# RN4020 Bluetooth® Low Energy Module User's Guide

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Microchip Technology Inc.
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Signed for and on behalf of Microchip Technology Inc. at Chandler, Arizona, USA

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VP Development Tools

12-Sep-14
Date

NOTES:

# RN4020 BLUETOOTH LOW ENERGY MODULE USER'S GUIDE

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# Preface

## NOTICE TO CUSTOMERS

**All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our web site (www.microchip.com) to obtain the latest documentation available.**

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**For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics to open a list of available online help files.**

## INTRODUCTION

This chapter contains general information that will be useful to know before using the RN4020 Bluetooth® Low Energy Module. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Recommended Reading
- The Microchip Web Site
- Development Systems Customer Change Notification Service
- Customer Support
- Document Revision History

## DOCUMENT LAYOUT

This document describes how to use the RN4020 Bluetooth® Low Energy Module as a development tool to emulate and debug firmware on a target board. This document includes the following chapters:

- **Chapter 1. "Introduction"** provides a brief overview of the RN4020, highlighting its features and uses.
- **Chapter 2. "RN4020 Command Interface"** provides information on the module interface.
- **Chapter 3. "Application Examples"** provides application examples that emphasize the features of the RN4020.
- **Appendix A. "PICtail™ Daughter Board Schematics"** provides schematic diagram information for the PICtail Daughter Board.

## CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

### DOCUMENTATION CONVENTIONS

| Description | Represents | Examples |
|---|---|---|
| Italic characters | Referenced books | *MPLAB® IDE User’s Guide* |
| | Emphasized text | ...is the *only* compiler... |
| Initial caps | A window | the Output window |
| | A dialog | the Settings dialog |
| | A menu selection | select Enable Programmer |
| Quotes | A field name in a window or dialog | “Save project before build” |
| Underlined, italic text with right angle bracket | A menu path | <u>*File > Save*</u> |
| Bold characters | A dialog button | Click **OK** |
| | A tab | Click the **Power** tab |
| Text in angle brackets < > | A key on the keyboard | Press <Enter>, <F1> |
| `Plain Courier New` | Sample source code | `#define START` |
| | Filenames | `autoexec.bat` |
| | File paths | `c:\mcc18\h` |
| | Keywords | `_asm, _endasm, static` |
| | Command-line options | `-Opa+, -Opa-` |
| | Bit values | `0, 1` |
| | Constants | `0xFF, ‘A’` |
| *`Italic Courier New`* | A variable argument | *`file`*`.o`, where *`file`* can be any valid filename |
| Square brackets [ ] | Optional arguments | `mcc18 [options]` *`file`* `[options]` |
| Curly brackets and pipe character: { \| } | Choice of mutually exclusive arguments; an OR selection | `errorlevel {0\|1}` |
| Ellipses... | Replaces repeated text | `var_name [, var_name...]` |
| | Represents code supplied by user | `void main (void)`<br>`{ ...`<br>`}` |
| Notes | A Note presents information that we want to re-emphasize, either to help you avoid a common pitfall or to make you aware of operating differences between some device family members. A Note can be in a box, or when used in a table or figure, it is located at the bottom of the table or figure. | **Note:** This is a standard note box.<br>**CAUTION**<br>**This is a caution note.**<br>**Note 1:** This is a note used in a table. |

## RECOMMENDED READING

The following documents are recommended as supplemental reference resources.

### RN4020 Family Data Sheet (DS50002279)

Consult this document for detailed information on the RN4020 Bluetooth® Low Energy Module. Reference information found in this data sheet includes:

- Device pinout and packaging details
- Device electrical specifications
- List of features included on the device

This document is available for download from the Microchip website (www.microchip.com).

### Bluetooth Core Specification v4.0, 30 June 2010

This specification is available for download from www.bluetooth.org.

### Bluetooth Core Specification v4.1, 3 December 2013

Bluetooth® Core Specification 4.1 is an important evolutionary update to the Bluetooth Core Specification. It rolls up adopted Bluetooth Core Specification Addenda (CSA 1, 2, 3, and 4) while adding new features and benefits. Bluetooth 4.1 improves usability for consumers, empowers innovation for product developers, and extends the technology's foundation as an essential link for the Internet of Things.

This specification is available for download from www.bluetooth.org.

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- Technical Support

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Technical support is available through the web site at: http://support.microchip.com

# DOCUMENT REVISION HISTORY

## Revision A (June 2014)

Initial release of this document.

## Revision B (December 2014)

This revision includes updates that document the changes for Firmware Version 1.20:

- Pin 15 in the RN4020 Module Pin Diagram was updated (see Figure 2-1)
- Pin 15 in the RN4020 Module Pin Description was updated (see Table 2-1)
- The commands, `SP`, `Q`, `[`, `]`, and `PF`, were added to the Command Descriptions (see Table 2-4)
- The Set/Get command, `SP`, was added (see SP,<0-7>)
- The Action command, `F`, was updated (see F,<hex16>,<hex16>)
- The Action command, `H`, was updated (see H)
- The Action command, `Q`, was added (see Q,<1>)
- A Note was added to the Action command `Y` (see Y)
- The Private Service Configuration command, PF, was added (see PF,<UUID><Z>)
- The following sections were added:
  - **2.2 “GAP Role Switching”**
  - **2.4 “Summary of RN4020 UART Outputs”**
  - **2.3.3 “I$^2$C™ Commands”**
  - **2.3.4 “PWM Commands”**
  - **2.3.7.2 “MLDPv2”**
  - **2.3.8.5 “Remote Function Call”**
- In addition, minor updates to text and formatting were incorporated throughout the document

NOTES:

# Chapter 1. Introduction

This chapter introduces the Microchip RN4020 Bluetooth Low Energy module which also includes some fundamentals concepts of Bluetooth Low Energy (BLE).

The RN4020 Bluetooth® Low Energy Module is a single mode Bluetooth Smart module that complies with Bluetooth Core Specification v4.1.

Through its high-speed UART interface, this module can be configured to act as either a central or peripheral role when establishing a connection. This module supports 13 public profiles and 17 public services, which are adopted by the Bluetooth Special Interest Group (SIG).

For all supported profiles and services, the RN4020 module can be configured to act as server and client roles at the same time. Furthermore, the RN4020 module supports the private Microchip Low-energy Data Profile (MLDP), which provides an asynchronous serial data connection between two RN4020 devices.

Finally, the Microchip RN4020 module also supports a user-defined private profile/service, which can precisely fit a user's particular application. All configurations will be saved in on-board non-volatile memory (NVM), so users need to set up the module only once.

The Microchip RN4020 module is easy to use and provides users with a fast-to-market, flexible, and powerful solution for BTLE technology.

## 1.1 BLUETOOTH LOW ENERGY FUNDAMENTALS

All BTLE device roles are built on top of the Generic Accessory Profile (GAP), which defines the devices to be either Central, Peripheral, Observer or a Broadcaster. When two BTLE devices need to establish a connection, one is in a central role and the other in a peripheral role. Only central role devices can initiate a connection to peripheral role devices. Likewise, peripheral devices are not allowed to initiate connections. The peripheral advertises its connection status, while the central device starts the connection process. Once connected, either end of the connection can initiate the bond. Once bonded, all security-related keys will be saved and the security process will be waived when reconnecting. The bonded peripheral device can only perform direct advertise; therefore, it is no longer able to connect to devices other than its bonded peer.

Similar to Bluetooth Classic, BTLE uses the concept of profiles to ensure interoperability between different devices. However, unlike Bluetooth Classic, BTLE profiles are a collection of services. All BTLE services are built on top of the Generic Attribute Profile (GATT), where GATT defines the accessibility of attributes, which are called characteristics. Therefore, the main functionality of BTLE profiles is built around these characteristics. Devices that maintain the value of characteristics in a service are the “server” of the service. Conversely, devices that acquire data from their peer are considered the “client”.

Each service and its characteristics are identified by their Universally Unique Identifier (UUID). The UUID can either be short form (16-bit) or long form (128-bit). All Bluetooth SIG adopted services and characteristics have a short UUID, whereas a user-defined private UUID must be in long form. For information on the Bluetooth SIG adopted services and characteristics, visit the Bluetooth Developer Portal at:

https://developer.bluetooth.org/gatt/profiles/Pages/ProfilesHome.aspx.

The accessibility of each characteristic is defined by the 8-bit characteristic property in bitmap format, as shown in Table 1-1.

**TABLE 1-1: CHARACTERISTIC PROPERTIES**

| Property | Bitmap | Description |
|---|---|---|
| Extended Property(1) | `0'b10000000` | Additional property available. |
| Authenticated Write(1) | `0'b01000000` | Write characteristic with authentication from client to server. |
| Indicate | `0'b00100000` | Indicate value of characteristic with acknowledgment from server to client. |
| Notify | `0'b00010000` | Notify value of characteristic without acknowledgment from server to client. |
| Write | `0'b00001000` | Write value of characteristic with acknowledgment from client to server. |
| Write Without Response | `0'b00000100` | Write value of characteristic without acknowledgment from client to server. |
| Read | `0'b00000010` | Read value of characteristic. Value is sent from server to client. |
| Broadcast(1) | `0'b00000001` | Broadcast value of characteristic. |

**Note 1:** The RN4020 does not currently support this property.

# Chapter 2. RN4020 Command Interface

The RN4020 module is a fully certified Bluetooth Low Energy single mode OEM module. The module is controlled by the user through input/output lines (i.e., physical device pins) and a UART interface.

The UART Interface supports ASCII commands to control/configure the RN4020 modules for any specific requirement based on the application.

The following topics are included in this chapter:

- RN4020 Control Lines
- RN4020 UART-ASCII Command and Responses
- Device Firmware Upgrade

## 2.1 RN4020 CONTROL LINES

The RN4020 module uses the WAKE_SW (pin 7), CMD/MLDP (pin 8), WAKE_HW (pin 15) pins to place the module into different states, and three output pins to indicate its current status.

WAKE_SW is used to control the operating state of the RN4020. When WAKE_SW is set high, the module wakes up and is set into Active mode. Upon waking up, "CMD" will be output to the UART and indicate that the module is in Command mode and ready to take commands from UART. Conversely, when WAKE_SW is set low, the module exits Command mode by outputting "END" to the UART, and then operates in Deep Sleep mode. The UART interface will not be responsive in Deep Sleep mode unless the UART baud rate is 2400 bps. When the module is in Deep Sleep mode, MLDP_EV (pin 11) will be held low.

CMD/MLDP (pin 8) is used to control the RN4020 module when an MLDP serial data service (see **Section 2.3.7 "Microchip MLDP Commands"**) is used. Once MLDP mode is entered by setting CMD/MLDP high, all data from the UART is sent to the peer device as a data stream. To exit MLDP mode, CMD/MLDP must be set low so that the RN4020 module is returned to Command mode by outputting "CMD" to the UART.

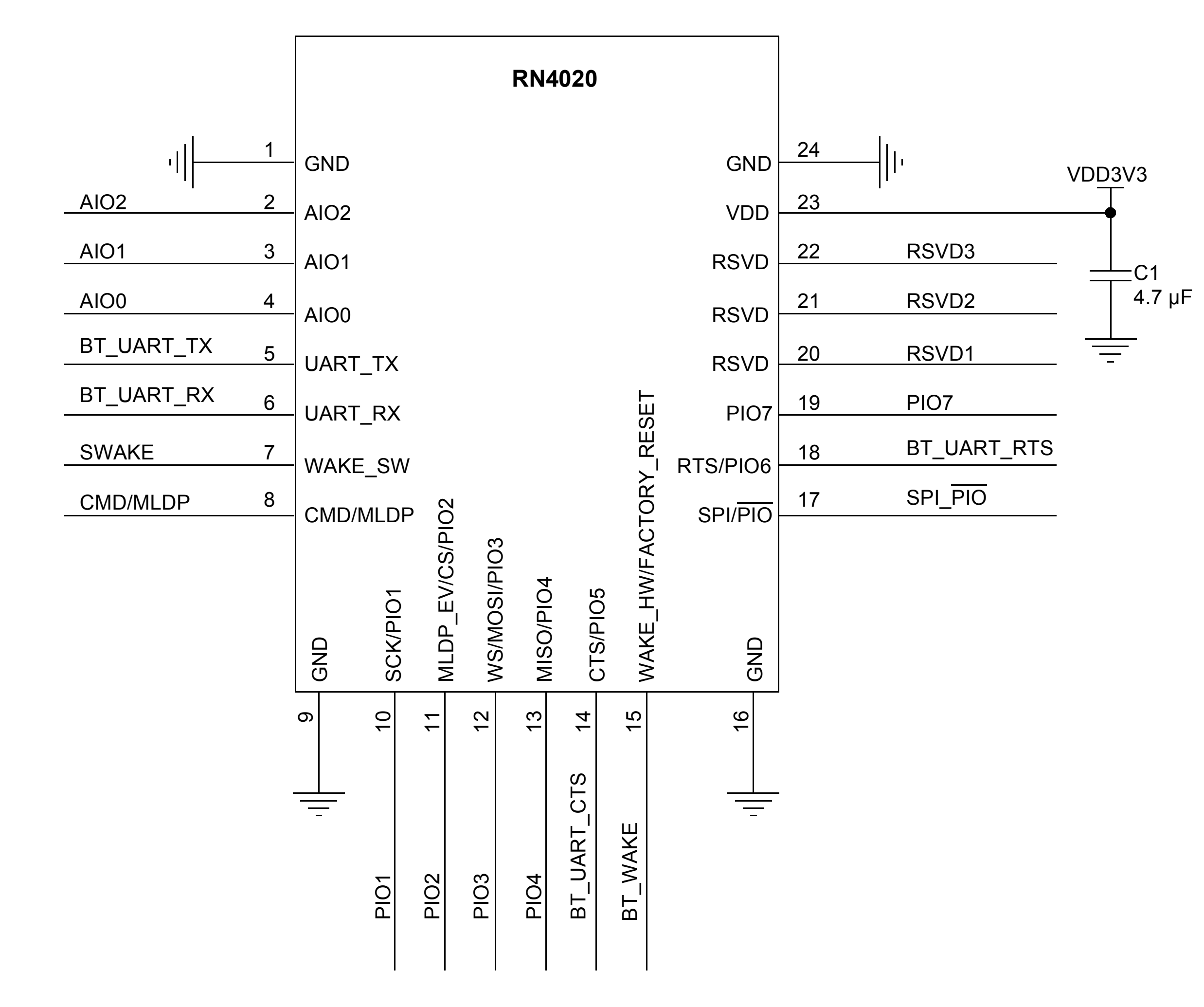
Setting WAKE_HW (pin 15) high wakes the RN4020 module from Dormant mode. After powering up, if WAKE_HW flips up and down three cycles (putting the WAKE_HW pin into high, and then low, and then high again is considered one flip cycle) in the first five seconds, the RN4020 module performs a factory Reset. If WAKE_SW is high when a factory Reset is performed, the factory Reset is complete; otherwise, it is a partial factory Reset that retains the device name, private service, and scripts. Refer to **Section 2.3.1 "Set/Get Commands"** for information on "SF,1" describing factory default.

When the RN4020 module is connected to a peer device, SCK/PIO1 – CONNECTION LED (pin 10) will output high; otherwise, CONNECTION LED outputs low.

When in MLDP mode, if the RN4020 module must output a status to the UART or is requesting a response from the host MCU, MLDP_EV will be set high. Once the RN4020 module exits MLDP mode and returns to Command mode, status and/or requests will be output to the UART. Once stored data is output to the UART, MLDP_EV will be set low. The maximum buffer size of status and requests is 256 bytes. When the RN4020 module is in Active mode, WS/MISO/PIO3 (pin 12) will be output high; otherwise, it outputs low.

Figure 2-1 and Table 2-1 provide the pin diagram and their descriptions for the RN4020 module. For additional information, refer to *"RN4020 Bluetooth Low Energy Module Data Sheet"* (DS50002279).

**FIGURE 2-1: RN4020 MODULE PIN DIAGRAM**



### TABLE 2-1: RN4020 MODULE PIN DESCRIPTION

| Pin | Symbol | Description | Function |
|---|---|---|---|
| 1 | `GND` | Ground. | Ground |
| 2 | `AIO2` | Bidirectional with programmable analog I/O. | 1.65V input, 1.35V out, and 30 mA max out |
| 3 | `AIO1` | Bidirectional with programmable analog I/O. | 1.65V input, 1.35V out, and 30 mA max out |
| 4 | `AIO0` | Bidirectional with programmable analog I/O. | 1.65V input, 1.35V out, and 30 mA max out |
| 5 | `UART TX` | UART Transmit (TX). | Output from RN4020. The line is 3.3V TTL |
| 6 | `UART RX` | UART Receive (RX). | Input to RN4020. The line is 3.3V TTL |
| 7 | `WAKE_SW` | Deep Sleep Wake; active-high to wake module from Deep Sleep. | Input; weak pull-down |
| 8 | `CMD/MLDP` | CMD – Command Mode – Module enters Command mode where UART commands and responses sent over UART are exchanged between the RN4020 command interpreter and the MCU host.<br>MLDP Mode – Data Mode – Data through UART is sent over the Bluetooth Low Energy connection to the remote device using MLDP data service. | Input; active-high to enter Command |
| 9 | `GND` | Ground. | Ground |
| 10 | `CONNECTION LED`<br>`SCK`<br>`PIO[1]` | Default state is output: Active-high indicates the module is connected to a remote device. Active-low indicates a disconnected state. Configurable as PIO[1] via software command.<br>SCK for diagnostics and factory calibration if pin 17 is asserted. | • Green LED<br>• PIO[1]<br>• SCK |
| 11 | `MLDP_EV`<br>`CS`<br>`PIO[2]` | Default function is output used for MLDP data event indicator (red LED). Active-high indicates MLDP data received or UART console data pending. Low level indicates no events. Event only triggered in CMD mode, when CMD/MLDP (pin 8) is high.<br>Configurable as PIO[2] via "\|O" and "\|I" commands.<br>CS for diagnostics and factory calibration if pin 17 is asserted. | • MLDP Data Event (Red LED)<br>• PIO[2]<br>• CS |
| 12 | `WS`<br>`MOSI`<br>`PIO[3]` | Default function is an output used for an Activity indicator (blue LED). High level indicates the module is awake and active. Low level indicates the module is in a Sleep state. Accessible as PIO[3] via "\|O" and "\|I" commands.<br>MOSI for diagnostics and factory calibration if pin 17 is asserted. | • WS (Blue LED)<br>• PIO[3]<br>• MOSI |
| 13 | `MISO`<br>`PIO[4]` | Trigger pin to generate event @PIOH and @PIOL.<br>MISO for diagnostics and factory calibration if pin 17 asserted. | • PIO[4]<br>• MISO |
| 14 | `CTS`<br>`PIO[5]` | Reserved for CTS if hardware flow control is on the UART. | • CTS (input)<br>• PIO[5] |

**TABLE 2-1: RN4020 MODULE PIN DESCRIPTION (CONTINUED)**

| Pin | Symbol | Description | Function |
|---|---|---|---|
| 15 | `WAKE_HW`<br>`FACTORY RESET` | Hardware wake from Hibernate or Dormant state. Setting `WAKE_HW` (pin 15) high wakes the RN4020 module from Dormant mode. After powering up, if `WAKE_HW` flips up and down three cycles (putting the `WAKE_HW` pin into high, and then low, and then high again, is considered as one flip cycle) in the first five seconds, the RN4020 module performs a factory Reset. If `WAKE_SW (SWAKE)` is high when a factory Reset is performed, the factory Reset is complete; otherwise, it is a partial factory Reset that retains the device name, private service, and scripts.<br>**CAUTION**<br>A full factory reset erases scripts and sets the device name to the serialized name. See the SF,<1,2> command for details. | Active-high; internal pull down |
| 16 | `GND` | Ground. | Ground |
| 17 | `SPI/PIO` | SPI/PIO for pins 10-13, active-high. | Input with internal pull down; selects SPI on 10-13 |
| 18 | `PIO[6]` | Reserved for RTS if hardware flow control on UART. | • RTS (output)<br>• PIO[6] |
| 19 | `PIO[7]` | Spare PIO. Refer to **Section 2.3.2 "Action Commands"** for the "\|O" and "\|I" commands. | Spare PIO configurable as input or output |
| 20 | `RSVD` | Do not connect. Factory diagnostics. | No Connect |
| 21 | `RSVD` | Do not connect. Factory diagnostics. | No Connect |
| 22 | `RSVD` | Do not connect. Factory diagnostics. | No Connect |
| 23 | `VDD` | Supply voltage. | 1.8 to 3.6V |
| 24 | `GND` | Ground. | Ground |

## 2.2 GAP ROLE SWITCHING

In the previous firmware version (1.10.09), the RN4020 module is configured to operate as either the Peripheral or central Generic Access Profile (GAP) role at boot time. The module's role is determined by bit 31 (0x80000000) in the "SR" command.

While in Peripheral mode, the RN4020 module is permitted to broadcast advertising packets and be connectable. Similarly in Central mode, the RN4020 module can scan for advertisements and connect to a peripheral. Changing the mode requires setting or clearing bit 31 with the "SR" command, and rebooting the RN4020 module.

Beginning in Firmware Version 1.20, the GAP roles are determined by Action commands or events.

> **Note:** Bit 31, or the "SR,80000000" command to set Peripheral or Central mode, is ignored in Firmware Version 1.20.

Table 2-2 summarizes the commands that switch the GAP roles.

**TABLE 2-2: ROLE SWITCH COMMANDS**

| Event/Action Command | Gap Roles |
|---|---|
| Boot up | None |
| A – Start advertising | Peripheral |
| F – Start scanning | Central |
| E – Connect command | Central |
| J,1 – Enter Observer | Observer |
| J,0 – Exit Observer | Peripheral |
| N – Enter Broadcaster | Broadcaster |

## 2.3 RN4020 UART-ASCII COMMAND AND RESPONSES

**Note:** Not all commands are available on all firmware releases. Refer to the RN4020 product page (http://www.microchip.com/RN4020) for the latest firmware information and release notes.

All commands are parsed through the UART, which acts as the main control interface for the RN4020 module. The default UART port configuration is shown in Table 2-3.

