Client Role
  - `Read Remote Characteristic Value`
  - `Write Remote Characteristic Value`

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- `Write Remote Characteristic Value for Multiple Links`
- `Discovery Remote Services`
- `List Remote Services`
- `List Remote Services For Specific Link`

- Data Transmission For Multi-link
  - `Send Transparent Data`
- Peripheral Commands
  - `Set UART Baud Rate`
  - `Set UART Baud Rate Immediately`
  - `Set Digital Input and Read port`
  - `Set Digital Output Port`
  - `Set Event Indication Mask`
  - `Get Event Indication Value`
  - `Set Link Quality Indication`
  - `Get Link Quality Indication Setting`
  - `Read ADC Input Voltage`
  - `Set ADC Reference Factors`
  - `Set PMU Mode`
  - `Get PMU Mode Status`
  - `Set UART Tx Indication`
  - `Get UART Tx Ind Setting`
- Device Test Mode (DTM)
  - `Device Test Mode Command`
  - `Software Reset Command`
  - `Read BD Address Command`
  - `LE Read Local Supported Features Command`
  - `LE Rx Test[v2] Command`
  - `LE Tx Test[v2] Command`
  - `LE Tx Test[v4] Command`
  - `LE Test End Command`
  - `Command Complete Event`

9. Supported Bluetooth Low Energy Profile and Services

The RNBD451 module supports the following built-in GATT profiles and services:

- Device Information Service (DIS)
- Microchip OTA profile and service handling OTA DFU execution
- Microchip transparent profile and service handling UART data streaming function

In addition to the above built-in profile and service, the RNBD451 module provides the capabilities below to register more GATT services and characteristic attributes by RN command sets. The internal Nonvolatile Memory (NVM), which is also called as Persistent Data Storage (PDS), saves these registered GATT services and characteristics.

- Up to six GATT services with 16-bit UUID and eight characteristic attributes for each GATT service
- Up to four GATT services with 128-bit UUID eight characteristic attributes for each GATT service

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10. Appendix A: Regulatory Approval

The RNBD451 module has received regulatory approval for the following countries:

- Bluetooth Special Interest Group (SIG) End Product List Declaration ID: D056857 (QDID)
- United States/FCC ID: 2ADHKWBZ451
- Canada/ISED:
  - IC: 20266-WBZ451
  - HVIN: RNBD451
- Europe/CE

10.1 United States

The RNBD451 module has received Federal Communications Commission (FCC) CFR47 Telecommunications, Part 15 Subpart C “Intentional Radiators” single-modular approval in accordance with Part 15.212 Modular Transmitter approval. Single-modular transmitter approval is defined as a complete RF transmission sub-assembly, designed to be incorporated into another device, that must demonstrate compliance with FCC rules and policies independent of any host. A transmitter with a modular grant can be installed in different end-use products (referred to as a host, host product or host device) by the grantee or other equipment manufacturer, then the host product may not require additional testing or equipment authorization for the transmitter function provided by that specific module or limited module device.

The user must comply with all of the instructions provided by the Grantee, which indicate installation and/or operating conditions necessary for compliance.

A host product itself is required to comply with all other applicable FCC equipment authorization regulations, requirements, and equipment functions that are not associated with the transmitter module portion. For example, compliance must be demonstrated: to regulations for other transmitter components within a host product; to requirements for unintentional radiators (Part 15 Subpart B), such as digital devices, computer peripherals, radio receivers, etc.; and to additional authorization requirements for the non-transmitter functions on the transmitter module (i.e., Suppliers Declaration of Conformity (SDoC) or certification) as appropriate (e.g., Bluetooth and Wi-Fi transmitter modules may also contain digital logic functions).

10.1.1 Labeling and User Information Requirements

The RNBD451 module has been labeled with its own FCC ID number, and if the FCC ID is not visible when the module is installed inside another device, then the outside of the finished product into which the module is installed must display a label referring to the enclosed module. This exterior label must use the following wording:

Contains Transmitter Module FCC ID: 2ADHKWBZ451 or Contains FCC ID: 2ADHKWBZ451 **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 user's manual for the finished product must include the following statement:

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 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

Additional information on labeling and user information requirements for Part 15 devices can be found in KDB Publication 784748, which is available at the FCC Office of Engineering and Technology (OET) Laboratory Division Knowledge Database (KDB) apps.fcc.gov/oetcf/kdb/index.cfm.

10.1.2 RF Exposure

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).

From the FCC Grant: Output power listed is conducted. This grant is valid only when the module is sold to OEM integrators and must be installed by the OEM or OEM integrators. This transmitter is restricted for use with the specific antenna(s) tested in this application for Certification and must not be co-located or operating in conjunction with any other antenna or transmitters within a host device, except in accordance with FCC multi-transmitter product procedures.

RNBD451: These modules are approved for installation into mobile or/and portable host platforms atleast 20cm away from the human body.

10.1.3 Helpful Web Sites

- Federal Communications Commission (FCC): www.fcc.gov.
- FCC Office of Engineering and Technology (OET) Laboratory Division Knowledge Database (KDB) apps.fcc.gov/oetcf/kdb/index.cfm.

10.2 Canada

The RNBD451 module has been certified for use in Canada under Innovation, Science and Economic Development Canada (ISED, formerly Industry Canada) Radio Standards Procedure (RSP) RSP-100, Radio Standards Specification (RSS) RSS-Gen and RSS-247. Modular approval permits the installation of a module in a host device without the need to recertify the device.

