Hardware Application Note

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Type 1XL/2XS Wi-Fi® + Bluetooth® Module

NXP 88W9098 Chipset for 802.11a/b/g/n/ac/ax 2x2 MIMO + Bluetooth 5.3 Hardware Application Note - Rev. 3.0

- Design Name: Type 1XL / Type 2XS
- P/N: LBEE5ZZ1XL-774 / LBEE5ZZ2XS-846

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About This Document

Murata's Type 1XL/2XS is a small and high-performance module based on NXP 88W9098 combo chipset, supporting IEEE 802.11a/b/g/n/ac/ax 2×2 MIMO + Bluetooth 5.3 BR/EDR/LE. This application note provides RF and hardware design guidance. Refer to Type 1XL Datasheet and Type 2XS Datasheet for module specification.

Audience & Purpose

Intended audience includes any customer looking to integrate this module into their product. In particular, RF, hardware, systems, and software engineers.

Document Conventions

Table 1 describes the document conventions.

Table 1: Document Conventions

Conventions	Description
	**Warning Note** Indicates very important note. Users are strongly recommended to review.
	**Info Note** Intended for informational purposes. Users should review.
	**Menu Reference** Indicates menu navigation instructions. **Example**: Insert➔Tables➔Quick Tables➔Save Selection to Gallery
	**External Hyperlink** This symbol indicates a hyperlink to an external document or website. **Example**: Embedded Artists AB Click on the text to open the external link.
	**Internal Hyperlink** This symbol indicates a hyperlink within the document. **Example**: Scope Click on the text to open the link.
`Console input/output or code snippet`	**Console I/O or Code Snippet** This text ***Style*** denotes console input/output or a code snippet.
`# Console I/O comment` `// Code snippet comment`	**Console I/O or Code Snippet Comment** This text ***Style*** denotes a console input/output or code snippet comment. • Console I/O comment (preceded by "#") is for informational purposes only and does not denote actual console input/output. • Code Snippet comment (preceded by "//") may exist in the original code.

1 Scope

This application note provides detailed information on schematic/layout design, and references RF performance benchmarks. Refer to Type 1XL Datasheet and Type 2XS Datasheet for module specification.

2 Module Introduction

Type 1XL/2XS is a small and very high-performance module based on NXP 88W9098 combo chipset which supports Wi-Fi 802.11a/b/g/n/ac/ax 2×2 MIMO + Bluetooth 5.3 BR/EDR/LE up to 1200 Mbps PHY data rate on Wi-Fi and 3 Mbps PHY data rate on Bluetooth.

The WLAN section supports PCIe 2.0 interface, with optional support for SDIO 3.0. The Bluetooth section supports high speed 4-wire UART interface (optional support for SDIO) and PCM for audio data.

The 88W9098 implements highly sophisticated enhanced collaborative coexistence hardware mechanisms and algorithms, which ensure that WLAN and Bluetooth collaboration is optimized for maximum performance. Dual 2×2 Wi-Fi operation is supported with implicit and explicit beamforming.

In IEEE 802.11ax mode, the WLAN operation supports rates of MCS0 - MCS9 (up to 1024 QAM) in 20 MHz, 40 MHz and 80 MHz channels for data rate up to 1200 Mbps.

2.1 Features

- WLAN 802.11a/b/g/n/ac/ax 2x2 MIMO + Bluetooth Classic and Low Energy (Version 5.3) combo SMD module with NXP 88W9098.
- Small size LGA package with metal shielding.
- Host interfaces: PCIe 2.0, and SDIO 3.0 for WLAN; HCI UART, and PCM for Bluetooth.
- MAC address and BD address are stored in OTP.

2.2 Hardware Block Diagrams

Figure 1 and **Figure 2** show hardware block diagrams for Type 1XL and Type 2XS. These two modules differ in the Bluetooth RF interface. Type 1XL has a dedicated Bluetooth antenna "ANT_BT" compared to Type 2XS which utilizes a shared WLAN-Bluetooth antenna "ANT_B".