**TABLE 2-3: RN4020 UART CONFIGURATION**

| Parameter | Value |
|---|---|
| Baud Rate | 115200 |
| Data Bits | 8 |
| Parity | None |
| Stop Bits | 1 |
| Flow Control | None |

The UART baud rate can be adjusted from 2400 to 932 Kbps with the "SB" command. When the UART baud rate is set to 2400, there is no need to wake the module via WAKE_SW (pin 7) before communicating with the module.

All control takes place through ASCII commands and their parameters. All commands and parameters are separated by commas. No spaces are allowed between commands and parameters. All commands are completed by either a line feed or a return.

All commands are divided into the following types:

- Set/Get Commands
- Action Commands
- Characteristic Access Commands
- Private Service Configuration Commands
- Microchip MLDP Commands
- RN4020 Scripting Commands
- Remote Command
- DFU Commands

Table 2-4 lists and provides brief descriptions of all commands by type.

TABLE 2-4: COMMAND DESCRIPTIONS

| Type | Command Name | Description |
|---|---|---|
| Set/Get | `S-` | Serialized name |
| | `SB` | Set UART baud rate |
| | `SDF` | Set firmware revision |
| | `SDH` | Set hardware revision |
| | `SDM` | Set model name |
| | `SDN` | Set manufacturer name |
| | `SDR` | Set software revision |
| | `SDS` | Set serial number |
| | `SF` | Factory default |
| | `SM` | Set Timers in µs |
| | `SN` | Set name |
| | `SP` | Set transmission power (see **Note 1**) |
| | `SR` | Set features |
| | `SS` | Set server services |
| | `ST` | Set connection parameters |
| Action | `+` | Echo |
| | @`O` | Output analog signal |
| | @`I` | Input analog signal |
| | \|`O` | Set PIO's output |
| | \|`I` | Get PIO's input |
| | `A` | Advertise |
| | `B` | Bond |
| | `D` | Dump configuration |
| | `E` | Establish connection |
| | `F` | Start scan |
| | `H` | Help |
| | `J` | Observer role |
| | `K` | Disconnect |
| | `M` | Get RSSI from peer |
| | `N` | Enter broadcast information |
| | `O` | Enter dormant state |
| | `Q` | Retrieve connection status (see **Note 1**) |
| | `R` | Reboot |
| | `T` | Change parameter for current connection |
| | `U` | Unbond |
| | `V` | Firmware version |
| | `X` | Stop scan |
| | `Y` | Stop advertisement |
| | `Z` | Stop connecting |
| I$^2$C™ | ] | I$^2$C interface commands. Refer to **Section 2.3.3 "I$^2$C™ Commands"** (see **Note 1**). |
| PWM | [ | PWM commands. Refer to **2.3.4"PWM Commands"** (see **Note 1**) |

**Note 1:** This command is only available with firmware version 1.20 or later.

TABLE 2-4: COMMAND DESCRIPTIONS (CONTINUED)

| Type | Command Name | Description |
|---|---|---|
| Services (GATT) | `LC` | List client services |
| | `LS` | List server services |
| | `CHR` | Read value from client handle |
| | `CHW` | Write value to client handle |
| | `CURC` | Read configuration of client UUID |
| | `CURV` | Read value of client UUID |
| | `CUWC` | Client UUID notify/indicate start |
| | `CUWV` | Write value to client UUID |
| | `SHR` | Read value of server handle |
| | `SHW` | Write value to server handle |
| | `SUR` | Read value of server UUID |
| | `SUW` | Write value to server UUID |
| Private Services | `PC` | Set private characteristic UUID |
| | `PF` | Set primary service UUID filter (see **Note 1**) |
| | `PS` | Set private service UUID |
| | `PZ` | Clear private service |
| MLDP | `SE` | Set MLDP security mode |
| | `I` | Enter MLDP mode |
| Scripting | `LW` | Show script |
| | `WC` | Clear script |
| | `WP` | Pause script |
| | `WR` | Run script |
| | `WW` | Write script |
| Remote | `!` | Enter Remote Command mode |
| DFU | `~` | Device Firmware Update |

**Note 1:** This command is only available with firmware version 1.20 or later.

### 2.3.1 Set/Get Commands

This group of commands is used to configure specific functions of the RN4020 module. The Set commands start with the letter S and are followed by one or two letters as the command identifier. The Set command parameters are mandatory and are separated from the command by a comma. The format of the Set commands is provided in Example 2-1.

**EXAMPLE 2-1: SET COMMAND FORMAT**

| | | | |
|---|---|---|---|
| S | Command Identifier | , | Input Parameter |

A reboot is required for most Set commands to ensure the new settings will take effect. Configurations from the Set commands are stored in the non-volatile memory (NVM) of the RN4020 module and restored after a power cycle or reset. All Set commands have a corresponding Get command to output the configurations to the UART. Get commands have the same command identifier as Set commands, but have no parameters.

## `S-,<string>`

### Description

This command sets the serialized Bluetooth-friendly name of the device, where `<string>` is up to 15 alphanumeric characters. This command automatically appends the last 2 bytes of the Bluetooth MAC address to the name, which is useful for generating a custom name with unique numbering.

### Default:

Not applicable.

### Example

```
S-,MyDevice   // Set device name to “MyDevice-ABCD”
```

## SB,<0-7>

### Description

This command sets the baud rate of the UART communication. The input parameter is a single digit number in the range of 0 to 7, representing a baud rate from 2400 to 921K, as shown in Table 2-5. When the baud rate is set to 2400, there is no need to wake the RN4020 module by pulling WAKE_SW high for UART communication.

**TABLE 2-5: UART BAUD RATE SETTINGS**

| Setting | Baud Rate | Comments |
|---|---|---|
| 0 | 2400 | When the UART is set to 2400 Kbps, the RN4020 module can remain in Deep Sleep. In other words, when set to 2400 Kbps, the UART is always accessible; therefore, the WAKE_SW line does *not* need to be pulled high to wake the RN4020 module for UART access. |
| 1 | 9600 | — |
| 2 | 19200 | — |
| 3 | 38400 | — |
| 4 | 115200 | — |
| 5 | 230400 | — |
| 6 | 460800 | — |
| 7 | 921600 | — |

## SDF,<text>

### Description

This command sets the value of the firmware revision characteristic in the Device Information Service.

The Device Information Service is used to identify the device. Since all of its characteristics rarely change, the values of the characteristics in the Device Information Service can be set and saved into NVM.

> **Note:** All characteristic values in the Device Information Service have a maximum size of 20 bytes.

### Default:

Determined by firmware version.

### Example

```
SDF,0.9
```

## SDH,<text>

### Description

This command sets the value of the hardware revision characteristics in the Device Information Service.

### Default

Determined by hardware version.

### Example

```
SDH,2.1
```

## SDM,<text>

### Description

This command sets the value of the model characteristics in the Device Information Service.

### Default

RN4020

### Example

```
SDM,RN4020
```

## SDN,<text>

### Description

This command sets the value of the manufacturer name characteristics in the Device Information Service.

### Default

Microchip

### Example

```
SDN,Microchip
```

## SDR,<text>

### Description

This command sets the value of the software revision characteristics in the Device Information Service.

### Default

Determined by software version.

### Example

```
SDR,1.0
```

## SDS,<text>

### Description

This command sets the value of the serial number characteristics in the Device Information Service.

### Default

The MAC address of the device.

### Example

```
SDS,12345678
```

## SF,<1,2>

### Description

This command resets the configurations to the factory default at the next reboot. The parameters for this command can be either ‘1’ and ‘2’.

When the input parameter is ‘1’, a majority of the settings will be restored to the factory default, but some settings, such as device name, device info, script and private services, stay the same. When the input parameter is ‘2’, all parameters are restored to factory default.

### Default

Not applicable.

### Example

```
SF,1
```

## SM,<1-3>,<hex32>

### Description

This command starts one of the application timers. The first parameter is the identifier of the timer to start, and the second parameter is the timer expiration time in microseconds if the value is in the range between 0x00000001 and 0x7FFFFFFF. The second parameter outside the this range will stop the timer.

### Default

Not applicable.

### Example

```
SM,1,000f4240       // Start Timer1 to expire in 1 second

SM,1,FFFFFFFF       // Stop Timer1 immediately
```

## SN,<string>

### Description

This command sets the device name, where `<string>` is up to 20 alphanumeric characters.

### Default

Not applicable.

### Example

```
SN,MyDevice      // Set the device name to “MyDevice”
```

## SP,<0-7>

**Note:** This command is only available in firmware version 1.20 or later.

### Description

This command sets the transmission power. The transmission power value will be saved in NVM and retrievable by the command "GP".

**Note:** A reboot is not needed for the new power value to become effective.

The default value set by factory default command is "4". The TX power values are provided in Table 2-6:

**TABLE 2-6: SP LEVEL/TX POWER OUT**

| SP Value | TX Power (dBm) |
|---|---|
| 0 | -19.1 |
| 1 | -15.1 |
| 2 | -10.9 |
| 3 | -6.9 |
| 4 | -2.5 (default) |
| 5 | 1.6 |
| 6 | 5.8 |
| 7 | 7.5 |

### Default

4

### Example

```
SP,0
```

```
SR,<hex32>
```

### Description

This command sets the supported features of current RN4020 module. The input parameter is a 32-bit bitmap that indicates features to be supported. After changing the features, a reboot is necessary to make the changes effective. The bitmap of features is shown in Table 2-7.

**TABLE 2-7: BITMAP FEATURES**

| Feature | Bitmap | Description |
|---|---|---|
| Central | 0x80000000 | If set, the device that starts the connection is central. If cleared, the device that starts advertisement as peripheral.<br>Beginning with Firmware Version 1.20, this option is ignored as GAP roles are determined by Action commands. Refer to **Section 2.2 “GAP Role Switching”** for more information. |
| Real-time Read | 0x40000000 | If set, the device request values from the host MCU through the UART and the host MCU must respond in a timely manner. If cleared, the device reads from the internal RAM of the RN4020 for the characteristic values that were previously set. |
| Auto Advertise | 0x20000000 | This setting only applies to a peripheral device. If set, the device starts advertisement after a power cycle, reboot, or disconnection. If cleared, the device starts advertisement after receiving command “A” from the UART in Command mode. |
| Enable MLDP | 0x10000000 | If set, the device enables the private service MLDP that provides asynchronous serial data over Bluetooth LE. If cleared, MLDP is disabled. See **Section 2.3.7 “Microchip MLDP Commands”** for more information. |
| Auto MLDP Disable | 0x08000000 | This setting is only effective when MLDP is enabled. If set, the device enters MLDP mode after receiving command “I” from the UART in Command mode, or when CMD/MLDP (pin 8) is set high. If cleared, the device enters MLDP mode not only by command “I” or the CMD/MLDP pin, but also by receiving an MLDP data stream from the peer device. |
| No Direct Advertisement | 0x04000000 | This setting is only effective for peripheral devices. If set, the peripheral will not issue a direct advertisement even if it is bonded; therefore, it is discoverable whenever it is advertising. This setting is useful when working with iOS or Android devices. |
| UART Flow Control | 0x02000000 | This setting is used to control RTS/CTS hardware flow control on the RN4020 module UART port. If set, flow control is enabled and the host needs to support the UART hardware flow control feature. Flow control is recommended when MLDP is enabled. |
| Run Script After Power On | 0x01000000 | This setting is used to control script execution. If set, after powering on, script execution will be automatically started by generating a @PW_ON event. |
| Reserved | 0x00800000 | — |
| Enable Authentication | 0x00400000 | This setting enables authentication during connection, preventing a Man-In-The-Middle (MITM) attack. When authentication is enabled, I/O capability is set to be keyboard and/or display. For details, refer to *Table 2.5: “Mapping of IO Capabilities to STK Generation Method”* in *Vol 3, Part H, Section 2.3.5.1 “Selecting STK Generation Method”* in “*Bluetooth Core Specification v4.1”*. |
| Enable Remote Command | 0x00200000 | This setting is only effective if the MLDP feature is enabled. This setting enables the local device to receive remote commands from a remote device and to send command output to a remote device through the MLDP data stream. |
| Do not Save Bonding | 0x00100000 | Once set, the bonding information will not be saved in NVM and the bonding is only valid for the current connection. |

TABLE 2-7: BITMAP FEATURES (CONTINUED)

| Feature | Bitmap | Description |
|---|---|---|
| I/O Capabilities | 0x000E0000 | I/O capability of the module. Only useful if the Enable Authentication bit is set.<br>• `'b000` = Display Only<br>• `'b001` = Display Yes/No<br>• `'b010` = Keyboard Only<br>• `'b011` = No Input, no output<br>• `'b100` = Keyboard Display |
| Block Set Commands in Remote Command Mode | 0x00010000 | If set, all "Set" commands are no longer effective in Remote Command mode. |
| Enable OTA | 0x00008000 | If set, DFU over the air is effective. Otherwise, support of DFU OTA is disabled. |
| iOS Mode | 0x00004000 | If set, connection parameters will be checked against Apple® Bluetooth Accessory Design Guidelines. See the ST,<interval>,<latency>,<timeout> command for details. |
| Server Only | 0x00002000 | If set, the RN4020 module will not act as a client. No service discovery will be performed after connection to save connection time and power. |
| Enable UART in Script | 0x00001000 | If set, allow normal UART output when running a script. |
| Auto-enter MLDP Mode | 0x00000800 | If set, and the Support MLDP bit is also set, once connected, the RN4020 module automatically enters MLDP mode. |
| MLDP without Status | 0x00000400 | If set, no additional status string, such as "CMD", "Connected", and "Connection End", is in the UART output. |

### Default

00000000

### Example

```
SR,20000000         // Set device as peripheral, and
                    // automatically start advertisement
```

## SS,<hex32>

### Description

This command sets the services supported by the device in a server role. The input parameter is a 32-bit bitmap that indicates the services supported as a server. Supporting the service-as-server role means that the host MCU needs to supply the values of all characteristics in the supported services and provides client access to those values upon request. The values for the service characteristics are written to the server database using the "SUW" or "SHW" commands. Once the service bitmap is modified, the device must reboot to make the new services effective. The 32-bit bitmap is provided in Table 2-8.

**TABLE 2-8: BITMAP SERVICES**

| Service | Bitmap | Used in Profiles |
|---|---|---|
| Device Information | 0x80000000 | Blood Pressure, Cycling Speed Cadence, Glucose, Health Thermometer, Heart Rate, Running Speed Cadence |
| Battery | 0x40000000 | |
| Heart Rate | 0x20000000 | Heart Rate |
| Health Thermometer | 0x10000000 | Health Thermometer |
| Glucose | 0x08000000 | Glucose |
| Blood Pressure | 0x04000000 | Blood Pressure |
| Running Speed Cadence | 0x02000000 | Running Speed Cadence |
| Cycling Speed Cadence | 0x01000000 | Cycling Speed Cadence |
| Current Time | 0x00800000 | Time |
| Next DST Change | 0x00400000 | Time |
| Reference Time Update | 0x00200000 | Time |
| Link Loss | 0x00100000 | Proximity |
| Immediate Alert | 0x00080000 | Find Me, Proximity |
| TX Power | 0x00040000 | Proximity |
| Alert Notification | 0x00020000 | Alert Notification |
| Phone Alert Status | 0x00010000 | Phone Alert Status |
| Scan Parameters | 0x00004000 | Scan Parameters |
| User Defined Private Service | 0x00000001 | User Defined Private Profile |

### Default

80000000

### Example

```
SS,060000                // Support blood pressure and running speed
                         // cadence as server role
```

## ST,<interval>,<latency>,<timeout>

### Description

This command sets the initial connection parameters for future connections. The three input parameters are all 16-bit values in hexadecimal format. To modify the current connection parameters, refer to the action command “T”.

For a central device, the connection parameters will be used to establish connections with peripherals. For a peripheral device, the connection parameters are used to request the connection update once a new connection is established. Acceptance of the connection update from a peripheral device depends on the central device.

The corresponding Get command “GT” returns the desirable connection parameters set by the “ST” command when a connection is not established. Once a connection is established, the actual connection parameters will be displayed in response to the command “GT”.

> **Note:** Every Set command has a corresponding Get command, which is used to obtain the setting. See **Section 2.3.1 “Set/Get Commands”** for more information.

Connection interval, latency and timeout are often associated with how frequently a peripheral device needs to communicate with central and is therefore closely related to power consumption. The three parameters’ ranges and relationships are listed in Table 2-9.

**TABLE 2-9: CONNECTION PARAMETERS**

| Parameter | Range | Default Value | Description |
|---|---|---|---|
| Interval | 0x0006-0x0C80 | 0006 | The time interval of communication between two connected devices. (unit: 1.25 ms) |
| Latency | 0x0000-0x01F3<br>Must less than:<br>(Timeout * 10 / Interval * 1.25 - 1) | 0000 | The number of consecutive connection events that the peripheral does not need to communicate with central. |
| Timeout | 0x000A-0x0C80 | 0064 | The maximum time between raw communications before the link is considered lost. (unit: 10 ms) |

Apple iOS devices have a special requirement of these parameters. As a result, if connection with an iOS device is expected, the iOS Mode bit in the “SR” command (see the SR,<hex32> command) will be enabled and the following rules must be applied:

- Interval ≥ 16
- Latency ≤ 4
- Timeout ≤ 600
- (Interval + 16) * (Latency + 1) < Timeout * 8 / 3

### Default

0006,0000,0064

### Example

```
ST,0064,0002,0064       // Set the interval to 125 ms,
                        // latency to 2, and time-out to 1 second
```

### 2.3.2 Action Commands

The group of action commands are mainly used to initiate functionality, as well as display critical information.

## +

### Description

This command toggles the local echo on and off. If the “+” command is sent in Command mode, all typed characters are echoed to the output. Entering the “+” command again will turn local echo off.

### Default

Off

### Example

```
+         // Turn on local echo
```

## @O,<0-2>,<hex16>
## @I,<0-2>

### Description

These commands set the analog port output (O) and get the input (I) voltage. The first parameter can be 0, 1, or 2, which specifies the analog port number. The second parameter is only for analog output, which sets the output voltage in mV. The range of output/input voltage is 0V to 1.3V (valid range is 0x0000 to 0x0514).

When outputting the analog signal, the RN4020 module cannot operate in Deep Sleep mode. Instead, the firmware will automatically adjust the operation mode to Shallow Sleep. Once the analog output is turned off by issuing the command `@O,<0-2>,0000`, the firmware will again automatically adjust the operation mode back to Deep Sleep mode, when available.

### Default

Not applicable.

### Example

```
@O,1,03E8    // Set AIO1 output voltage to be 1000 mV
```

```
|O,<hex8>,<hex8>
|I,<hex8>
```

### Description

The “|O” and “|I” commands set the output (O) and get the input (I) on the digital I/O pins (PIO1, PIO3, and PIO7). The first input parameter is a bitmap to indicate which PIO is affected by this command and the second parameter indicates the digital value to set. Table 2-10 shows the bitmap of the pins. Notice that PIO1 through PIO3 are used as output to indicate status by default.

For example, the RN4020 PICtail™ Daughter Board uses these status PIOs to drive indicator LEDs (see **Appendix A. “PICtail™ Daughter Board Schematics”**). Once these pins are read or written by setting the first three bits in the first parameter, the status is no longer output and the user has full control over the pins.

**TABLE 2-10: BITMAP OF “|O” AND “|I” COMMANDS**

| Bitmap | PIO |
|---|---|
| 0‘b00000001 | PIO1 |
| 0‘b00000010 | PIO2 |
| 0‘b00000100 | PIO3 |
| 0‘b00001000 | PIO7 |

### Default

Not applicable.

### Example

```
|O,07,05          // Set PIO1 and PIO3 output to be high and PIO2
                  // output to be low

|I,06             // Read states of PIO2 and PIO3. The result is a one
                  // byte bitmap. If the result is 04, PIO2 is low
                  // and PIO3 is high.
```

**CAUTION**

**Accessing PIO1-PIO3 will disable the default behavior of serving as status indicators (blue, green, red).**

## `A,<hex16>,<hex16>`

### Description

This command is only available to a device that operates as a peripheral in a broadcaster role.

The “A” command is used to start advertisement.  When the device acts in a broadcaster role, which is enabled by the “N” command, the advertisement is an undirected, unconnectable, manufacturer-specific broadcast message. The payload of the message is set by the “N” command.

When the device acts in a peripheral role and it is not bonded, the advertisement is undirected connectable, which means it is discoverable by all BTLE central devices. When the device is bonded, the advertisement is directed if the no_direct_adv bit is cleared using the “SR” command; otherwise, the advertisement is undirected if the no_direct_adv bit is set. When direct advertisement is used, it is directed to the bonded device so that other BTLE devices are not heard.

When the “A” command is issued without a parameter, by default, the advertisement interval is 100 ms and advertising is indefinite. The “A” command can be followed by two 16-bit hex parameters, which indicates an advertisement interval in milliseconds and total advertisement window time in milliseconds. The second parameter must be larger than the first parameter.

### Default

100 ms

### Example

```
A,0050,07D0      // Start advertisement with interval of
                 // 80 milliseconds for 2 seconds
```

## B,<0,1>

### Description

This command is used to secure the connection and bond two connected devices. The “B” command is only effective if two devices are already connected. Bonding can be issued from either a central or a peripheral device.

If no input parameter is provided or the input parameter is ‘1’, the connection will be secured and the peer device remembered. In this situation, the two devices are considered bonded. If the input parameter is ‘0’, the connection is secured; however, the peer device is not saved into NVM. In this situation, the connection is not bonded.

Once bonded, security information is saved to both ends of the connection if the “do_not_save_bonding” setting is cleared using the “SR” command. Therefore, reconnection between bonded devices does not require authentication, allowing reconnection to be done in a short amount of time. For bonded peripheral devices, advertisement can only be directed. As a result, bonded peripheral devices are not available for inquiry or connection.

After a bonded connection is lost due to any reason, reconnection does not provide a secured link automatically. To secure the connection, another “B” command will be issued. However, this command is only for securing links rather than saving connection information.

### Default

‘0’ (Not bonded)

### Example

```
B      // bond with connected peer device
```

## D

### Description

This command displays critical information about the current device over the UART. The following information will be output after issuing a “D” command:

- Device MAC Address
- Device Name
- Device Connection Role (Central or Peripheral)
- Connected Device: Show the MAC address and address type (Public or Random) if connected, or “no” if no active connection
- Bonded Device: Show the MAC address and address type (Public or Random) if connected, or “no” if no bonding device
- Server Services: Bitmap of services that are supported in the server role
- Features[(1)]: Current value of features bitmap. Refer to “SR” command
- Transmit Power[(1)]: Current value of transmit power. Refer to “SP” command

**Note 1:** Added in Firmware 1.20

### Default

The “D” command has no parameters.