10.2.1 Labeling and User Information Requirements

Labeling Requirements (from RSP-100 - Issue 12, Section 5): The host product shall be properly labeled to identify the module within the host device.

The Innovation, Science and Economic Development Canada certification label of a module shall be clearly visible at all times when installed in the host device; otherwise, the host product must be labeled to display the Innovation, Science and Economic Development Canada certification number of the module, preceded by the word “Contains” or similar wording expressing the same meaning, as follows:

Contains IC: 20266-WBZ451

User Manual Notice for License-Exempt Radio Apparatus (from Section 8.4 RSS-Gen, Issue 5, February 2021): User manuals for license-exempt radio apparatus shall contain the following or equivalent notice in a conspicuous location in the user manual or alternatively on the device or both:

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 licence contenu dans le présent appareil est conforme aux CNR d'Innovation, Sciences et Développement économique Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:

1. L'appareil ne doit pas produire de brouillage;

2. L'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Transmitter Antenna (From Section 6.8 RSS-GEN, Issue 5, February 2021): User manuals, for transmitters shall display the following notice in a conspicuous location:

This radio transmitter [IC: 20266-WBZ451] 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 [IC: 20266-WBZ451] a été approuvé par Innovation, Sciences et Développement économique Canada pour fonctionner avec les types d'antenne énumérés cidessous 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.

Immediately following the above notice, the manufacturer shall provide a list of all antenna types approved for use with the transmitter, indicating the maximum permissible antenna gain (in dBi) and required impedance for each.

10.2.2 RF Exposure

All transmitters regulated by Innovation, Science and Economic Development Canada (ISED) must comply with RF exposure requirements listed in RSS-102 - Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands).

This transmitter is restricted for use with a specific antenna tested in this application for certification, and must not be co-located or operating in conjunction with any other antenna or transmitters within a host device, except in accordance with Canada multi-transmitter product procedures.

RNBD451: The device operates at an output power level which is within the ISED SAR test exemption limits at any user distance > 20cm.

10.2.3 Helpful Web Sites

Innovation, Science and Economic Development Canada (ISED): www.ic.gc.ca/.

10.3 Europe

The RNBD451 module has is/are a Radio Equipment Directive (RED) assessed radio module that is CE marked and has been manufactured and tested with the intention of being integrated into a final product.

The RNBD451 module has has/have been tested to RED 2014/53/EU Essential Requirements mentioned in the following European Compliance table.

Table 10-1. European Compliance Information

Certification	Standard	Article
Safety	EN 62368	3.1a
Health	EN 62311	
EMC	EN 301 489-1	3.1b
	EN 301 489-17	
Radio	EN 300 328	3.2

The ETSI provides guidance on modular devices in the "*Guide to the application of harmonised standards covering articles 3.1b and 3.2 of the RED 2014/53/EU (RED) to multi-radio and combined radio and non-radio equipment*" document available at http://www.etsi.org/deliver/etsi_eg/203300_203399/20 3367/01.01.01_60/eg_203367v010101p.pdf.

Note: To maintain conformance to the standards listed in the preceding European Compliance table, the module shall be installed in accordance with the installation instructions in this data sheet and shall not be modified. When integrating a radio module into a completed product, the integrator becomes the manufacturer of the final product and is therefore responsible for demonstrating compliance of the final product with the essential requirements against the RED.

10.3.1 Labeling and User Information Requirements

The label on the final product that contains the RNBD451 module has must follow CE marking requirements.

10.3.2 Conformity Assessment

From ETSI Guidance Note EG 203367, section 6.1, when non-radio products are combined with a radio product:

If the manufacturer of the combined equipment installs the radio product in a host non-radio product in equivalent assessment conditions (i.e. host equivalent to the one used for the assessment of the radio product) and according to the installation instructions for the radio product, then no additional assessment of the combined equipment against article 3.2 of the RED is required.

10.3.2.1 Simplified EU Declaration of Conformity

Hereby, Microchip Technology Inc. declares that the radio equipment type RNBD451 is in compliance with Directive 2014/53/EU.

The full text of the EU declaration of conformity, for this product, is available at www.microchip.com/design-centers/wireless-connectivity/.

10.3.3 Helpful Websites

A document that can be used as a starting point in understanding the use of Short Range Devices (SRD) in Europe is the European Radio Communications Committee (ERC) Recommendation 70-03 E, which can be downloaded from the European Communications Committee (ECC) at: http://www.ecodocdb.dk/.

Additional helpful web sites are:

- Radio Equipment Directive (2014/53/EU):
  https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/red_en
- European Conference of Postal and Telecommunications Administrations (CEPT):
  http://www.cept.org
- European Telecommunications Standards Institute (ETSI):
  http://www.etsi.org
- The Radio Equipment Directive Compliance Association (REDCA):
  http://www.redca.eu/

10.4 Other Regulatory Information

- For information about other countries' jurisdictions not covered here, refer to the www.microchip.com/design-centers/wireless-connectivity/certifications.
- Should other regulatory jurisdiction certification be required by the customer, or the customer needs to recertify the module for other reasons, contact Microchip for the required utilities and documentation.

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11. Document Revision History

Table 11-1. Document Revision History

Revision	Date	Section	Description
A	12/2022	Document	Initial Revision

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