### Example

```
D      // Dump information
```

## `E,<0,1>,<mac address>`

### Description

The “E” command starts the process to establish a connection with a peer peripheral device.

> **Note:** This command is only available to devices in a central role.

If the central device is already bonded with a peripheral, issuing the “E” command without parameters will automatically start the process of connecting with the bonded peripheral. Usually, the bonded central device needs to first issue the “E” command, and then the bonded peripheral starts the directed advertisement.

If the central device is not bonded with the peripheral, two input parameters are required to establish connection with a peripheral device. The first parameter is the MAC address type, and second parameter is the MAC address of the peripheral device. The MAC address type is either ‘0’ for public address or ‘1’ for a random address. The address type will be available in the result of an inquiry using the “F” command. The second parameter is a 6-byte MAC address, which is also available as a result of using the “F” command.

### Default

Bonded MAC address

### Example

```
E,0,00035B0358E6        // Connect to peripheral with
                        // public address 00035B0358E6
```

## `F,<hex16>,<hex16>`

### Description

This command is only available to a device in a central or observer role. For a central device, it is used to query the peripheral devices before establishing a connection. For the observer role, it is used to receive broadcast messages.

If no parameter is provided, the “F” command starts the active scan process with a default scan interval of 375 milliseconds and a scan window of 250 milliseconds. The user has the option to specify the scan interval and scan window as the first and second parameter, respectively, as a 16-bit hex value in milliseconds.

The “F” command can also be used to display the UUID of the primary service upon results of the scan. The “F” command will stop after eight (8) unique devices or the timeout window expires. The format of the scan result is:

```
<BTADDR>,<PRIVATE>,<BTName>,<UUID>,<RSSI>
```

### Default

375 ms for scan interval, 250 ms for scan window.

### Example

```
F,012C,00C8          // Start inquiry with 300 ms scan interval
                     // and 200 ms scan window
```

## H

> **Note:** The “H” command has been removed beginning with Firmware Version 1.20, which was done to release system resources for additional features. The new commands that are available in Firmware Version 1.20 are described in this document.

### Description

This command sends a help page to the UART. The help page is grouped into “Set Commands”, “Action Commands”, “Service Commands”, “Private Service Commands” and “MLDP Commands”. According to the feature settings from “Set Commands”, the help page displays only commands that apply to the current settings.

### Default

The “H” command has no parameters.

### Example

```
H      // Display the help page
```

## J,<0,1>

### Description

This command places the device into or out of an observer role.

If the input parameter is ‘1’, the RN4020 module enters Observer mode. After issuing the “F” command, the RN4020 module is able to receive undirected, unconnectable advertisements from broadcasters. If the input parameter is ‘0’, the RN4020 module exits Observer mode.

### Default

Not applicable.

### Example

```
J,1    // Enter observer mode. To receive broadcast,
       // the “F” command must be issued.
```

## K

### Description

This command is used to disconnect the active BTLE link. The "K" command can be used in a central or peripheral role. An error is returned if there is no connection.

### Default

The "K" command does not have any parameters.

### Example

```
K      // Kill the active BTLE connection
```

## M

### Description

This command is used to obtain the signal strength of the last communication with the peer device. The signal strength can be used to estimate the distance between the device and its peer.

The return value of the "M" command is the Received Signal Strength Indication (RSSI) in dBm. The accuracy of the result is within 6 dBm.

### Default

The "M" command does not have any parameters.

### Example

```
M      // Check the signal strength of the last
       // communication with the peer device
```

## N,<hex>

### Description

This command is used to place the RN4020 module into a broadcaster role and to set the advertisement content. The input parameter is in hexadecimal format, with a limit of up to 25 bytes. After setting the advertisement content, use the "A" command to start advertisement.

### Default

The "N" command does not have any parameters.

### Example

```
N,11223344    // Place RN4020 module into a broadcaster role and set
              // advertisement content to be 0x11, 0x22, 0x33, and 0x44.
```

## O

### Description

This command places the module into a Dormant mode that consumes very little power, and can be issued by either a central or peripheral device.

When the RN4020 module is in Dormant mode, power consumption is less than 700 nA. For comparison, power consumption is less than 5 µA in Deep Sleep mode. Once the RN4020 module enters Dormant mode, the WS pin (pin 10, PIO1/BLUE LED) will assert low and all connection will be lost, as well as any data in RAM. To exit Dormant mode and enter Deep Sleep, pull the WAKE_HW pin (pin 15) high. Once the module has exited from Dormant mode, it behaves the same as after a reboot. To exit Deep Sleep and enter Active mode, pull WAKE_SW high.

### Default

The “O” command does not have any parameters.

### Example

```
O          // Enter low-power dormant mode
```

## Q,<1>

**Note:** This command is available in firmware version 1.20 or later.

### Description

If connected, the “Q” command returns the Bluetooth connection status <BT address>,<0-1>. The first parameter is the Bluetooth address of the remote device. The second parameter indicates whether the address is private/random (1) or public (0). If not connected, the “Q” command returns “No Connection”.

The command “Q,1” returns the bonding state of the RN4020 module <BT address>,<0-1>. The first parameter is the Bluetooth address of the remote device. The second parameter indicates whether the address is private (1) or public (0). If not bonded, the command “Q,1” returns “No Bonding”.

### Default

Not applicable.

### Example

```
Q,1        // Return bonded status

Q          // Return connection status
```

## R,1

### Description

This command forces a complete device reboot (similar to a power cycle). It has one mandatory parameter of '1'. After rebooting the RN4020 module, all prior change settings take effect.

### Default

Not applicable.

### Example

```
R,1       // Reboot the RN4020 module
```

## T,<interval>,<latency>,<timeout>

### Description

This command is used to change the connection parameters, interval, latency, and time-out for the current connection. The parameters of the "T" command are lost after a power cycle. All parameters are 16-bit values in hexadecimal format. The "T" command is only effective if an active connection exists when the command is issued.

For the definitions, ranges and relationships of connection interval, latency, and timeout, please refer to the "ST" command and Table 2-9 for details.

When a "T" command with valid parameters is issued by a peripheral device, a minimum time-out interval is required between the two connection parameter update requests. Also, whether to accept the connection parameter update request is up to the central device. When the RN4020 module acts as a central device, it accepts all valid connection parameter update requests.

### Default

Interval: 6

Latency: 0

Time-out: 100

### Example

```
T,0190,0001,03E8       // Request Connection Parameter to be interval
                       // 400 ms, latency 1, and timeout 1000 ms
```

## U

### Description

This command removes the existing bonding. The “U” command not only removes the bonding, but it also changes the advertisement method. If a peripheral is advertising when a “U” command is issued, the RN4020 module will remove the bonding, stop the directed advertisement, and then start undirected advertisement.

### Default

The “U” command does not have any parameters and can be issued by either the central or peripheral device.

### Example

```
U      // Remove existing bond
```

## V

### Description

This command displays the firmware version.

### Default

Not applicable.

### Example

```
V      // Display the firmware version
```

## X

### Description

This command is only available to a central or observer device. For a central device, it stops the inquiry process. For observers, it stops receiving broadcast messages.

### Default

The “X” command does not have any parameters.

### Example

```
X      // Stop inquiry
```

## Y

### Description

This command is only available to a peripheral or broadcaster device. It stops advertisement that was started by an “A” command.

> **Note:** The command, `SR,20000000`, overrides the “Y” command.

### Default

The “Y” command does not have any parameters.

### Example

```
Y      // Stop advertisement
```

## Z

### Description

This command is only available to a central device. It stops the connection process that was started by an “E” command.

### Default

The “Z” command does not have any parameters.

### Example

```
Z      // Stop the connection process
```

### 2.3.3 I$^2$C™ Commands

**Note:** These commands are only available in Firmware Version 1.20 or later.

Beginning with Firmware Version 1.20, the RN4020 module supports the I$^2$C interface through two predefined pins: 21 and 22. Pin 21 is the SDA data line and pin 22 is the SCL clock line. The RN4020 module always acts as the I$^2$C master.

RN4020 supports I$^2$C access to any device that appears as a standard I$^2$C EEPROM (i.e. real EEPROM devices or other peripherals that provide a memory-mapped register interface). RN4020 also supports raw I$^2$C access by generating discrete I$^2$C conditions such as START, RESTART, STOP, ACKs, and NACKs, and sending or receiving individual bytes.

These commands provide access to the I$^2$C master interface on pins 21 (SDA) and 22 (SCL). The I$^2$C is used for connecting peripherals to the RN4020 module. The commands to access and configure I$^2$C are listed in Table 2-11.

**TABLE 2-11: I$^2$C™ COMMANDS**

| Command | Syntax | Description |
|---|---|---|
| Enable I$^2$C™ | `]A,<clock>,<pio-power>` | Clock is speed of I$^2$C interface:<br>1 = 100 kHz, 4 = 400 kHz.<br>PIO used to supply power to I$^2$C bus. Valid values are 1, 2, 3, 7 to designate which PIO is used to power I$^2$C. |
| Disable I$^2$C | `]Z` | Pulls PIO power low. |
| Read EEPROM | `]ER,<i2c_addr>,<mem>,<length>` | Reads data (32 bytes max) from EEPROM device. |
| Write EEPROM | `]EW,<i2c_addr>,<mem>,<data>` | Writes data (32 bytes max) to EEPROM device. |
| I$^2$C Bus Event | `]C,<event>` | Generates events on bus:<br>0 – Start,1 – Restart, 2 – Stop,<br>3 – Wait for ACK, 4 – Send ACK,<br>5 – Send NACK. |
| I$^2$C Read Data | `]R,<len>` | Reads data from I$^2$C slave peripheral, max 32 bytes. |
| I$^2$C Write Data | `]W,<data>` | Write data to I$^2$C slave peripheral, max 32 bytes. |

#### 2.3.3.1 ENABLE I$^2$C

The command “]A” is used to initialize and enable I$^2$C interface. It expects two parameters.

The first parameter is either 1 or 4, indicating the clock speed of I$^2$C interface to be either 100 KHz standard mode or 400 KHz fast mode. User needs to choose the proper I$^2$C speed according to speed capability of I$^2$C peripherals.

The second parameter is the PIO that could be used to control power supply to I$^2$C peripherals. When I$^2$C interface on RN4020 is enabled on RN4020, the assigned PIO will pull high; when I$^2$C interface on RN4020 is disabled, the assigned PIO will pull low. The available pins to support this feature are PIO1/2/3/7. Any number other than those 4 will be ignored and I$^2$C peripheral should control its own power supply.

### Syntax

```
]A,<1,4>,<1-3,7>
```

#### 2.3.3.2 DISABLE I$^2$C

The command "]Z" is used to disable the I$^2$C interface. If one of the pins is assigned to control the power of the I$^2$C, that pin will pull low after issuing this command.

### Syntax

```
]Z
```

#### 2.3.3.3 I$^2$C EEPROM ACCESS

RN4020 can access peripherals that behave like a standard EEPROM, which use 16-bit memory address to access data. There are two commands that have been defined to read and write data.

##### 2.3.3.3.1 Reading Data

The command "]ER" is used to read data from the EEPROM, which expects three parameters.

The first parameter is the address of the I$^2$C peripheral. Currently, only a 7-bit address is supported. The address does not include a read/write indication bit.

The second parameter is the address of the memory, or the address of the register if the device operates like an EEPROM.

The third parameter is the length of data to be read in bytes. The range of length is between 01 and 20 in hex, or 1 to 32 bytes in decimal. Notice that some EEPROM devices do not allow a read across the page boundary. If that is the case, the user needs to make sure that there is no page boundary within the data to be read.

### Syntax

```
]ER,<H16>,<H16>,<H8>
```

##### 2.3.3.3.2 Writing Data

The command "]EW" is used to write data to the EEPROM. It expects three parameters.

The first parameter is the address of the I$^2$C peripheral. Currently, only a 7-bit address is supported. The address does not include a read/write indication bit.

The second parameter is the address of the memory, or the address of the register if the device operates like an EEPROM.

The third parameter is the data to be written to the EEPROM in hex format between 1 and 32 bytes.

### Syntax

```
]EW,<H16>,<H16>,<H8 data>
```

### 2.3.3.4 I$^2$C BASIC OPERATIONS

Other than accessing EEPROM-like devices, the RN4020 I$^2$C interface also defines commands to operate in basic modes to access any I$^2$C peripherals.

#### 2.3.3.4.1 Events

The command "]C" generates I$^2$C events on the bus. One parameter in the range of 0 to 5 is expected for this command. Table 2-11 lists the parameter and its associated I$^2$C event.

**TABLE 2-12: I$^2$C™ EVENTS**

| Parameter | Event |
|---|---|
| 0 | Send START condition |
| 1 | Send RESTART condition |
| 2 | Send STOP condition |
| 3 | Wait for ACK |
| 4 | Send ACK |
| 5 | Send NACK |

**Syntax**

```
]C,<0-5>
```

#### 2.3.3.4.2 Reading Data

The command "]R" reads data directly from the I$^2$C peripheral and expects one parameter.

The input parameter is in hex format in the range of 01 to 20, or 1 to 32 in decimal. The parameter is the number of bytes to be read.

**Syntax**

```
]R,<H8>
```

#### 2.3.3.4.3 Writing Data

The command "]W" writes data directly to the I$^2$C slave. This command expects one parameter of data to be written to the I$^2$C slave in hex format. The parameter maximum input size is 32 bytes.

**Syntax**

```
]W,<H8 data>
```

### 2.3.3.5 EXAMPLE OF ACCESSING THE MICROCHIP I$^2$C EEPROM 24LC512

The Microchip 24LC512 is a standard EEPROM with an I$^2$C interface. The following procedure shows how to access the EEPROM through both EEPROM access methods and basic EEPROM operations.

The 24LC512 can be configured to use one of eight available I$^2$C addresses through the A0, A1, and A2 chip configuration pins. In this example, we connected A0, A1, and A2 all to GND and, therefore, configured its I$^2$C address to be 0x0050.

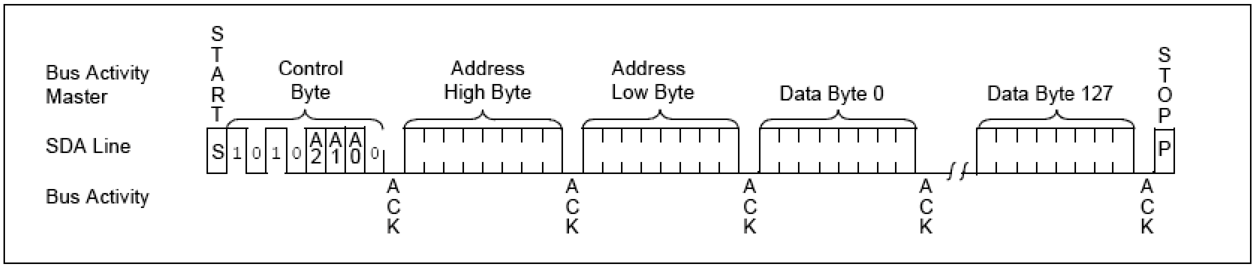
Using the "]A" command, the 24LC512 device can be accessed at a 400 kHz I$^2$C clock and powered by PIO2. The following command is issued for this configuration:

```
]A,4,2
```

2.3.3.5.1 Writing Data to the 24LC512

Writing data via the I$^2$C interface is done through the following procedure.

**FIGURE 2-2: WRITING DATA VIA THE I$^2$C™ INTERFACE**



To write data using basic I$^2$C operations, the following command should be used:

```
]C,0                    // Send START event
]W,A00010AABBCCDDEEFF   // Write AABBCCDDEEFF to memory
                        // 0010 of I2C address 0x0050
                        //(0xA0 with write bit 0)
]C,2                    // Send STOP event
```

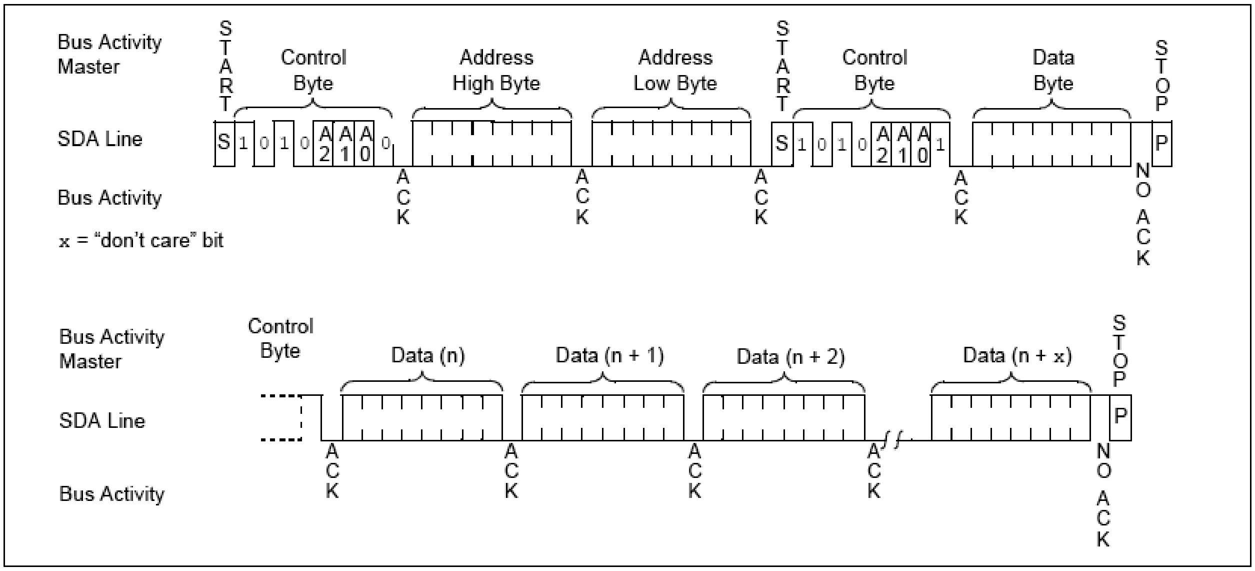
Alternatively, we could directly write 6 bytes to 24LC512, starting from address 0x0010, through a standard EEPROM access command:

```
]EW,0050,0010,AABBCCDDEEFF
```

2.3.3.5.2 Reading Data From the 24LC512

Reading data via the I$^2$C interface is done through the following procedures:

**FIGURE 2-3: READING DATA VIA THE I$^2$C™ INTERFACE**



To read data using basic I$^2$C operations, the following commands should be used:

```
]C,0                // Send START event
]W,A00010           // Send access address
]C,1                // Send RESTART event
]W,A1               // Send Control Byte
]R,06               // Read 6 bytes
]C,2                // Send STOP event
```

Alternatively, 6 bytes can be read directly from the 24LC512, starting from address 0x0010, through the standard EEPROM access command:

```
]ER,0050,0010,06
```

### 2.3.4 PWM Commands

**Note:** These commands are only available in Firmware Version 1.20 or later.

These commands support up to four HIGH/LOW Pulse Width Modulation (PWM) patterns. These PWMs can be used to flash an LED in a pattern, control voltage to a motor/servo, or to drive an audio tone to a speaker.

Beginning with Firmware Version 1.20, up to four concurrent two-pattern PWMs are supported on four configurable PIO pins (PIO1, PIO2, PIO3, and PIO7).

The command "[" is used to start the PWM service. The command syntax is as follows:

```
[,<1-3,7>,<H8>,<H8>,<H8>,<H8>,<H8>,<H8>
```

The first parameter is used to specify the PWM pin. The available pins are PIO1, PIO2, PIO3, and PIO7, with parameters 1, 2, 3, and 7, respectively.

Next, are six 8-bit hex value parameters for two PWM patterns. The first three parameters are for the first pattern, and the next three parameters are for the second pattern.

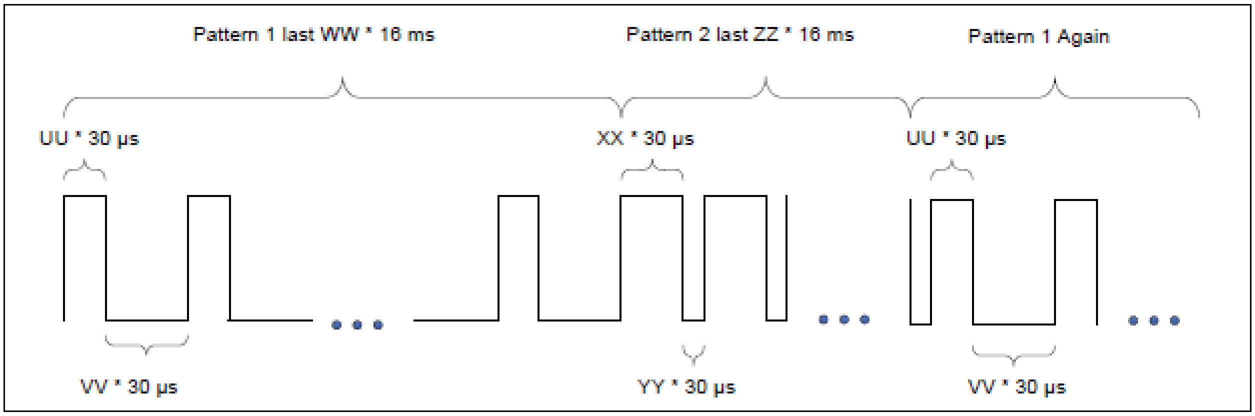
Parameters 2 and 5 are used to identify the total time in a cycle that the PWM outputs high in units of 30 µs for pattern 1 and pattern 2, respectively.

Parameters 3 and 6 are used to identify the total time in a cycle that the PWM outputs low in units of 30 µs for pattern 1 and pattern 2, respectively.

Parameters 4 and 7 are used to identify the pattern lasting time in units of 16 ms for pattern 1 and pattern 2, respectively.

For the command "[,1,UU,VV,WW,XX,YY,ZZ", the PWM waveform shown in Figure 2-4 will be generated.

**FIGURE 2-4: PWM WAVEFORM**



If only one pattern is required, and depending on the resolution requirement, two methods could be used.

If the pulse width and cycle time are both short and the resolution requirement is high, we could ignore the pattern 2 parameters. Under this configuration, the maximum pulse width is 4.08 ms (255 * 16 µs) and the maximum cycle time is pulse width plus 4.08 ms. The following command can be used under this configuration.

```
[,2,UU,VV,WW,00,00,00
```

If pulse width and duty cycle are higher than the first configuration, then we could use pattern 1 as the pulse on time and pattern 2 as the pulse off time. In this configuration, the minimum pulse width is 30 ms, minimum cycle time is pulse width plus 30ms, maximum pulse width is 7.65 seconds (255 * 30 ms), and maximum cycle time is pulse width plus 7.65 seconds. For instance, the following command describes a PWM waveform that is on for WW * 30 ms and off for ZZ * 30 ms.

```
[,3,FF,00,WW,00,FF,ZZ
```

## [<pio>,<h1>,<l1>,<d1>,<h2>,<l2>,<d2>

### Description

This command enables the specified PWM. Table 2-13 lists the available parameters.

TABLE 2-13: PWM PARAMETERS

| Parameter | Description |
|---|---|
| <pio> | The PIO number: 1, 2, 3, or 7. |
| <h1> | Byte indicating the time to hold High increments of 30 μs. |
| <l1> | Byte indicating the time to hold Low increments of 30 μs. |
| <d1> | Pattern 1. |
| <h2> | Byte indicating the time to hold High increments of 16 μs. |
| <l2> | Byte indicating the time to hold Low increments of 16 μs. |
| <d2> | Pattern 2. |

### Default

Not applicable

### Example

```
[,2,UU,VV,WW,00,00,00      // PIO2 Max pulse width of 4.08 ms
                           // PIO2 Max cycle time of 4.08 ms
```

### 2.3.5 Characteristic Access Commands

The main functionality of BTLE profiles and services are providing access to the values and configurations of characteristics. The RN4020 module provides a set of commands to address this issue.

#### 2.3.5.1 DEFINITION OF CHARACTERISTIC ACCESS COMMANDS

The RN4020 module can be configured to act as a server and client at the same time. When it performs dual roles as the server and client, two sets of services and characteristics are known to the RN4020 module. For services where the RN4020 module acts as the server, these are called “server services”, where all values and configurations of characteristics are stored locally. For services where the RN4020 module acts as the client, these are called “client services”, where all data and configurations of the characteristics are stored remotely in the peer device. To address server services, the first letter of a characteristic access command is “S”, and to address client services, the first letter of a characteristic access command is “C”.

The Bluetooth SIG adopted a group of public services specifications, which are the basis of interoperability between devices. All Bluetooth SIG public service and characteristics in the service have been assigned 16-bit short UUIDs. However, users are able to define their own private service and its associated characteristics with 128-bit long UUIDs. Conversely, even though it is rare, one public characteristic may be used in more than one service. Furthermore, because addressing a 128-bit private characteristic may not be very efficient, the RN4020 module provides a unique 16-bit reference handle to each characteristic. Therefore, a characteristic can be addressed either by its UUID or its handle. To address a characteristic by its UUID, the second letter of a characteristic access command is “U”, and to address a characteristic by its handle, the second letter of a characteristic access command is “H”.

In addition, the value or configuration of a characteristic can either be read or write. To read a characteristic, the third letter of a characteristic access command is “R”, and to write a characteristic, the third letter of a characteristic access command is “W”.

Finally, access to a characteristic may be directed to its value or its configuration. Usually, only client services need to access the configuration of a characteristic. If the address is done by handle, this problem has been solved, since the value and configuration of a characteristic have different handles. However, if addressing is done by UUID, a fourth letter “V” or “C” needs to be added to indicate whether the access request to client service is for either the value (V) or the configuration (C) of a characteristic.

Before addressing the characteristics, users may want to determine the accessible characteristics. The Characteristic Access Commands group provides two commands, “LC” and “LS”, to list the client services and server services, respectively.

## LC

### Description

This command lists the available client services and their characteristics. Client services and their characteristics are only available under two conditions:

- An active connection exists
- Peer device supports services in a server role

The output of the “LC” command follows this format:

- The first line is the primary service UUID. If there are more services available, they can be accessed using the Primary Service Filter command, “PF” command (see “PF,<UUID><Z>” for details).
- The second line starts with two spaces, and then follows the characteristic UUID, handle, and characteristic property
- The property for the characteristic value follows the definitions shown in Table 1-1 in **Chapter 1. “Introduction”**. The property for the characteristic value must have bit 4 and bit 5 cleared (no notification or indication), while the property for the characteristic configuration must have either bit 4 or bit 5 set

Example 2-2 shows the Battery Service output. 0x180F is the UUID for the Battery Service. The second line shows that the Battery Level UUID is 0x2A19, its handle is 0x001A and the property is 0x02 (Readable, a value handle (see Table 1-1)). The third line shows that the Battery Level UUID is 0x2A19, its handle is 0x001B and its property is 0x10 (Notify, a configuration handle).

When the “LC” command has no parameter, it displays all client services along with their characteristics. Optionally, the “LC” command can accept one or two parameters.

If one parameter is provided to the “LC” command, it must be the UUID of the client service. Then, only the client service with the provided UUID along with all of its characteristics will be displayed. If two parameters are provided to the “LC” command, the first parameter is the UUID of the client service, and the second parameter is the UUID of its characteristic. Only the characteristic with the provided UUID in the client service with the given UUID is displayed.

**EXAMPLE 2-2: LISTING CLIENT SERVICE AND CHARACTERISTICS**

```
180F
 2A19,001A,02
 2A19,001B,10
```

## LS

### Description

This command lists the server services and their characteristics.

The output format of the “LS” command is similar to that of the “LC” command, as follows:

- The first line is the primary service UUID
- The second line starts with two spaces, and then follows the characteristic UUID, handle, and letter “V” or “C” to indicate the value handle or configuration handle, respectively.

### Example

```
LS     // Display all server services
```

## CHR

### Description

The “CHR” command reads the content of the characteristic of the client service from a remote device by addressing its handle.

The parameter of the “CHR” command is the 16-bit hexadecimal value of the handle, which corresponds to a characteristic of the client service. Users can find a match between the handle and its characteristic UUID using the “LC” command.

This command is only effective if an active link with a peer exists, the handle parameter is valid, and the corresponding characteristic is readable according to its property. The value returned is retrieved from the remote peer device.

### Example

```
CHR,001A         // Read the content of the characteristic with
                 // the handle 0x001A from a remote device
```

## CHW

### Description

The "CHW" command writes the contents of the characteristic in the client service from a remote device by addressing its handle.

This command expects two parameters. The first parameter is the 16-bit hexadecimal value of the handle, which corresponds to a characteristic of the client service. Users can find a match between the handle and its characteristic UUID using the "LC" command. The second parameter is the content to be written to the characteristic. The format of each public characteristic is defined in the Bluetooth SIG specifications. The format of each private characteristic is defined by the user.

This command is only effective if an active link with a peer exists, the handle parameter is valid, and the corresponding characteristic is writable according to its property. The content value is written to the remote peer device. The writing method depends on the property of the characteristic.

When writing to a configuration handle of a remote device, the Bluetooth Specification defines the format to be 0x0000, 0x0001, or 0x0002. Value 0x0001 (01 00 over the air in little-endian) starts notification, value 0x0002 (02 00 over the air in little-endian) starts indication, and value 0x0000 stops both of them. To start notification or indication depends on the service specification, as well as the property of the characteristic. Please refer to Table 1-1 in **Chapter 1. "Introduction"** and Example 2-2 for details.

### Example

```
CHW,001A,64      // Set the value of the characteristic
                 // with the handle value 0x001A to be
                 // 100 on the remote device

CHW,001B,0100    // Start notification on the characteristic
                 // by writing 0x0001 to its configuration
                 // handle 0x001B on the remote device
```

## CURC

### Description

The “CURC” command reads the configuration of a characteristic in the client service from a remote device by addressing its UUID.

This command expects one parameter, which is the UUID of the characteristic in the client service. The UUID can be either a 16-bit short UUID for a public characteristic, or a 128-bit long UUID for a private characteristic. Only characteristics with a property of notification or indication have a configuration and, therefore, are addressable by this command.

This command is only effective if an active link with a peer exists and the UUID parameter is valid. The configuration of a characteristic, if it exists, is always readable. The value returned is retrieved from the remote peer device. The return value is 0000, 0100, or 0200, or endian format for value 0x0000, 0x0001, and 0x0002. A return value of 0000 means no indication or notification started, a return value of 0100 means a notification started, and 0200 means an indication started.

### Example

```
CURC,2A19         // Read the configuration of the characteristic
                  // Battery Level with the UUID 0x2A19 from the
                  // remote device
```

## CURV

### Description

The “CURV” command reads the value of a characteristic in the client service from a remote device by addressing its UUID.

This command expects one parameter, which is the UUID of the characteristic in the client service. The UUID can be either a 16-bit short UUID for a public characteristic, or a 128-bit long UUID for a private characteristic.

This command is only effective if an active link with a peer exists, the UUID parameter is valid, and the characteristic is readable according to its property. The value returned is retrieved from the remote peer device.

### Example

```
CURV,2A19         // Read the value of the characteristic
                  // Battery Level with the UUID 0x2A19
                  // from the remote device
```

## CUWC

### Description

The “CUWC” command writes the configuration of a characteristic in the client service to a remote device by addressing its UUID.

This command expects two parameters. The first parameter is the UUID (either a 16-bit short UUID or a 128- bit long UUID) of the characteristic. The second parameter is either ‘0’ or ‘1’. Parameter ‘1’ starts notification or indication, depending on the property of the configuration handle. Parameter ‘0’ turns off notification or indication. Only characteristics with a property of notification or indication have a configuration and, therefore, are addressable by this command.

This command is only effective if an active link with a peer exists and the UUID parameter is valid. The characteristic configuration, if it exists, is always writable.

### Example

```
CUWC,2A19,1      // Start notification on the remote device
                 // for the characteristic Battery Level with
                 // the UUID 0x2A19
```

## CUWV

### Description

The “CUWV” command writes the value of a characteristic in the client service to a remote device by addressing its UUID.

This command expects two parameters. The first parameter is the UUID (either a 16-bit short UUID or a 128-bit long UUID) of the characteristic. The second parameter is the hexadecimal value of the contents to be written. The format of the public characteristic is defined in the Bluetooth SIG specifications. The format of the private characteristic is defined by the user.

This command is only effective if an active link with a peer exists, the UUID parameter is valid, and the characteristic is writable according to its property. The content value is written to the remote peer device. The writing method depends on the property of the characteristic.

### Example

```
CUWV,2A19,64     // Write 100% to the remote device for the
                 // characteristic Battery Level with the
                 // UUID 0x2A19
```

## SHR

### Description

The “SHR” command reads the contents of the characteristic of the server service on a local device by addressing its handle.

The parameter of the “SHR” command is the 16-bit hexadecimal value of the handle, which corresponds to a characteristic of the server service. Users can find a match between the handle and its characteristic UUID using the “LS” command.

This command is effective with or without an active link. Reading the contents of a characteristic locally is always permitted regardless of characteristic property. The characteristic property is only used for remote access. The value returned is retrieved from the local device and equal to what was written the most recently.

### Example

```
SHR,001A         // Read the local content of the characteristic
                 // with the handle 0x001A
```

## SHW

### Description

The “SHW” command writes the contents of the characteristic in the server service to a local device by addressing its handle.

This command takes two parameters. The first parameter is the 16-bit hexadecimal value of the handle, which corresponds to a characteristic of the server service. Users can find a match between the handle and its characteristic UUID using the “LS” command. The second parameter is the content to be written to the characteristic. The format of each public characteristic is defined in the Bluetooth SIG specifications. The format of each private characteristic is defined by the user.

This command is effective only if the handle is valid in the server service. The characteristic in the server service is always writable regardless of its property. The characteristic property is only for remote access. The contents of a configuration handle, which starts or stops notification/indication, is usually set remotely. It is highly recommended to not write to the configuration handle, although that operation is not prohibited.

When the Real-Time Read feature is enabled (see the “SR” command), the RN4020 module requests the contents of a characteristic from the host MCU when receiving a read request from the remote device. The host MCU needs to use the “SHW” or “SUW” command to write the contents and, therefore, responds to the request.

When the “SHW” command is used to change the local contents of a characteristic, a notification or indication will be sent to the remote device, provided the following conditions are met:

- An active connection exists
- The remote device supports the corresponding service and characteristic in a client role
- The property of the corresponding characteristic supports notification or indication
- The notification or indication service for the corresponding characteristic has been started by the remote device

### Example

```
SHW,001A,64       // Set the local value of characteristic Battery
                  // Level with value handle 0x001A to be 100%. If the
                  // notification service was previously started on
                  // Battery Level, the local device will notify the
                  // new value of 100% to the remote peer device
```

## SUR

### Description

The “SUR” command reads the value of the characteristic in the server service on a local device by addressing its UUID.

The parameter of the “SUR” command is the hexadecimal value of the UUID of a characteristic. The UUID can be either a 16-bit short UUID for a public characteristic, or a 128-bit long UUID for a private characteristic.

This command can only read the value of a characteristic. Generally, the configuration of a characteristic in a server service is accessed remotely by a peer device. Therefore, the local device does not care about the setting. If the user needs to know the configuration of a local characteristic, the “SHR” command will be used to retrieve this information.

This command is effective with or without an active link. Reading the value of a characteristic locally is always permitted regardless of the characteristic property. The characteristic property is only used for remote access. The value returned is retrieved from the local device and is equal to what was written the most recently.

### Example

```
SUR,2A19          // Read the local value of the characteristic with
                  // the UUID 0x2A19
```

## SUW

### Description

The "SUW" command writes the contents of the characteristic in the server service to a local device by addressing its UUID.

This command takes two parameters. The first parameter is the hexadecimal value of the UUID of a characteristic. The UUID can be either a 16-bit short UUID for a public characteristic, or a 128-bit long UUID for a private characteristic. The second parameter is the content to be written to the characteristic. The format of each public characteristic is defined in the Bluetooth SIG specifications. The format of each private characteristic is defined by the user.

The "SUW" command is effective only if the UUID is valid in the server service. The characteristic in the server service is always writable regardless of its property. The characteristic property is only for remote access. The configuration of a characteristic, which starts or stops notification/indication, is usually set remotely. Therefore, the "SUW" command cannot be used to modify the configuration of a local characteristic. In the exceptional case that such a configuration has to be modified, the "SHW" command will be used.

When the Real-Time Read feature is enabled (see the "SR" command), the RN4020 module requests the contents of a characteristic from the host MCU when receiving a read request from the remote device. The host MCU needs to use the "SHW" or "SUW" command to write the content and, therefore, responds to the request.

When the "SUW" command is issued to change the local contents of characteristic, a notification or indication will be sent to the remote device, provided the following conditions are met:

- An active connection exists
- The remote device supports the corresponding service and characteristic in a client role
- The property of the corresponding characteristic supports notification or indication
- The notification or indication service for the corresponding characteristic has been started by the remote device

### Example

```
SUW,2A19,64      // Set the local value of the characteristic Battery
                 // Level with value handle 0x001A to be 100%. If the
                 // notification service was previously started on
                 // Battery Level, the local device will notify the
                 // new value of 100% to the remote peer device
```

### 2.3.6 Private Service Configuration Commands

The Bluetooth SIG Specification defines public profiles, services, and characteristics to ensure interoperability between devices. Alternatively, it is possible to define a private service to address unique requirements not provided by a public service. The RN4020 module provides the capability to define their own private service or characteristics in the server role, as well as working with private service or characteristics in the client role.

All Bluetooth adopted public service/characteristics have a 16-bit short UUID. Conversely, all private service/characteristics have a 128-bit long UUID. Once the private service is enabled (see the “SS” command and its bitmap parameter), the private service/characteristic commands will be displayed in a help page (see the “H” command).

All private service/characteristic configuration commands begin with the letter “P”. The main function of those commands is to define the private service and its private characteristics. All definitions will be saved in NVM on the RN4020 module, which can be restored after a power cycle.

**PC**

#### Description

The “PC” command sets the private characteristic. This command must be called after the private service UUID has been set (see the “PS” command). Calling this command adds one private characteristic to the private service at a time. Calling this command later will not overwrite the previous settings, but instead will add another private characteristic. This command is only effective if the private service bit is set (see the “SS” command and its bitmap parameter). The new settings will not take effect until a power cycle is performed.

**Note:** The RN4020 module supports up to 10 private characteristics.

Private characteristics with a property of notification or indication occupy two slots, whereas those characteristics without a property of notification or indication occupy one slot.

The “PC” command expects three or four parameters.

The first parameter is the 128-bit UUID for the private characteristic. There are many ways that a user can generate the 128-bit UUID with little possibility of conflict. For information, refer to the related Wikipedia page:

http://en.wikipedia.org/wiki/Universally_unique_identifier

The second parameter is the 8-bit property bitmap of the characteristic. Refer to Table 1-1 in **Chapter 1. “Introduction”** for the characteristic property.

The third parameter is an 8-bit value that indicates the maximum data size in bytes that the private characteristic holds. The real data size can be smaller. The maximum data size of a characteristic cannot exceed 20 bytes.

The optional fourth parameter is the 8-bit security flag bitmap of the characteristic. The bitmap is described in Table 2-14. Note that if an authenticated read or write is defined, the authentication bit in the "SR" command must be set and the RN4020 module must have I/O capability for security keys. If this parameter is not provided, access to the characteristic requires no additional GATT security.

TABLE 2-14: SECURITY FLAGS OF CHARACTERISTIC

| Name | Bitmap | Description |
|---|---|---|
| ENCR_R | 0b00000001 | Encryption required to read the characteristic |
| AUTH_R | 0b00000010 | Authentication required to read the characteristic |
| ENCR_W | 0b00010000 | Encryption required to write the characteristic |
| AUTH_W | 0b00100000 | Authentication required to write the characteristic |

## PF,<UUID><Z>

**Note:** This command is only available in Firmware Version 1.20 or later.

### Description

The “PF” command sets the primary UUID filter of the private service.

Previous versions of RN4020 firmware would only recognize the first private service enumerated by the GATT server on the remote module. Other private services were not accessible. Beginning with Firmware Version 1.20, a primary service filter can be used to specify a unique GATT service on the remote module to access by the local RN4020 as a client. The command “PF,<UUID>” sets the service filter value. The command “PF,Z” clears the filter. The parameter UUID must be a 128-bit private UUID.

### Example

```
PF,Z      // Clear the filter
```

## PS

### Description

The “PS” command sets the UUID of the private service. This command must be called before the “PC” command is called. This command is only effective if the private service bit is set (see the “SS” command and its bitmap parameter).

The effect of the “PS” command can only be shown after a valid “PC” command has been issued and after a power cycle.

The “PS” command expects one parameter, which is the 128-bit UUID for the private service. The UUID generation process is the same as that of private characteristics. For information, refer to the related Wikipedia page: http://en.wikipedia.org/wiki/Universally_unique_identifier.

### Example

```
PS,0102030405060708090000A0B0C0D0E0F
// Define a private service with UUID 0x0102030405060708090000A0B0C0D0E0F
```

## PZ

### Description

The “PZ” command clears all settings of the private service and the private characteristics. A power cycle is required to make the changes effective.

### Example

```
PZ        // Clear all private service and characteristics settings
```

### 2.3.7 Microchip MLDP Commands

#### 2.3.7.1 MICROCHIP LOW-ENERGY DATA PROFILE (MLDP)

Built on top of BTLE GATT, Microchip developed the private service MLDP to simulate the operation of SPP.

To enable MLDP, the MLDP bit has to be set (see the "SR" command).

To run MLDP between two RN4020 modules, both devices must have the MLDP feature enabled.

The throughput of MDLP communication highly depends on the connection parameters, which decide the frequency of communication between a central device and a peripheral device (see the "T" command). High MLDP throughput requires frequent communication between the two devices and, therefore, consumes more power and shortens battery life. If battery life is the priority of the application, the expectation of MLDP throughput can be lowered.

Once MLDP is enabled, connection parameters are decided and an active link has been established between a central and peripheral device. Setting CMD/MLDP (pin 8) high enters MLDP mode. In MLDP mode, any data input from the UART module of the RN4020 will be sent wirelessly to the peer device. To exit MLDP mode, CMD/MLDP must be set low. After exiting MLDP mode, the RN4020 module will be back to the default Command mode.

To ensure data streams between the two RN4020 devices, both devices must enter MLDP mode. Conversely, the user has the option to enter MLDP mode automatically when receiving an MLDP message from the peer device by setting the MLDP_ENABLE_RX bit in the RN4020 features (see the "SR" command). When the MLDP_ENABLE_RX bit is set, MLDP mode can be initiated from one side of communication.

Besides being controlled by the CMD/MLDP pin, MLDP mode can also be entered by issuing the "I" command.

**I**

#### Description

This command places the RN4020 module into MLDP simulation mode.

The "I" command is only effective if all of the following conditions are met:

- Central and peripheral devices have been connected
- MLDP mode is enabled using the "SR" command, which takes effect after a power cycle on both of the RN4020 devices

Once the "I" command is issued, the RN4020 module enters MLDP mode and all data through the UART will be wirelessly transmitted to the peer device. The only way to exit MLDP mode is to assert CMD/MLDP low.

#### Default

This command does not have any parameters.

#### Example

```
I      // Enter MLDP mode
```

## SE,<0-2>

### Description

The “SE” command sets the security mode for MLDP communications and expects one parameter.

If the parameter is ‘0’, no additional security is required.

If the parameter is ‘1’, MLDP data over the air will be encrypted. Bonding is required before the MLDP service starts.

If the parameter is ‘2’, MLDP data over the air will be authenticated. If this mode is enabled, the Enable Authentication bit must be set for the “SR” command, the RN4020 module must have I/O capability, and bonding must be done before the MLDP service starts.

### Default

0

### Example

```
SE,1      // Secure MLDP data over the air
```

#### 2.3.7.2 MLDPv2

**Note:** This feature is only available in Firmware Version 1.20 or later.

MLDPv2 increases the over-the-air throughput to 7 KB/s when used with two RN4020 modules with the UART set to 115200 Kbps. This is done by allowing unacknowledged writes to increase data throughput.

For point-to-point connections where two RN4020s are connected, the MLDPv2 is enabled by setting a configuration bit using the “SR” command on bit 9.

To effectively use MLDPv2, the UART baud rate must be configured above the desired over-the-air data rate, and UART flow control should be enabled. Since MLDPv2 uses unacknowledged writes, a write-response is not returned to the sender to indicate successful delivery.

On the remote side, configured as a BTLE central device (e.g., smartphone or tablet), the remote end should send data to the RN4020 module by using the Write_CMD method. In the same manner, the remote BTLE should initiate notification on the MLDP data characteristics to received unacknowledged data transfers from the RN4020 module.

If an RN4020 module exchanges MLDPv2 data between itself and other BLE devices (e.g., smartphone or tablet), the other BLE device should send data using the write_command to enable the RN4020 module to receive the unacknowledged data stream. Conversely, other BLE devices should start notification instead of indication on the MLDP data characteristic to obtain the unacknowledged data stream from the RN4020 module to other BLE devices.

The UART baud rate of the RN4020 module should be high enough to maintain sustained data high throughput over the BLE link. If the data throughput over the BLE link is higher than that of the UART, data may be lost.

### 2.3.8 RN4020 Scripting Commands

#### 2.3.8.1 RN4020 SCRIPTING CAPABILITIES

In a typical setup, a host MCU via ASCII commands drives the RN4020 BLE module over the UART interface. However, for simple applications that do not require the I/O and computing functions of a host MCU, the RN4020 on-board I/O and scripting capabilities can be used. These scripts are ASCII commands that do not need to be compiled or processed before writing to the RN4020. The RN4020 firmware is not changed by writing, reading or executing the scripts. Scripts are written into the NVM of the RN4020 module, so a power cycle does not affect the script contents.

The scripting capability on the RN4020 module may be useful under the following circumstances:

- Reduced cost of the host MCU
- The user application uses proprietary service and characteristics
- The user application lends itself to the analog or digital ports that are available on the RN4020
- The user application logic is simple; instead of the RN4020, a peer device can perform interpolation of data
- A script cannot exceed 1000 bytes and be less than 100 lines
- The scripting capability can also be used to lower the load of the host MCU and can be used to initialize settings and perform operations once a certain event is triggered
- User-defined functions (only available in Firmware Version 1.20 or later)

##### 2.3.8.1.1 RN4020 Script Fundamentals

The main functionalities of scripting are achieved by executing ASCII commands, which are the same as those via the UART interface.

#### 2.3.8.2 EVENT DRIVEN

A script is driven by events. Currently, there are 11 events defined. Table 2-15 lists the supported events and their labels. All event scripts start with an event label, which is then followed by one or more logic operations or ASCII commands. Once an event is triggered, if an event label is defined, control is passed over to the script engine. The script engine begins executing the commands that are listed following the event label until the end of script or until another event label is encountered.

**TABLE 2-15: LIST OF EVENTS AND EVENT LABELS**

| Event | Event Label |
|---|---|
| Power On | @PW_ON |
| Timer1 expired | @TMR1 |
| Timer2 expired | @TMR2 |
| Timer3 expired | @TMR3 |
| Connected | @CONN |
| Disconnected | @DISCON |
| PIO4 (pin 13) Input Change to Low | @PIOL |
| PIO4 (pin 13) Input Change to High | @PIOH |
| High Priority Alert | @ALERTH |
| Low Priority Alert | @ALERTL |
| Alert Off | @ALERTO |

#### 2.3.8.3 COMMENTS

The RN4020 script engine handles each script line by line. Each line can start with multiple spaces or tabs and end with a return or line feed. Even though spaces are generally not supported between ASCII commands and their parameters, which is the same as commands through the UART, spaces or tabs are supported in assignment and logic expressions, as shown in the following example.

Comment lines can be added to the script. A comment line starts with the '#' character and lasts the whole line. The script engine will ignore the comment line and jump to the next script line once a comment line is detected.

The following script line is treated as a comment:

```
# This is an example of a comment line
```

#### 2.3.8.4 VARIABLES

The RN4020 script engine defines two variables: $VAR1 and $VAR2. Variable names are case sensitive. Using the '=' operator, the value of the variables can be assigned to a constant value, or a value that is returned by an ASCII command. For instance, the following script line assigns the value 0x1234 to the variable $VAR1:

```
$VAR1 = "1234"
```

Similarly, the following script line assigns the reading of AIO1 to the variable $VAR2:

```
$VAR2 = @I,1
```

After assigning a value, variables can then be used in an ASCII command. For instance, the following ASCII command assigns the value of the variable $VAR1 to the server characteristic handle 0x0019.

```
SHW,0019,$VAR1
```

The range of variables can be defined so that if a variable value is not in the defined range, the corresponding ASCII command(s) with variables would not be executed.

The range of a variable can be a single condition, such as the following script line, which defines that the variable $VAR1 must be larger than 0x0100.

```
$VAR1 > "0100"
```

The variable range can also be defined by two conditions using the Boolean operators "&&" for logical AND, and "||" for logical OR. In the following script lines, $VAR1 is defined to be valid in the range between 0x0050 and 0x0120, while $VAR2 is defined to be either larger than 0x0100 or less than 0x0020.

```
$VAR1 > "0050" && $VAR1 < "0120"
$VAR2 > "0100" || $VAR2 < "0020"
$VAR1 = @I,0
$VAR2 = @I,1
SHW,0019,$VAR1
SHW,0021,$VAR2
```

In the first two lines of the script, the variable ranges are defined. The following two script lines read the values of analog port AIO0 and AIO1, respectively, and assigns them to the two variables. If the read of AIO0 is between the values of 0x0050 and 0x0120, the value is assigned to server characteristic handle 0x0019; otherwise, no value is assigned to the handle. Similarly, if the read of AIO1 is larger than 0x0100 or less than 0x0020, the value is assigned to server characteristic handle 0x0021; otherwise, no value is assigned to the handle.

Currently, only two single character logic operators, ">" and "<", are supported.

#### 2.3.8.4.1 Handle Association

An I/O port can be associated with the handle of a server characteristic. Once the handle receives requests from a peer device to read or write, the I/O port is read or written, respectively, without further instruction. The analog port and four digital ports can be associated with a handle. The associated handle can be identified by the proceeding identifier “%”.

For instance, the following script line associates server characteristic handle 0x0021 with a read operation of analog port AIO2, so whenever the peer device wants to read handle 0x0021, AIO2 is read and the value will be returned to the peer device.

```
%0021 = @I,2
```

The following script line associates server characteristic handle 0x0023 with a write operation of analog port AIO0, so whenever the peer device wants to write to handle 0x0023, the written value from the peer device will be used to set the output voltage on AIO0.

```
@O,0,%0023
```

In the same manner, a characteristic value can be associated with, or linked to, one or more ports using “|I” or “|O”. For example, the following command maps PIO1 and PIO7 to characteristic handle 0x0021 for reading:

```
%0021 = |I,09
```

The following command maps PIO2 and PIO3 to characteristic handle 0x0023 (hex) for writing:

```
|O,06,%0023
```

**NOTICE**

**Association with digital I/O ports can be either read and/or write; however, a read or write association can only be done once. A subsequent read association will overwrite the previous read. The same rule applies to write association, but a read association does not overwrite a write association.**

### 2.3.8.5 REMOTE FUNCTION CALL

RN4020 Firmware Version 1.20 supports an association between a characteristic handle and a user-defined function in a script.

#### 2.3.8.5.1 Function Definitions

RN4020 Firmware Version 1.20 supports three custom functions. These functions are defined as `?FUNC1`, `?FUNC2` and `?FUNC3`. Each function can be associated with a write operation of a characteristic handle using the following syntax:

```
%handle = ?FUNCx
```

As an example, the following line in a script associates the write operation of handle 0x0018 to the function `?FUNC2`:

```
%0018 = ?FUNC2
```

The characteristic (most likely a private characteristic) of the handle must have the property of Write or Write_CMD. If the function expects a return value, such a characteristic must have the property of Read or Notify. The data size of the character should be the higher of the input parameter or return value. For simplicity, we can just assign the maximum data size to be 20 when defining such a private characteristic.

One or more ASCII commands can be executed within the function until reaching the next function definition or next event. The function body format is the same as an event, with the exception of the following differences.

#### 2.3.8.5.2 Parameters of Function

New Variables $PM1, $PM2, $PM3, $PM4, and $PM5 have been defined to pass input parameters to the function. A remote peer could write an ASCII value of the handle that associates with the function in the following format:

```
<Parameter1>,<Parameter2>…
```

The parameters are in ASCII format in 1, 2, or 4 characters to specify up to a 16-bit hex value. If the function does not expect any parameters, the user is free to write any dummy value to the handle to start the function. Up to 5 input parameters in total length (including separating commas) up to 20 characters are supported.

For example, the following ASCII value written to handle 0x0018 passes input parameters to function `?FUNC2`:

```
1234,0,56
```

When function `?FUNC2` is called after the written operation to handle %0018, variables are assigned as follows:

```
$PM1:1234
$PM2:0
$PM3:56
```

All parameters could be used in ASCII commands as input parameters.

If a function returns a value, either the command SHW (recommended), or the command SUW could be used to set the return value to the same handle. Notice that the input parameter is in ASCII format, while the return value is in binary format.

Example 2-3 shows how to use functions to read an EEPROM through I$^2$C.

**EXAMPLE 2-3: FUNCTION EXAMPLE**

```
@PW_ON
# handle associates with function
%0018 = ?FUNC1

?FUNC1
# enable I2C, powered by PIO2
]A,4,2
# read EEPROM, assign to $VAR1
$VAR1 = ]ER,$PM1,$PM2,$PM3
# disable I2C
]Z
# assign return value
SHW,0018,$VAR1
```

From the remote peer, the following ASCII value is written to handle 0x0018:

```
0050,0010,06
```

or, in hex format:

```
303035302C303031302C3036
```

If a private characteristic is configured to be able to notify and the peer has started notification, the return value will be sent to the peer automatically. Otherwise, the peer needs to read the same handle to get the return value.

### 2.3.9 RN4020 Script Commands

The following ASCII commands over the UART were developed to support the scripting functionality on the RN4020 module.

## LW

### Description

The "LW" command lists the current script that is loaded in the RN4020 module. After all script lines are output, the string "END" will be output to the UART.

### Default

The "LW" command has no parameters.

### Example

```
LW        // List the complete script loaded in the RN4020 module
```

## WC

### Description

The "WC" command clears the script, if any, that is loaded in the RN4020.

### Default

The "WC" command has no parameters.

### Example

```
WC        // Clear the script loaded in the RN4020 module
```

## WP

### Description

The "WP" command stops script execution.

### Default

The "WP" command has no parameters.

### Example

```
WP        // Stop running the script
```

## WR,<0-9>

### Description

The "WR" command starts script execution. If no parameter is provided, the script runs normally by starting a @PW_ON event. When a parameter in the range of 0 to 9 is provided, the script starts running the corresponding event in Debugging mode. When the script is running Debugging mode, all variables assigned and any ASCII commands executed would be output to the UART for debugging purposes by the developer.

The input parameters and their associated events are listed in Table 2-16.

To minimize power consumption, the UART output is disabled when running a script. Use the "SR,00001000" command to override UART mute when running a script.

**TABLE 2-16: "WR" COMMAND INPUT PARAMETERS AND ASSOCIATED EVENTS**

| Input Parameter | Event |
|---|---|
| 0 | @PW_ON |
| 1 | @TMR1 |
| 2 | @TMR2 |
| 3 | @CONN |
| 4 | @DISCON |
| 5 | @PIOL |
| 6 | @PIOH |
| 7 | @ALERTH |
| 8 | @ALERTL |
| 9 | @ALERTO |

### Default

Not applicable.

### Example

```
WR,1          // Starts script by entering @TMR1 event
```

## WW

The "WW" command enters Script Input mode. When in Script Input mode, the script can be input through the UART line by line terminated by either a Carriage Return (\r) or a Line Feed (\n). Once all script lines are input, press the "ESC" (\x1b) key to exit Script Input. The "END" status message is returned to indicated Script Input is completed and Command mode is resumed.

### Default

The "WW" command has no parameters.

### Example

```
WW        // Enter script input mode
```

### 2.3.10 Remote Command

The RN4020 module has the capability of executing an ASCII command remotely from connected devices. This remote command feature is built on top of MLDP, so it is a prerequisite to support MLDP before using the remote command feature.

The remote command feature enables users to execute commands on connected peer devices. The command is sent to the connected remote device, executed at the remote device, and the result is sent back to the local device. Since the UART output rate is usually much higher than the BLE transmission rate, if the output data (such as the “H” or “LS” command, etc.) exceeds the buffer size (128 bytes), the local device may only receive whatever is stored in the buffer.

The remote command capability provides a mechanism for another Bluetooth device running in Central mode to send commands to a remote RN4020 module in Peripheral mode. A host device can use a remote command to gain access to the remote device and access and control all of its analog or digital I/O ports. All application logic is performed on the host device. Therefore, no programming or application logic needs to be run on the remote device. To summarize, the remote command function allows the central host to connect to any RN4020 peripheral device and invoke commands.

## `!,<0,1>`

### Description

The “!” command enables the remote command feature. This command is only effective under the following three conditions:

- The local and remote devices both support the MLDP feature
- The Enable Remote Command bit of the remote device was set using the “SR” command
- The two devices are connected

The “!” command expects one parameter, either ‘1’ or ‘0’.

If the input parameter is ‘1’, the Remote Command mode is enabled, the device enters Remote Command mode automatically, and the message “RMT_CMD” is sent from the remote device to indicate the start of the remote command session.

To exit Remote Command mode, the local device sets the CMD/MLDP pin low, and then issues the command “!,0”. The remote device will then exit Remote Command mode and return to local command mode.

## 2.4 SUMMARY OF RN4020 UART OUTPUTS

The RN4020 uses its UART module as the primary control interface to interact with the Host controller. The Host controller can send ASCII commands to the RN4020 module to operate the Bluetooth Low Energy (BLE) module. RN4020 ASCII commands that are available to the Host controller are documented in **Section 2.3 “RN4020 UART-ASCII Command and Responses”**. This section describes UART communications from the RN4020 module to the Host controller.

The RN4020 module will respond to all ASCII commands from the Host controller. The Host controller should wait until responses are received before issuing the next set of ASCII commands. Except as described in the following paragraphs, the RN4020 module responds to the ASCII commands with the status, either success or failure.

Other than the following commands, if ASCII commands are received and parsed successfully, the status “AOK” will be sent by the RN4020 module. Conversely, if there is an issue for any ASCII command, the status “ERR” will be sent. The possible reasons for ASCII command failure may be due to the following:

- The ASCII command does not exist
- The ASCII command is not allowed within the current configuration. For example, if a device is set as a peripheral, the command “E” for establishing connection will return “ERR”
- The ASCII command is not allowed within the current state. For example, if a peripheral is already advertising, issuing the command “A” to start advertisement will return “ERR”
- The ASCII command has an invalid input parameter. For example, if the command expects a 16-bit parameter, but an 8-bit parameter is provided; if the ASCII command expects two parameters, but only one parameter is provided; or the parameter is not within the valid range

All ASCII commands that do not respond with the status “AOK” are described in the following sections.

### 2.4.1 ASCII Commands with Non-Standard Response

When there are errors, all ASCII commands respond with the status “ERR”. When ASCII commands are valid and are executed successfully, some ASCII commands may have a response other than the standard “AOK” response. Table 2-17 shows the expected response for those ASCII commands with a non-standard response.

TABLE 2-17: NON-STANDARD RESPONSE FOR ASCII COMMANDS

| Command | UART Response Description |
|---|---|
| `GB` | Single digit number that indicates the current baud rate setting. See Table 2-5 for information. |
| `GE` | Single digit number that indicates the current security setting for the MLDP connection. |
| `GDF` | ASCII string of the firmware version in Device Info Service. |
| `GDH` | ASCII string of the hardware version in Device Info Service. |
| `GDM` | ASCII string of the model number in Device Info Service. |
| `GDN` | ASCII string of the manufacture name in Device Info Service. |
| `GDR` | ASCII string of the software version in Device Info Service. |
| `GDS` | ASCII string of the serial number in Device Info Service. |
| `GM,<1-3>` | Current Timer (1-3) expiration setting in 32-bit hex format. The output is the total expiration time that does not change with time. The expiration time resets to ‘0’ after the timer expires. |
| `GN` | ASCII string of the device name. |
| `GP` | Returns the current transmit power level as set by the “SP” command. |
| `GR` | 32-bit hex value that represents RN4020 feature settings. See Table 2-7 for information. |
| `GS` | 32-bit hex value that represents supported server services. See Table 2-8 for information. |
| `GT` | Three 16-bit hex values, separated by a comma, which, in order, represent connection interval, slave latency, and supervision timeout. See Table 2-9 for information. |
| `+` | Toggle echo by outputting either “Echo On” or “Echo Off”. |
| `@I,<0-2>` | 16-bit hex value of analog port (0-2) reading in mV. |
| `\|I,<hex8>` | 8-bit hex value of bitmap that indicates high or low of digital port inputs. See Table 2-10 for information. |
| `B` | Normal “AOK” status will be output to indicate that the command was accepted. Bonding status will be output later as either “Bonded” when bonding for the first time or “Secured” for reconnection. |
| `D` | Dump the main settings of the RN4020: Device MAC address, Device Name, Device GAP Role, Connected Device, Bonded Device and Server Services. |
| `E` | If the MAC address is provided, the standard “AOK” status will be output first to accept the command. Connection status will be output later as “Connected” after service discovery. If reconnecting to a bonded device without providing the MAC address, no “AOK” status is output before the “Connected” status output after service discovery. |

TABLE 2-17: NON-STANDARD RESPONSE FOR ASCII COMMANDS

| Command | UART Response Description |
|---|---|
| F | Standard "AOK" will be output to accept the command.<br>If the RN4020 module is in the Peripheral role, when a new device found, it will output to the UART. Every new device starts a new line. Several parameters will be output and each item is separated by a comma. For example:<br>`<48bit MAC Address>,<1bit Address Type>,<Optional Device Name>,<Optional UUIDs>,<negative 8bit RSSI value>`<br>If the RN4020 module is in the Observer role, when a broadcast message is received, it will output the message to the UART. Every new message starts a new line with the following format:<br>`<48bit MAC address>,<1bit Address Type>,<8bit RSSI value>,Brcst:<broadcast message>` |
| H | Output the help page (not applicable for Firmware Version 1.20 or later). |
| K | Output "Connection End" once disconnected. |
| M | Negative 8-bit hex that indicates signal strength in dBm. |
| Q | "No Connection" or "<BT Addresss>,<0-1>". |
| Q,1 | "No Bonding" or "<BT Addresss>,<0-1>". |
| R,1 | Output "Reboot" before rebooting. |
| T | If the connection parameter update is not successful, message "PERR" will be sent to UART; otherwise, "AOK" will be sent. |
| V | Display the ASCII string of current firmware version. |
| LC | List client side services and their characteristics. See Example 2-2 for the output format. "END" is attached to the end of the list in a separate line. |
| LS | List server side services and their characteristics. The output format is very similar to that of the command "LC". The property item in the list is replaced by the letter "V" for the value handle or the letter "C" for the configuration handle. "END" is attached to the end of the list in a separate line. |
| CHR | Upon successful reading of the handle value from the server, the value is sent to the UART, starting with the letter "R", followed by a comma, and then the characteristic value in little-endian format. For example:<br>`R,3412       // return characteristic value 0x1234`<br>Finally, "AOK" is output for a successful read. If the read was not successful, the following message appears: `Err(<16bit error code>)` |
| CURC | Upon a successful read of the characteristic configuration from the server, the value is sent to the UART, starting with the letter "R", followed by comma, and then the characteristic value in little-endian format. For example:<br>`R,3412       // return characteristic value 0x1234`<br>Finally, "AOK" is output for a successful read. If the read was not successful, the following message appears: `Err(<16bit error code>)` |
| CURV | Upon successful reading of characteristic value from the server, the value is sent to the UART, starting with the letter "R", followed by a comma, and then the characteristic value in little endian format.<br>`R,3412       // return characteristic value 0x1234`<br>Finally, "AOK" is output for successful read. If the read was not successful, the following message appears: `Err(<16bit error code>)` |

TABLE 2-17: NON-STANDARD RESPONSE FOR ASCII COMMANDS

| Command | UART Response Description |
|---|---|
| `CUWC` | Upon a successful write of the new configuration to the characteristic configuration, a normal "AOK" message will be returned. If the server already has data set for the characteristic, a notification or indication will be displayed in the following format:<br>`Notify,<16bit handle>,<characteristic value in little endian>`<br>`Indicate,<16bit handle>,<characteristic value in little endian>`<br>If the write is not successful, the following message will appear:<br>`Err(<16bit error code>).` |
| `SHR` | Upon a successful read of the value via the handle from the server, the value is sent directly to the UART in little-endian format. |
| `SUR` | Upon a successful read of the value via the UUID from the server, the value is sent directly to the UART in little-endian format. |
| `I` | Upon successfully entering MLDP mode by issuing the command "I", the string "MLDP" will be output to the UART, unless the "MLDP without Status" bit is set. Refer to Table 2-3 for information. |
| `LW` | The "LW" command will output the current script stored in the RN4020 module. At the end of the script, the string "END" will be output in a separate line. |
| `WW` | The command "WW" will return the standard "AOK" message. However, any additional input from the UART will be treated as a script and stored in the NVM of the RN4020 module. After script entering is complete, pressing the <ESC> key triggers a send of the string "END" to indicate the end of the script input. |
| `!` | When the command "!" has an input parameter of 1, the string "RMT_CMD" will be sent to the UART to indicate the start of the Remote Command mode. |
| `~` | When the command "~" has an input parameter of 1, the string "DFU" indicates the start of the Device Firmware Upgrade (DFU) process. When the input parameter is 2, the string "OTA" indicates the start of the Over-The-Air DFU process.<br>Upon a successful upgrade, the message "Upgrade OK" will be sent to the UART and RN4020 module reboots; otherwise, the message "Upgrade Err" will be sent. |

### 2.4.2 UART Response to PIO Switches

The RN4020 has four optional digital input pins. The RN4020 may respond to the voltage change to those pins. Table 2-18 provides the UART response to PIO events.

TABLE 2-18: UART RESPONSE TO PIO EVENTS

| PIO Pins | Description of UART Response |
|---|---|
| WAKE_SW<br>(SWAKE) | The rising edge of the signal on the pin triggers UART output “CMD” and indicates the UART is ready to receive ASCII commands.<br>The falling edge of the pin triggered UART output “END” and indicates the UART is turned OFF for input. |
| CMD/MLDP | The rising edge of the signal on the pin triggered UART output “MLDP” to enter MLDP mode.<br>The falling edge of the pin triggered the UART to output “CMD” to return to Command Input mode. |
| WAKE_HW<br>(BT_WAKE) | When the RN4020 module is in Dormant mode, the rising edge of the signal on the pin wakes the RN4020 module. No UART output is triggered. |
| PIO4 | The rising edge of the signal on the pin triggers event @PIOH.<br>The falling edge of the signal on the pin triggers event @PIOL. No UART output is triggered. |

### 2.4.3 UART Notifications

When the RN4020 has a status to report or requests data from the host MCU, a message will be sent through the UART interface. Table 2-19 lists UART notifications under various circumstances.

TABLE 2-19: UART NOTIFICATION

| UART Notification | Conditions |
|---|---|
| AOK<br>NFail | When a server characteristic value is set, if notification/indication has been supported and started on such characteristic, in addition to the “AOK” message of characteristic setting commands such as “SHW” or “SUW”, if sending of notification/indication is successful, message “AOK” will be sent; otherwise, message “NFail” will be sent. |
| WV,<hex16>,<various> | When connected, if the other end writes a value to the local server characteristic, message “WV” is output to the UART. The “WV” message has two parameters. The first parameter is the 16-bit handle of the server characteristic; the second parameter is the value that has been written to the characteristic. |
| WC,<hex16>,<hex16> | When connected, if the other end writes a configuration to the local server characteristic to start/stop notification/indication, message “WC” is output to the UART. The “WC” message has two parameters. The first parameter is the 16-bit handle of the configuration for the server characteristic; the second parameter is the new configuration of the characteristic:<br>0000: Stop notification/indication<br>0100: Start notification<br>0200: Start indication |
| RV,<hex16>. | When connected, if the “Real-time Read” bit is set in command “SR” (see Table 2-7 for bitmap features), message “RV” is sent to the UART to notify the host MCU to update the value of the server characteristic. Message “RV” has one parameter, which is the 16-bit handle of the server characteristic. The host MCU is supposed to respond by setting the value of server characteristic with a command such as “SUW” or “SHW”. |

**TABLE 2-19: UART NOTIFICATION (CONTINUED)**

| UART Notification | Conditions |
|---|---|
| `Notify,<hex16>,<various>`<br>`Indicate,<hex16>,<various>` | When connected, if the peer device in the GATT server role sends a notification or indication, message “Notify” or “Indicate” will be output to the UART. Two parameters are expected. The first parameter is the 16-bit handle of the characteristic; the second parameter is the new value of the characteristic. |
| `Passcode:` | When authentication is enabled by setting the “Enable Authentication” bit in the “SR” command, and “I/O Capabilities” bits are set to support the keyboard (see Table 2-7 for bitmap features), during the authentication process, message “Passcode:” is sent to the UART to wait for input of the passcode. Usually under such setting, the peer device should have display capability and show a six digit passcode. The six digit ASCII passcode should then input through the UART to finish the authentication process. |
| `Peer Passcode:<6 digit passcode>` | When authentication is enabled by setting the “Enable Authentication” bit in the “SR” command, and “I/O Capabilities” bits are set to support “Display” but not “Display Yes/No” (see Table 2-7 for bitmap features), during the authentication process, message “Peer Passcode:” is sent to the UART followed by a random six digit pass code. The passcode needs to be displayed and the peer device is expected to enter the same six digit passcode to finish the authentication process. |
| `ConnParam:<hex16>,<hex16>,<hex16>` | When connected and connection parameters are updated by the peer device, message “ConnParam” is sent to the UART. Message “ConnParam” has three 16-bit parameters, which are connection interval, slave latency and supervision timeout respectively. |

## 2.5 DEVICE FIRMWARE UPGRADE

The Device Firmware Upgrade (DFU) feature allows the RN4020 module to upgrade its firmware in the field. As with any DFU process, a firmware upgrade should be handled carefully to avoid unrecoverable damage to the device.

The RN4020 module supports two methods for performing a DFU:

- A wired solution through the UART
- A wireless solution Over-the-Air (OTA)

Both solutions provide firmware integrity support. If an upgrade fails for any reason, keep the RN4020 module alive and try to recover by applying the DFU process again.

The following conditions must be met when the RN4020 module performs a DFU through the UART:

- UART hardware flow control (RTS/CTS) must be used
- No UART communication other than streaming the DFU image
- No RF communication attempts. All other operations during a DFU period should be avoided

The following conditions must be met when the RN4020 performs DFU through OTA:

- Only a one-to-one connection is allowed between the device whose firmware is to be updated and the device that provides the update image
- Avoid RF interference whenever possible
- The module that is streaming the image to the remote device must have UART hardware flow control enabled

See **Section 2.5.1 "DFU Commands"** for a description of the actions that occur during a DFU.

### 2.5.1 DFU Commands

#### `~,<1,2>`

#### Description

The "~" command places the device into Device Firmware Service mode. To use this command, it is mandatory to enable the UART flow control. The "~" command expects one input parameter.

If the input parameter is '1', DFU mode is set for the upgrade to be handled through the UART. The message "DFU" will be output and the RN4020 module waits for the DFU image to be sent through the UART. The user must then stream the signed Microchip RN4020 image to the UART. If a terminal emulator is used, it is recommended to use a feature such as "send file" or something similar.

If the input parameter is '2', DFU mode is set for the upgrade to occur OTA. A valid BLE connection must be established before the command "~,2" can be issued from the device that will send the DFU image. Both ends of the connection must support MLDP, and ENABLE OTA must be set by the "SR" command.

Once both devices enter OTA mode, the message "OTA" is sent to the UART of the device that is to send the DFU image. The device sending the DFU image can then begin streaming the valid and signed Microchip RN4020 image. If a terminal emulator is used, it is recommended to use the "send file" feature to upload the DFU image. Visit http://www.microchip.com/RN4020 for the latest DFU images.

Once the DFU has completed and is verified as successful, the message "`Upgrade OK`" is displayed and the RN4020 module reboots to use the new firmware. If the DFU is not successful, the message "`Upgrade Err`" is displayed and both RN4020 modules remain in OTA mode. Users should NOT reset or power down either module, but instead try to stream the valid and signed Microchip RN4020 image again until the upgrade is successful.

NOTES:

# Chapter 3. Application Examples

This chapter provides application examples for the RN4020 module. The following topics are included:

- Demonstration with a Smart Device
- Connecting Two RN4020 Modules
- MLDP Demonstration
- RN4020 Scripting Demonstration

The Bluetooth Low Energy capabilities of the RN4020 module can be demonstrated either between the RN4020 and a third-party Bluetooth Smart/Smart Ready device (such as a smartphone or tablet), or between two RN4020 modules.

## 3.1 DEMONSTRATION WITH A SMART DEVICE

In this section, a step-by-step procedure is detailed which demonstrates how the RN4020 module can interface with a smartphone or tablet device. To support BTLE, the following hardware and software are required:

- Bluetooth Low Energy enabled smart phone or tablet
- Bluetooth Low Energy Browser APP - BTLE BROWSER APP (see the **Note**)
- Terminal emulator connected to the RN4020 UART for access to the command interface

> **Note:** The following diagrams show a generic version Smartphone BTLE Service Browser APP, which is referred to as the BTLE BROWSER APP.

### 3.1.1 Setup

Before connecting an RN4020 module to a smartphone device, users may need to set up the RN4020 module as follows:

1. Set the WAKE_SW pin high to enter Command mode.
2. Open a terminal emulator that connects to the serial port of the RN4020 module with the following parameters:
   - Baud rate: 115200
   - Data bits: 8
   - Parity: None
   - Stop bits: 1
3. Issue the "+" command to turn on echo.
4. Issue the command `SF,1` to reset to the factory default configuration.
5. Issue the command `SS,C0000000` to enable support of the Device Information and Battery services.
6. Issue the command `SR,00000000` to set the RN4020 module as a peripheral.
7. Issue the command `R,1` to reboot the RN4020 module and to make the new settings effective.

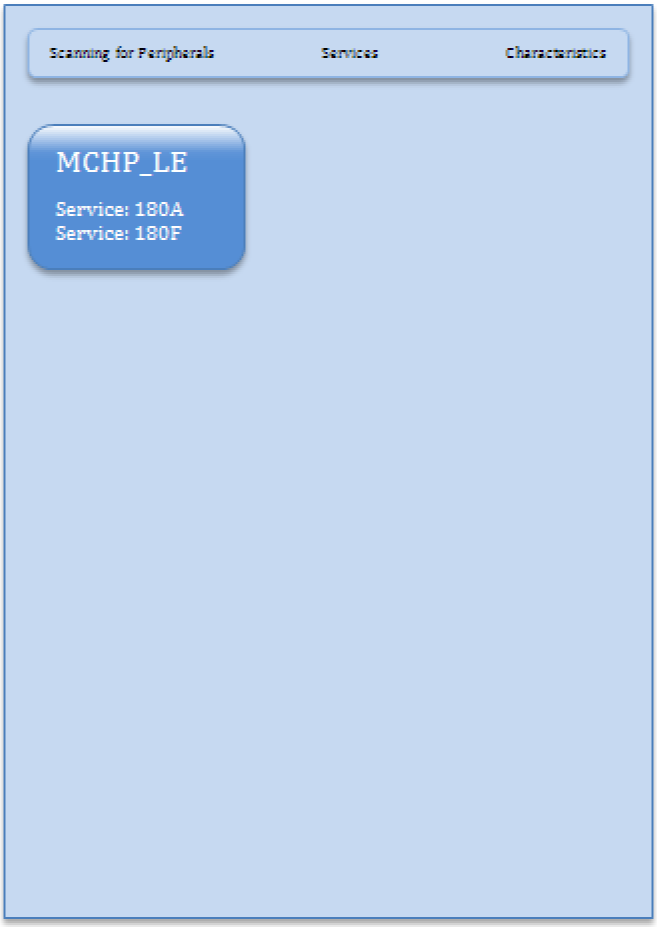
8. After the RN4020 module has powered up and "CMD" is displayed on the terminal emulator, issue the "LS" command to display the current services that the RN4020 module enumerates and supports in the server role. The output of the "LS" command will be as follows:

```
180A
  2A25,000B,V
  2A27,000D,V
  2A26,000F,V
  2A28,0011,V
  2A29,0013,V
  2A24,0015,V
180F
  2A19,0018,V
  2A19,0019,C
END
```

### 3.1.2 Running the Demonstration

1. On the terminal emulator, enter the "A" command to start advertisement.
2. Launch your BTLE BROWSER APP.
3. Configure the BTLE BROWSER APP to be the "Central" device and start active scan for BTLE peripherals. After the scan is completed, the RN4020 module will be listed as "RN4020-xxxx", where "xxxx" is the first two bytes of the Bluetooth device address. The RN4020 module is now ready to be connected.

**FIGURE 3-1: DISCOVERING THE RN4020 MODULE**

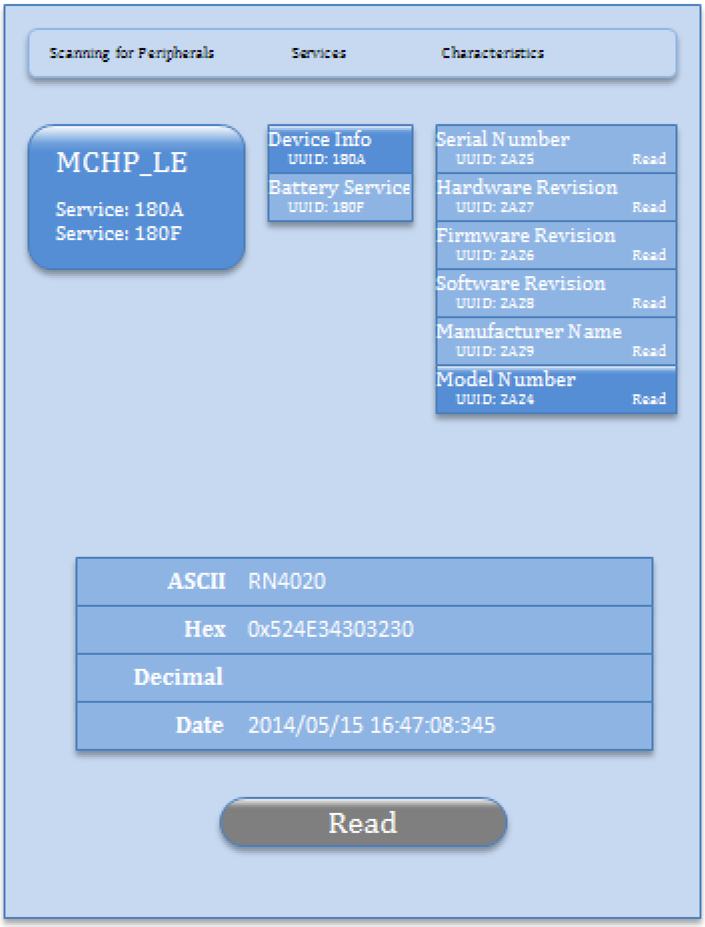


MCHP_LE

Service: 180A
Service: 180F

4. From BTLE BROWSER APP, issue the command to connect to the RN4020. The BTLE BROWSER APP will list the handle of the services, service “180A” and “180F”, and the UUIDs of the Device Information and Battery Services, respectively, will be seen.
5. Opening the service “180A” will display six additional UUIDs for the characteristics of the Device Information service. Access each of the six characteristic UUIDs to display the characteristic window. Invoke the read command in the BTLE BROWSER APP to read the current settings of those characteristics. Figure 3-2 shows an example of the application displaying the Model Number String of RN4020 in the Device Information Service.

**FIGURE 3-2: READING THE MODEL NUMBER STRING FROM THE DEVICE INFORMATION SERVICE**



| | |
|---|---|
| ASCII | RN4020 |
| Hex | 0x524E34303230 |
| Decimal | |
| Date | 2014/05/15 16:47:08:345 |

6. Read UUID “180F” to show one characteristic Battery Level with UUID “2A19”. Reading the “2A19” characteristic shows this characteristic’s property: readable and notification can be started.

7. Return to the terminal emulator to control the RN4020 directly to set the Battery Level to 99% using either of the following two commands:

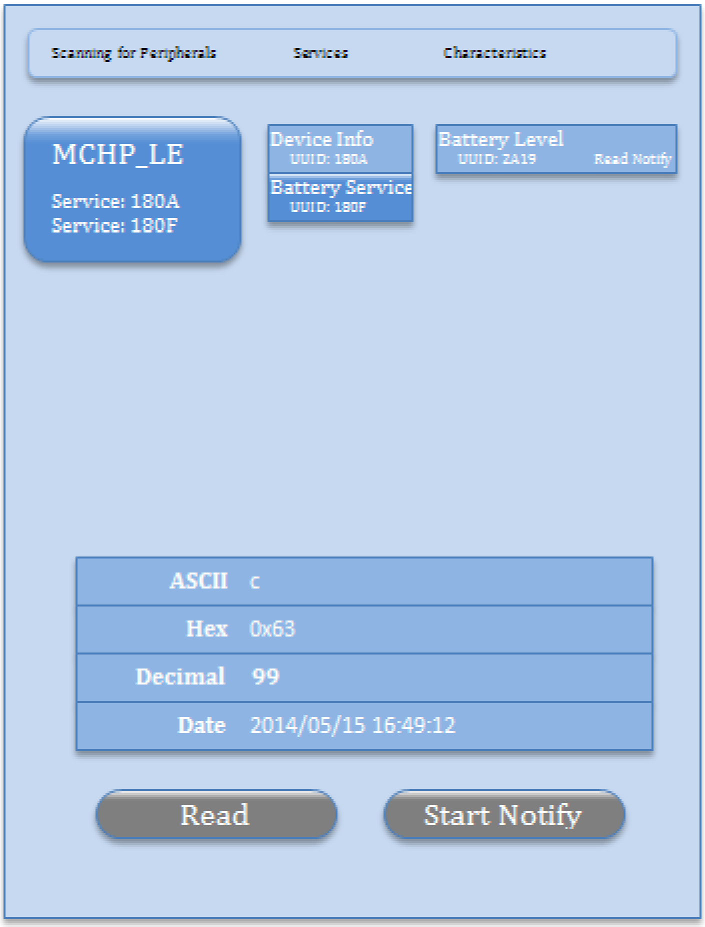
   ```
   SUW,2A19,63
   SHW,0018,63
   ```

   The first command sets the value of characteristic Battery Level to be 99 (0x63) by addressing its UUID 0x2A19.

   The second command sets the value of characteristic Battery Level to be 99 (0x63) by addressing its handle 0x0018. The match between handle and UUID can be found by command “LS”. The handle value for each characteristic stays the same for the same set of server service settings. As long as the supported server services are not changed by command “SS”, the handles of the characteristics stay the same.

8. Read the characteristic identified by UUID 0x2A19. The returned value will show 63 in hexadecimal and 99 in decimal, as shown in Figure 3-3.

**FIGURE 3-3: READING BATTERY LEVEL IN BATTERY SERVICE**



ASCII c

Hex 0x63

Decimal 99

Date 2014/05/15 16:49:12

The application can also start notification on the Battery Level characteristic by tapping the “Start Notify” button. On the RN4020 side, a notification will output to the screen and display as follows:

```
WC,0019,0100
```

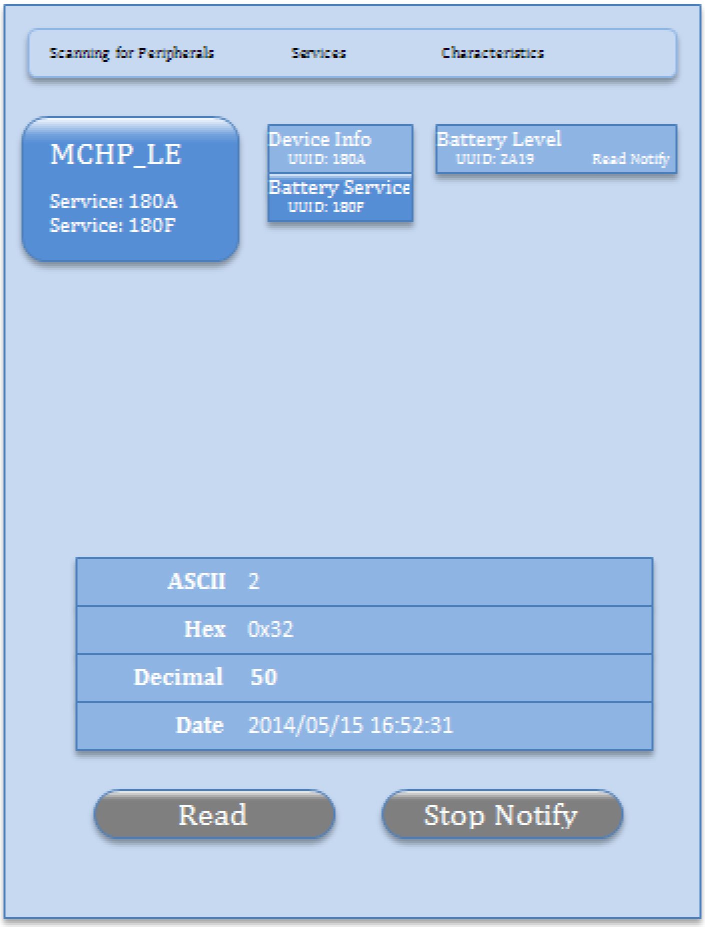
This output means the application tried to write the two byte value, 0x0001 (little endian over air makes it 0100), to the configuration handle of the Battery Level characteristic with the UUID 0x2A19 in the Battery Service with the UUID 0x180F, effectively enabling notification for this characteristic. Refer to *Table 3.11: "Client Characteristic Configuration bit field definition"* in *Volume 3, Part G, Section 3.3.3.3 "Client Characteristic Configuration"* of *"Bluetooth Core Specification v4.1"*, for details.

9. Update the battery level to 50% on the RN4020 module by entering either of the following two commands:

```
SUW,2A19,32
SHW,0018,32
```

After issuing either of the two commands, users will see that the characteristic value of UUID 2A19 in the BTLE BROWSER APP automatically updates to 0x32 (50 decimal). This is because with an active notification, any update to the value of a characteristic on the server side will be notified to the client side. See Figure 3-4 for an example.

**FIGURE 3-4: NOTIFICATION RESULT OF BATTERY LEVEL**



ASCII 2

Hex 0x32

Decimal 50

Date 2014/05/15 16:52:31

If desired, the private services that can be defined by the user on the RN4020 module can be tested. The command procedures and their descriptions are shown in Example 3-1.

**EXAMPLE 3-1: USER-DEFINED PRIVATE SERVICES**

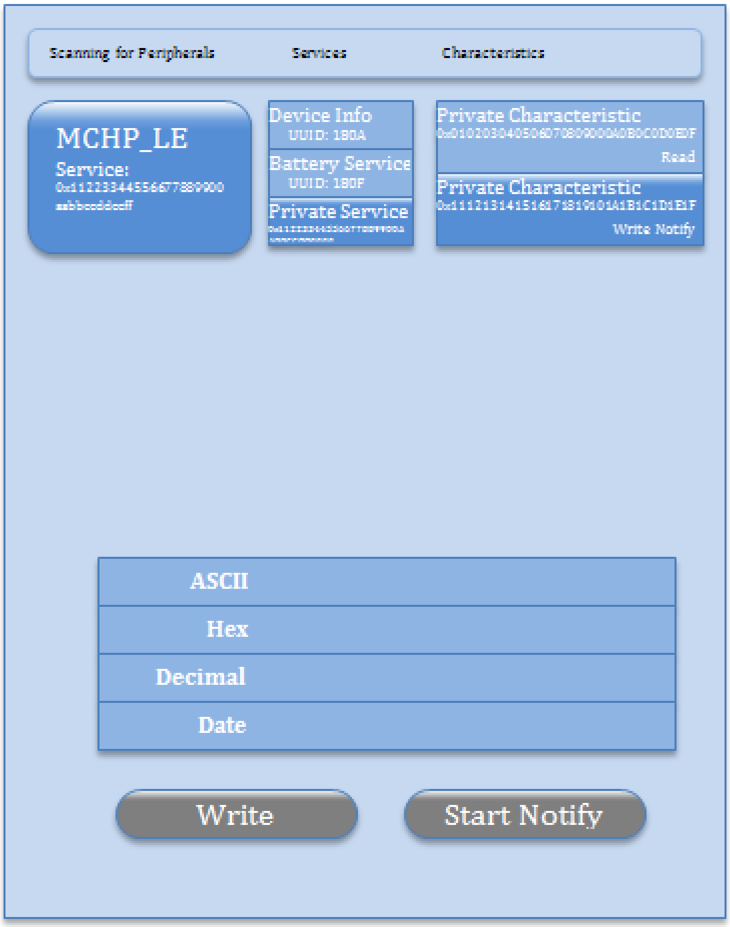
```
SS,C0000001   //Enable private service support
PZ            // Clear the current private service and characteristics
PS,11223344556677889900AABBCCDDEEFF
// Set private service UUID to be 0x11223344556677889900AABBCCDDEEFF

PC,010203040506070809000A0B0C0D0E0F,02,05
// Add private characteristic 0x010203040506070809000A0B0C0D0E0F to
// current private service. The property of this characteristic is 0x02
// (readable; see Table 1-1) and has a maximum data size of 5 bytes

PC,111213141516171819101A1B1C1D1E1F,18,02
// Add private characteristic 0x111213141516171819101A1B1C1D1E1F to
// current private service. The property of this characteristic is 0x18 (writable
// and could notify; see Table 1-1) and has a maximum data size of 2 bytes.

U             // Unbond to make device discoverable
R,1           // Reboot RN4020 to make the changes effective
+             // Enable echo
LS            // list the services on server side. Private service and
              // characteristics could be found in the list
```

The following results will be returned for the server services:

```
180A
  2A25,000B,V
  2A27,000D,V
  2A26,000F,V
  2A28,0011,V
  2A29,0013,V
  2A24,0015,V
180F
  2A19,0018,V
  2A19,0019,C
11223344556677889900AABBCCDDEEFF
  010203040506070809000A0B0C0D0E0F,001C,02,05
  111213141516171819101A1B1C1D1E1F,001E,08,02
  111213141516171819101A1B1C1D1E1F,001F,10,02
END
```

Since the service settings were changed, but the previous settings are still in the smartphone/tablet’s cache, rebooting the smartphone/tablet device may be necessary to clear the device cache. After power cycling and launching the BTLE BROWSER APP, the private service and characteristics will be seen. Figure 3-5 shows that the BTLE BROWSER APP has discovered the private services that were just defined.

FIGURE 3-5: PRIVATE SERVICES DISCOVERED AFTER POWER CYCLE

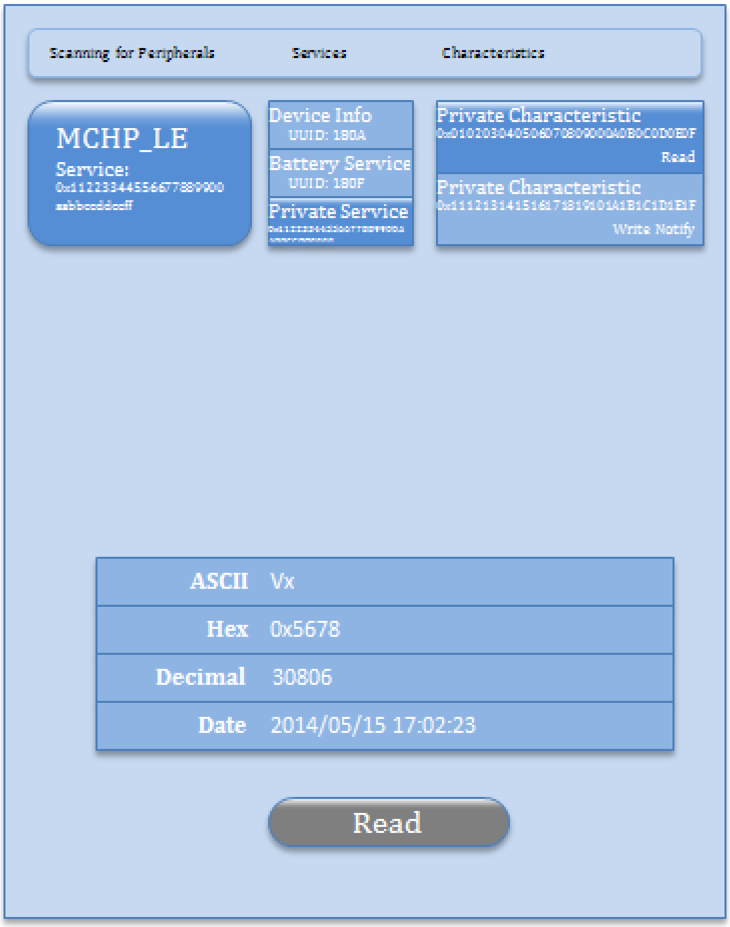


Just as with public services, such as Device Information and Battery service, these characteristics can read, write and get notification by issuing commands as follows:

```
SUW,0102030405060708090000A0B0C0D0E0F,1234
// Set value 0x3412 to characteristic
// 0x0102030405060708090000A0B0C0D0E0F

SHW,001C,5678
// Set value 0x7856 to handle 0x001C, which is associated
// with characteristic 0x0102030405060708090000A0B0C0D0E0F
```

The application can then read the value of characteristic 0x0102030405060708090000A0B0C0D0E0F, as shown in Figure 3-6.

**FIGURE 3-6: READING THE PRIVATE CHARACTERISTIC**



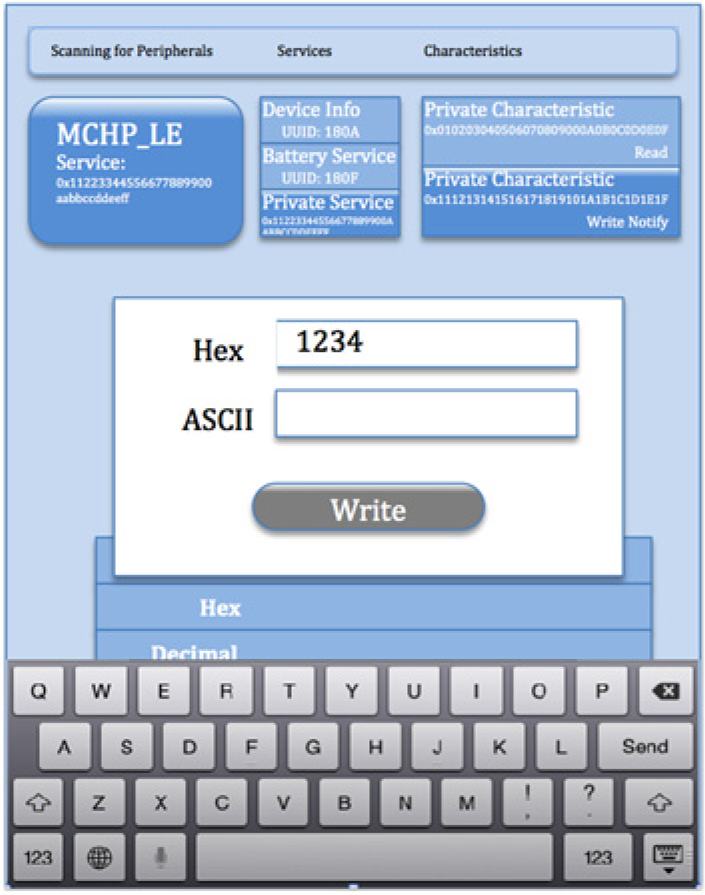
| | |
|---|---|
| **ASCII** | Vx |
| **Hex** | 0x5678 |
| **Decimal** | 30806 |
| **Date** | 2014/05/15 17:02:23 |

The BTLE BROWSER APP can also write or start notification on characteristic 0x111213141516171819101A1B1C1D1E1F. The effect is the same as operating on a public characteristic. The only difference to the RN4020 module is that the public characteristic has a short 16-bit UUID, while the private characteristic has a long 16-byte UUID.

Figure 3-7 shows writing the value 0x3412 (little endian) to the private characteristic 0x111213141516171819101A1B1C1D1E1F from the application. On the terminal emulator of the RN4020 module, the following status message will appear, which means the value of characteristic 0x111213141516171819101A1B1C1D1E1F (with handle 0x001E) has been written as 0x3412 (little endian).

```
WV,001E,1234
```

**FIGURE 3-7: WRITING VALUES TO PRIVATE CHARACTERISTICS**



Hex 1234

Notification on a private characteristic can also be enabled. The RN4020 module will notify the host of the start of notification by the following status message, which means the configuration of characteristic 0x111213141516171819101A1B1C1D1E1F has been written as 0x0001 (little endian); therefore, the notification has been started.

```
WC,001F,0100
```

Once the notification has been started, the value of the private characteristic is updated from the RN4020 module, and the updated value is displayed in the BTLE BROWSER APP.

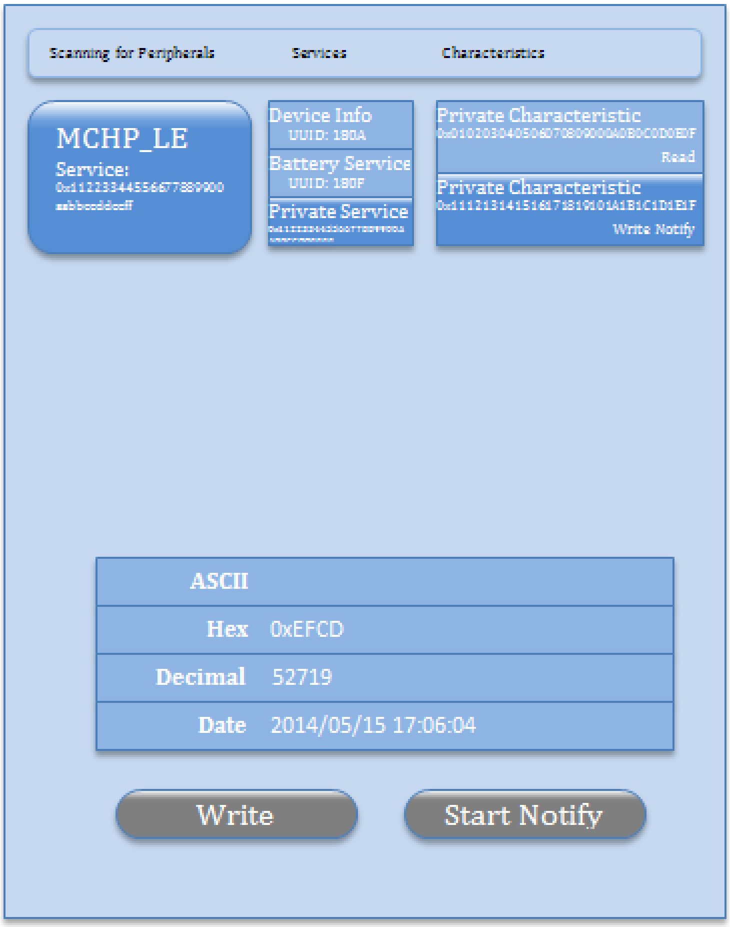
Use the following commands to update the value of the private characteristic:

```
SUW, 111213141516171819101A1B1C1D1E1F,AB90
// Set value 0x90AB to characteristic
// 0x111213141516171819101A1B1C1D1E1F
```

```
SHW,001E,EFCD
// Set value 0xCDEF to handle 0x001E, which is associated
// with characteristic 0x111213141516171819101A1B1C1D1E1F
```

The value of the private characteristic 0x111213141516171819101A1B1C1D1E1F will be updated automatically to 0x90AB and 0xCDEF, respectively, as shown in Figure 3-8.

**FIGURE 3-8: NOTIFICATION TO PRIVATE CHARACTERISTIC**



| | |
|---|---|
| **ASCII** | |
| **Hex** | 0xEFCD |
| **Decimal** | 52719 |
| **Date** | 2014/05/15 17:06:04 |

## 3.2 CONNECTING TWO RN4020 MODULES

BTLE functionality can be demonstrated between two RN4020 modules.

> **Note:** In this demonstration, one RN4020 module must act in a central role and the other in a peripheral role. In addition, the services as server and client roles will also be demonstrated.

To demonstrate module-to-module connectivity, two RN4020 modules are required. For this demonstration, the RN4020 Bluetooth Low Energy PICtail™/PICtail Plus Daughter Board is recommended.

### 3.2.1 Configure the First Device (Module A)

The first RN4020 module, which is referred to as Module A, must be configured to be in a central role. The following commands are issued to configure the device:

1. Pull WAKE_SW high to enter Command mode. On the daughter board, this is the default state.
2. Open a terminal emulator that connects to the serial port of Module A with the following parameters:
   - Baud rate: 115200
   - Data bits: 8
   - Parity: none
   - Stop bits: 1
   - Flow control: hardware

```
3. +              // turn echo on
4. SF,1           // factory reset
5. SS,C0000000    // Support Device Info and Battery as server
6. SR,92000000   // Set device as central, support MLDP and enable
                 // UART flow control
7. R,1           // reboot to make changes effective
```

### 3.2.2 Configure the Second Device (Module B)

The second RN4020 module, which is referred to as Module B, must be configured to be in a peripheral role. The following commands are issued to configure this device:

1. Pull WAKE_SW high to enter Command mode. On the daughter board, this is the default state.
2. Open a terminal emulator that connects to the serial port of Module A with the following parameters:
   - Baud rate: 115200
   - Data bits: 8
   - Parity: none
   - Stop bits: 1
   - Flow control: hardware

```
3. +              // turn echo on
4. SF,1           // factory reset
5. SS,30000000    // Support Heart Rate and Health Thermometer
                  // services as server. Notice that server services
                  // in Module B overlap client services in Module A
6. SR,32000000    // Set device as peripheral with automatic
                  // advertisement, and support for MLDP and flow
                  // control features
7. R,1            // Reboot the device to make the changes effective
```

### 3.2.3 Connecting the Two Devices

When Module B is powered up, it automatically starts advertisement since the automatic advertisement feature is enabled with the “SR” command. Module A can then try to connect to Module B using the “F” command:

```
F         // Start scan
```

The scan result will appear quickly as follows, where the three elements are the MAC address, the MAC address type, and the device name, respectively.

```
00035B0358E6,0,MCHP-LE,-50
```

Issue an “X” command followed by an “E” command to stop scanning and then establish a connection:

```
X                   // Stop scanning
E,0,00035B0358E6    // Try to establish connection with device of
                    // public MAC address 0x00035B0358E6
```

### 3.2.4 Checking Server and Client Services

Once connected, the message “Connected” will appear on the terminal emulators of both devices. Then we can check the server and client services on both modules.

From Module A, issue the following commands:

```
LS            // List server services
LC            // List client services
```

The server and client services for Module A are listed in Table 3-1.

**TABLE 3-1: MODULE A SERVER AND CLIENT SERVICES**

| Server Services | Client Services |
|---|---|
| 180A<br>2A25,000B,V<br>2A27,000D,V<br>2A26,000F,V<br>2A28,0011,V<br>2A29,0013,V<br>2A24,0015,V<br>180F<br>2A19,0018,V<br>2A19,0019,C<br>END | 180D<br>2A37,000B,00<br>2A37,000C,10<br>2A38,000E,02<br>2A39,0010,08<br>1809<br>2A1C,0013,00<br>2A1C,0014,20<br>2A1D,0016,02<br>END |

From Module B, issue the following commands:

```
LS            // List server services
LC            // List client services
```

The server and client services for Module B are listed in Table 3-2.

TABLE 3-2: MODULE B SERVER AND CLIENT SERVICES

| Server Services | Client Services |
|---|---|
| 180D | 180A |
| 2A37,000B,V | 2A25,000B,02 |
| 2A37,000C,C | 2A27,000D,02 |
| 2A38,000E,V | 2A26,000F,02 |
| 2A39,0010,V | 2A28,0011,02 |
| 1809 | 2A29,0013,02 |
| 2A1C,0013,V | 2A24,0015,02 |
| 2A1C,0014,C | 180F |
| 2A1D,0016,V | 2A19,0018,02 |
| END | 2A19,0019,10 |
|  | END |

Users will notice that the server services on Module A match the client services on Module B and vice versa. Therefore, the data exchange between Module A and Module B can follow the client-server model where the server maintains the data and the client has access to the data.

### 3.2.5 Setting the Battery Service

From Module A, the Battery Service is a server service, so the battery level can be set to 100% by either of the following commands as server services access:

```
SUW,2A19,64      // Set Battery Level (UUID 0x2A19) to be 100
SHW,0018,64      // Set Battery Level (handle 0x0018) to be 100
```

From Module B, the Battery Service is in a client role, so the battery level can be read from the server service on Module A using the following commands as client access:

```
CURV,2A19
CHR,0018
```

Both commands will return the value of Battery Level characteristic 0x2A19 to be 100 as follows:

```
R,64
```

The output means the characteristic read returns data of 1 byte in length and a value of 0x64.

From Module B, notification can be started by issuing either of the following commands:

```
CUWC,2A19,1
CHW,0019,0100
```

The client service command, “CUWC”, writes a configuration of UUID 0x2A19 to be notification enabled. The client service command, “CHW”, writes value 0x0001 (little-endian format) to handle 0x0019, which corresponds to the characteristic UUID of 0x2A19. According to *Table 3.11: “Client Characteristic Configuration bit field definition”* in *Volume 3, Part G*, *Section 3.3.3.3 “Client Characteristic Configuration”* of *“Bluetooth Core Specification 4.1”,* the value 0x0001 means start notification.

Once notification is successfully started, Module A will notify the host of the event with the following format:

```
WC,0019,0100
```

This means the configuration for primary service 0x180F (Battery Service), characteristic 0x2A19 (Battery Level), has been written by 2 bytes with value 0x0001 (little endian format), or means notification has started. If the Battery Level characteristic had a set value before, a notification will be sent to Module B automatically.

Once notification is successfully started, and the Battery Level characteristic has been set to the previous value, a notification will be received by Module B with the following format:

```
Notify,0018,64
```

This means that the value of characteristic 0x2A19 (Battery Level) in the primary service 0x180F (Battery Service) has been updated to 0x64.

After notification starts, the value change on the Battery Level on Module A will be updated on Module B. Use either of the following commands on Module A and check the automatic updates on Module B.

```
SUW,2A19,5A      // Set Battery Level to be 90% on Module A
SHW,0018,50      // Set Battery Level to be 80% on Module A
```

Similar operations can be performed on Heart Rate or Health Thermometer services, where Module B sets the values and Module A reads values.

## 3.3 MLDP DEMONSTRATION

Once access of characteristics in public services have been verified, the MLDP service can be started. The MLDP service is built on top of the private service, but acts transparently to the user. To use the MLDP service between two RN4020 devices, both devices must enable MLDP with the proper parameters using the “SR” command. MLDP mode can only be started when two RN4020 modules both have MLDP enabled and are connected together.

To start MLDP mode, simply assert the CMD/MLDP pin to be high. The RN4020 module will output “MLDP” to indicate the start of MLDP mode. Once in MLDP mode, any data from the UART will be sent to the peer device. When receiving MLDP data from the peer, if the AUTO_MLDP_DISABLE feature is not enabled (see the “SR” command), the RN4020 module will automatically enter MLDP mode; otherwise, all data will be ignored until CMD/MLDP is set high to enter MLDP mode.

From Module A, assert CMD/MLDP to be high and wait until “MLDP” is output to the terminal emulator. Provided Module B shows “MLDP”, anything typed on the terminal emulator of Module A Type will appear on the terminal emulator of Module A. Users can also try to type on the terminal emulator of Module B, which shows the same output on the terminal emulator of Module A.

To exit MLDP mode, set CMD/MLDP to be low and “CMD” will appear on the terminal emulator to indicate that the RN4020 module is back in Command mode. Next, set CMD/MLDP to be low on Module B (WAKE_HW and CMD/MLDP have weak pull down resistors, so they will stay low if not pulled high). Then, disable the notification on Battery Level with either of the following commands:

```
CHW,0019,0000
CUWC,2A19,0
```

On Module A, the status change will be notified to the host. However, Module A is currently in MLDP mode and only output MLDP data is sent to the UART. Instead, PIO2 will be set high (the red LED (MLDP_EV) illuminates on the RN4020 PICtail Daughter Board) to indicate the pending status message. Once CMD/MLDP is set low to enter Command mode, the status message will be output to the UART. The maximum status message that can be held is 256 bytes.

## 3.4 RN4020 SCRIPTING DEMONSTRATION

In this section, a step-by-step guide is provided to demonstrate the capability of scripting on the RN4020 Bluetooth Low Energy PICtail™/PICtail Plus Daughter Board.

### 3.4.1 Setting Up Private Service and Characteristics

The scripting function works best with the private service and characteristics. The main input/output peripherals in scripting are the analog or digital ports. The predefined data format of public services and characteristics may not always work with the reading or output of RN4020 ports. However, private service and characteristics can define the data format freely. Therefore, a peer device of the BLE connection is able to take over the data interpolation functionality without involvement of the device that runs scripts.

The following UART ASCII commands set up the private service and characteristics:

```
+             // Echo on
SF,1          // Factory Reset
SS,00000001   // Enable private service
SR,00000000   // Set as Peripheral
PZ            // Clean private Service
PS,123456789012345678901234567890FF  // Set private service UUID
PC,12345678901234567890123456789011,12,02   // Set private
   // characteristic to be readable, notifiable and 2 bytes
   // in length
PC,12345678901234567890123456789022,02,02   // Set private
   // characteristic to be readable and 2 bytes in length
R,1           // Reboot
```

After rebooting, the “LS” command can be used to check the server characteristics:

```
123456789012345678901234567890FF
 12345678901234567890123456789011,000B,02,02
 12345678901234567890123456789011,000C,10,02
 12345678901234567890123456789022,000E,02,02
```

### 3.4.2 Script Input

To start writing the script, it must first be cleared and Script Input mode is entered using the following commands:

```
WC            // Clean script
WW            // Enter script input mode
```

Next, input the following script. After entering the script, press the “ESC” key to exit.

```
@PW_ON
# start advertisement
A
# define range of variable $VAR1
$VAR1 < “0300”
# associate handle 0x000E to reading of AIO2
%000E = @I,2

@CONN
# set timer 1 to be around 5 seconds
SM,1,00500000

@TMR1
# read AIO0
$VAR1 = @I,0
# set handle 0x000B to the AIO0 value
SHW,000B,$VAR1
# restart timer
SM,1,00500000
```

After powering on, event @PW_ON is generated. The script will first start advertisement. Then, it defines the range of $VAR1 to be less than 0x0300. Finally, it associates handle 0x000E to the analog port AIO1, which is the temperature sensor.

Once connection is established, event @CONN is generated. The script sets up Timer1 to expire in approximately five seconds.

Once Timer1 is expired, event @TMR1 is generated. AIO0 is read and the value is assigned to $VAR1. If the read is within the predefined range (less than 0x0300), the value is written to handle 0x000B; otherwise, handle 0x000B is not updated.

If desired, the command “WR,<0-9>” can be used to debug the script.

### 3.4.3 Running the Script

Run the script by enabling the script after power on using the following commands:

```
SR,01000000   // Run script after power on
R,1           // Reboot
```

After rebooting, the script will be running. Users can open the Bluetooth access application from a smartphone or tablet and connect to the RN4020 module. Click the characteristic 0x12345678901234567890123456789011 and start notify.

Every five seconds, AIO0 (the light sensor) will be read. If the AIO0 value matches the rule for $VAR1 < “0300”, the value of the characteristic will be updated every five seconds.

When the light sensor is exposed to bright light, the reading of AIO0 is usually higher than 0x0400; therefore, the value to handle 0x000B is not updated. If the light sensor is blocked from bright light, the AIO0 reading may be lowered to less than 0x0300; therefore, the value will be updated on the Bluetooth access application.

Conversely, for characteristic 0x12345678901234567890123456789022, users can read its value using a BTLE BROWSER APP. Since the corresponding handle 0x000E has been associated with AIO2, a read of handle 0x000E will return the reading of AIO2 without involvement of a host MCU.

In this demonstration, the script runs the RN4020 module and performs tasks independently. It shows that for a simple application like this, the RN4020 module can run stand-alone without the need for a host MCU.

# Appendix A. PICtail™ Daughter Board Schematics

This appendix provides the schematic diagrams for the PICtail Daughter Board and includes the following figures:

FIGURE A-1: RN4020 MODULE

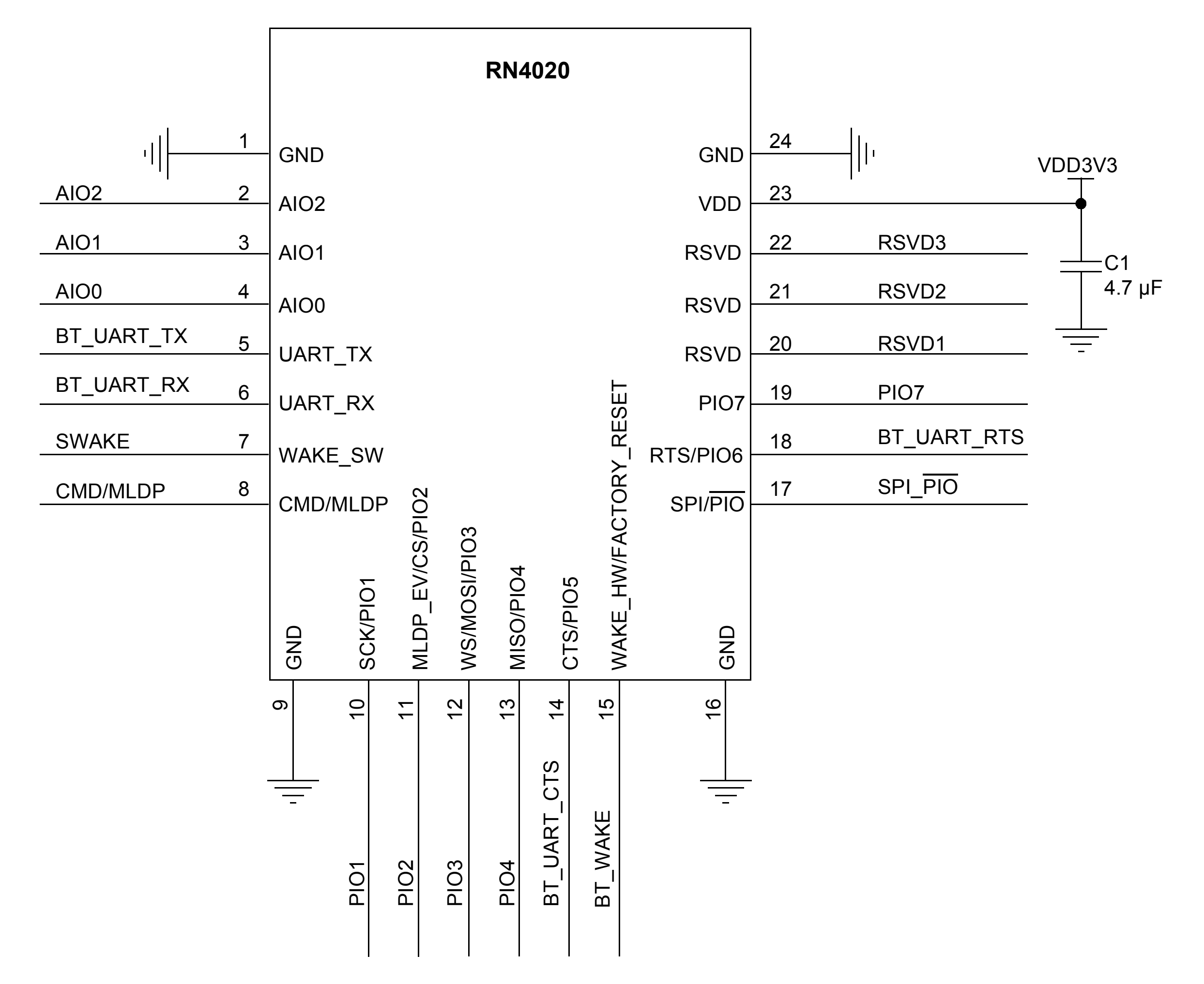


**FIGURE A-2: PIC18LF25K50-I/ML DEVICE**

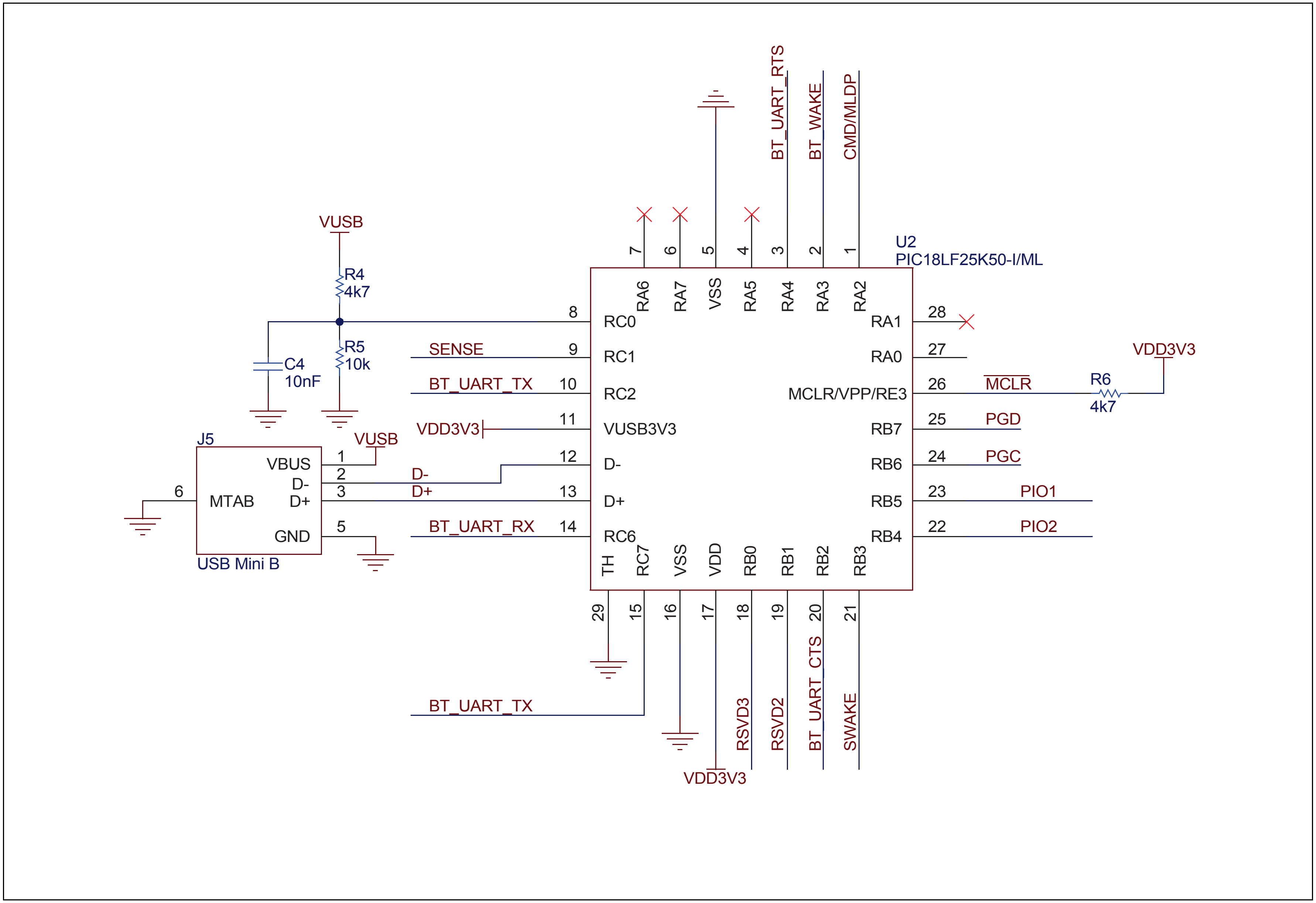


**FIGURE A-3: 28-PIN AND 30-PIN PICtail™ CONNECTORS**

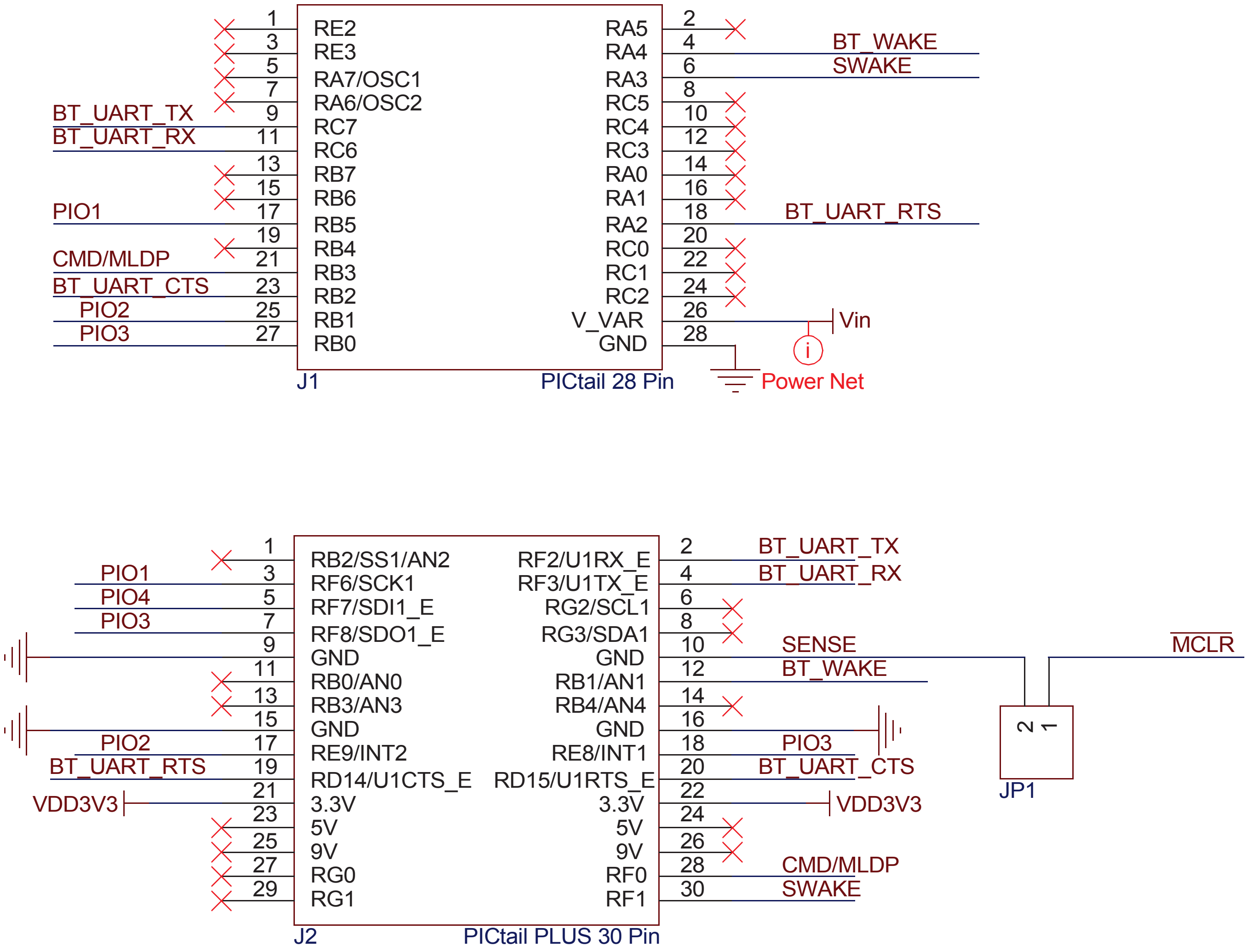


**FIGURE A-4: RN4020 MODULE BREAKOUT PINS**

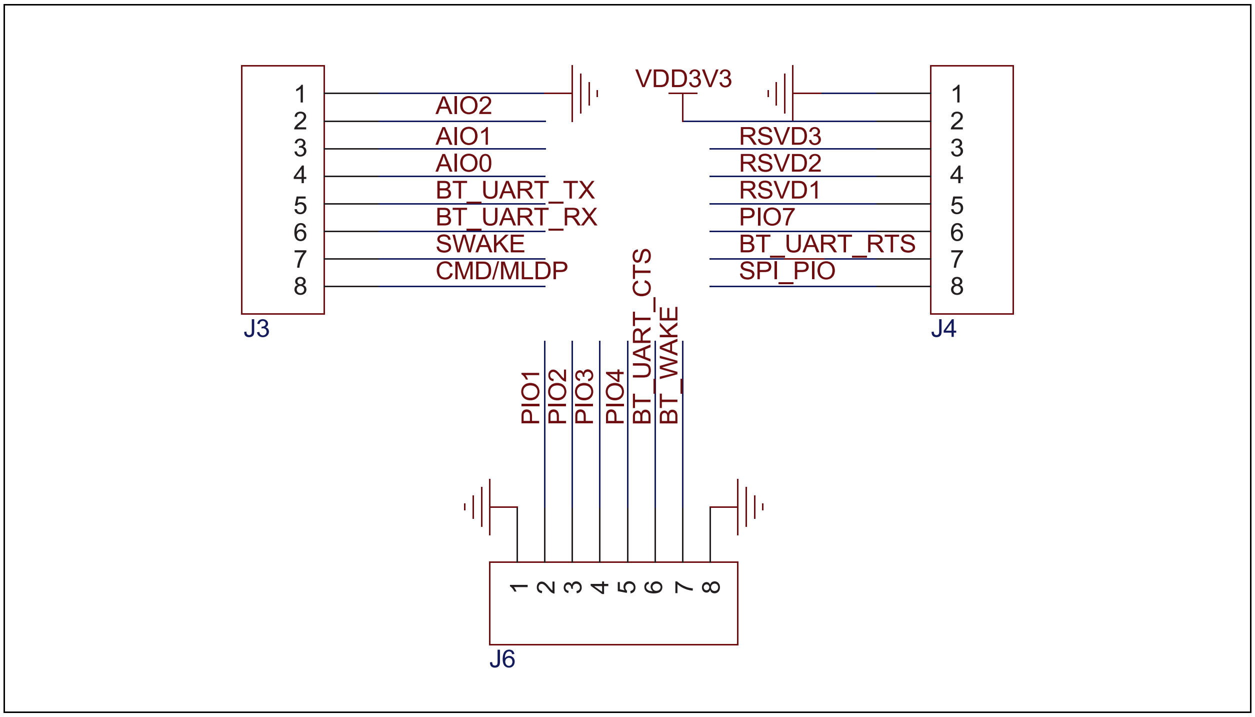


**FIGURE A-5: STATUS LEDs**

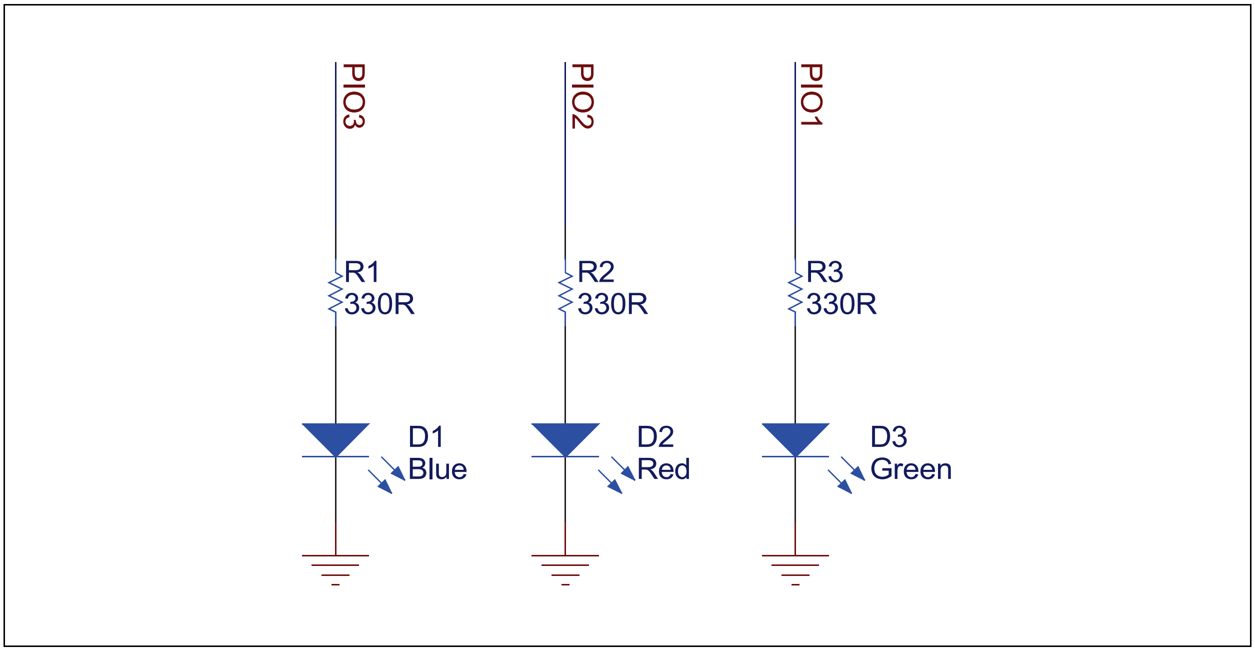


**FIGURE A-6: VOLTAGE REGULATOR**

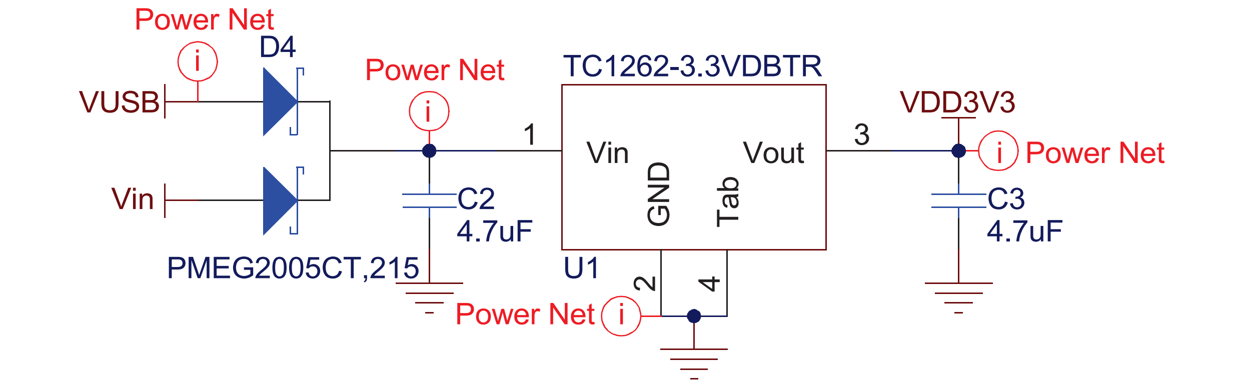


**FIGURE A-7: DECOUPLING CAPACITOR FOR THE PIC18LF25K50-I/ML DEVICE**

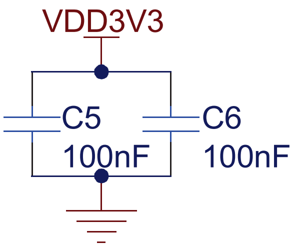


**FIGURE A-8: TEST SWITCH**

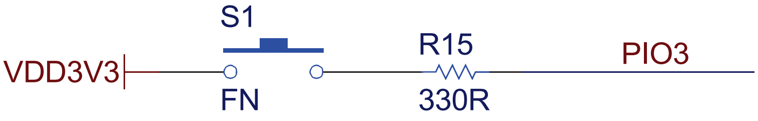
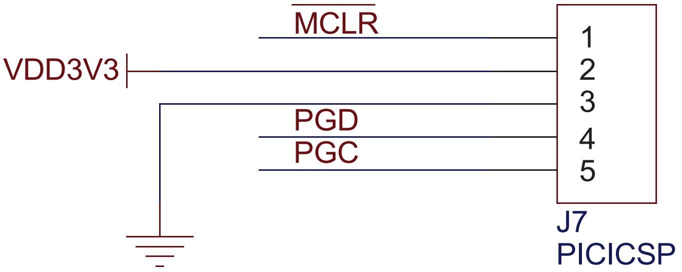


**FIGURE A-9: ICSP™ CONNECTOR**



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