Figure 1: Block Diagram - Type 1XL

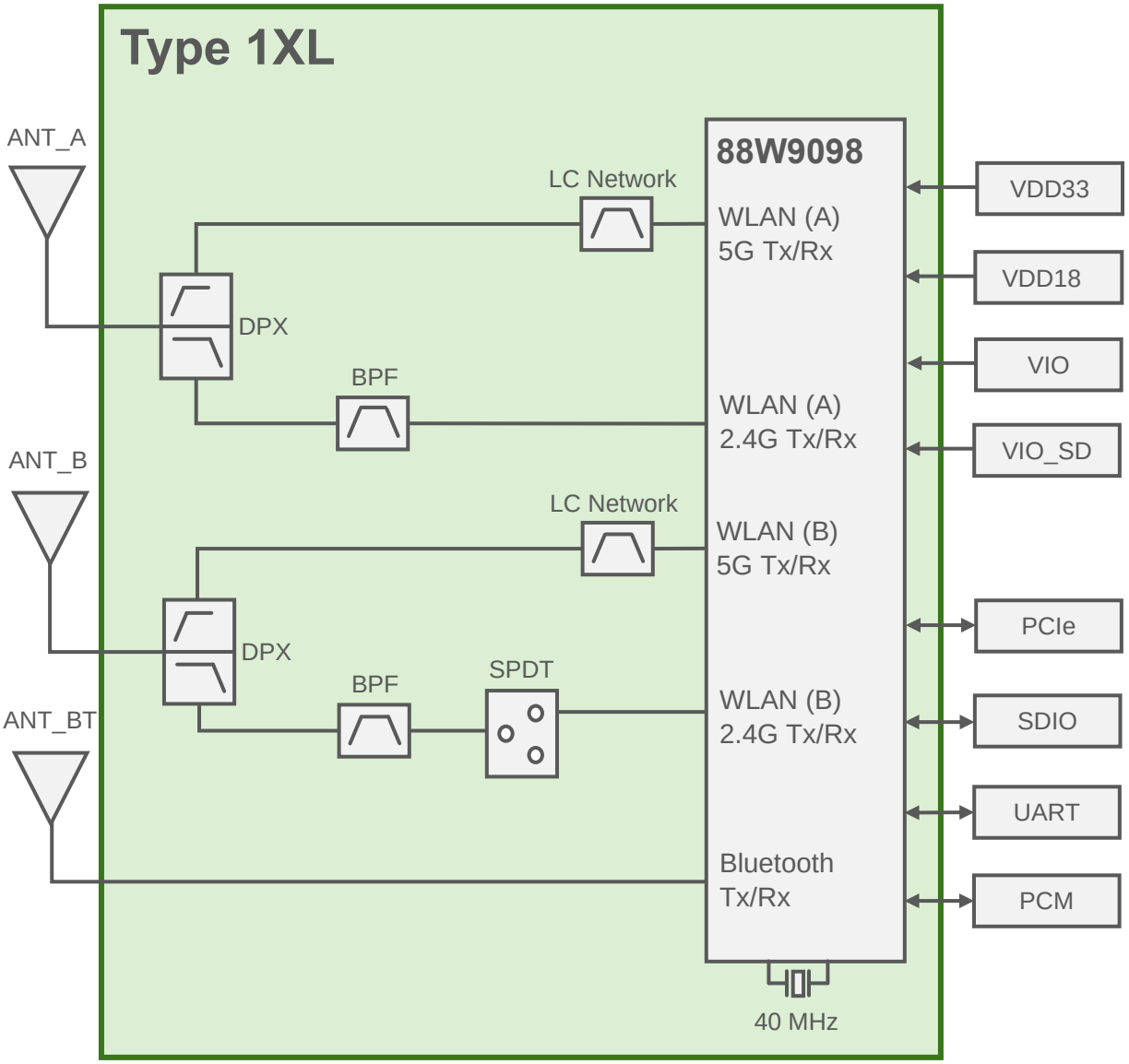
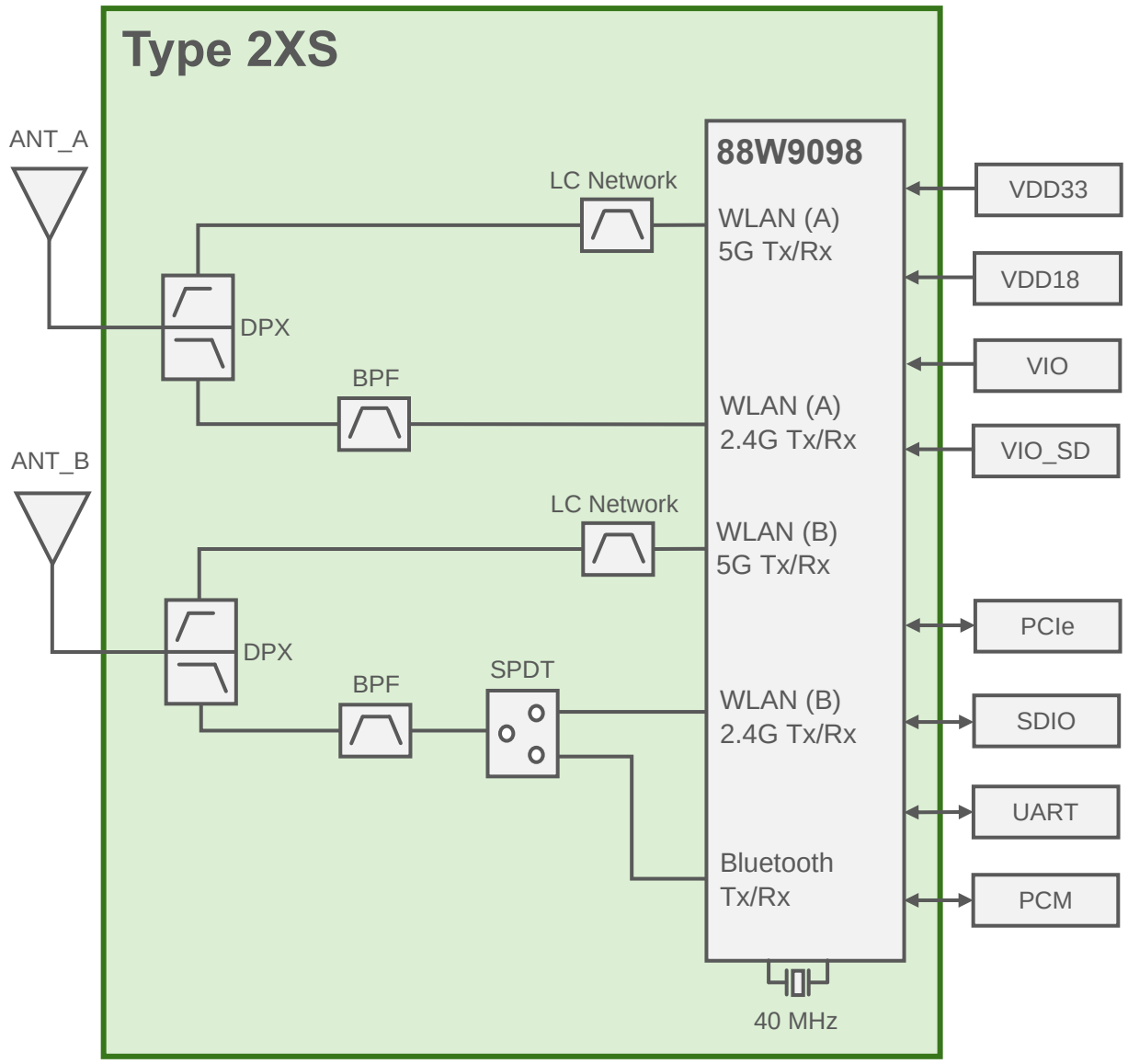


Figure 2: Block Diagram -Type 2XS



3 Reference Design

This section describes the reference designs for Type 1XL and Type 2XS.

3.1 Reference Circuit

Figure 3 shows the reference circuit design for Type 1XL. **Figure 3**: Reference Circuit - Type 1XL

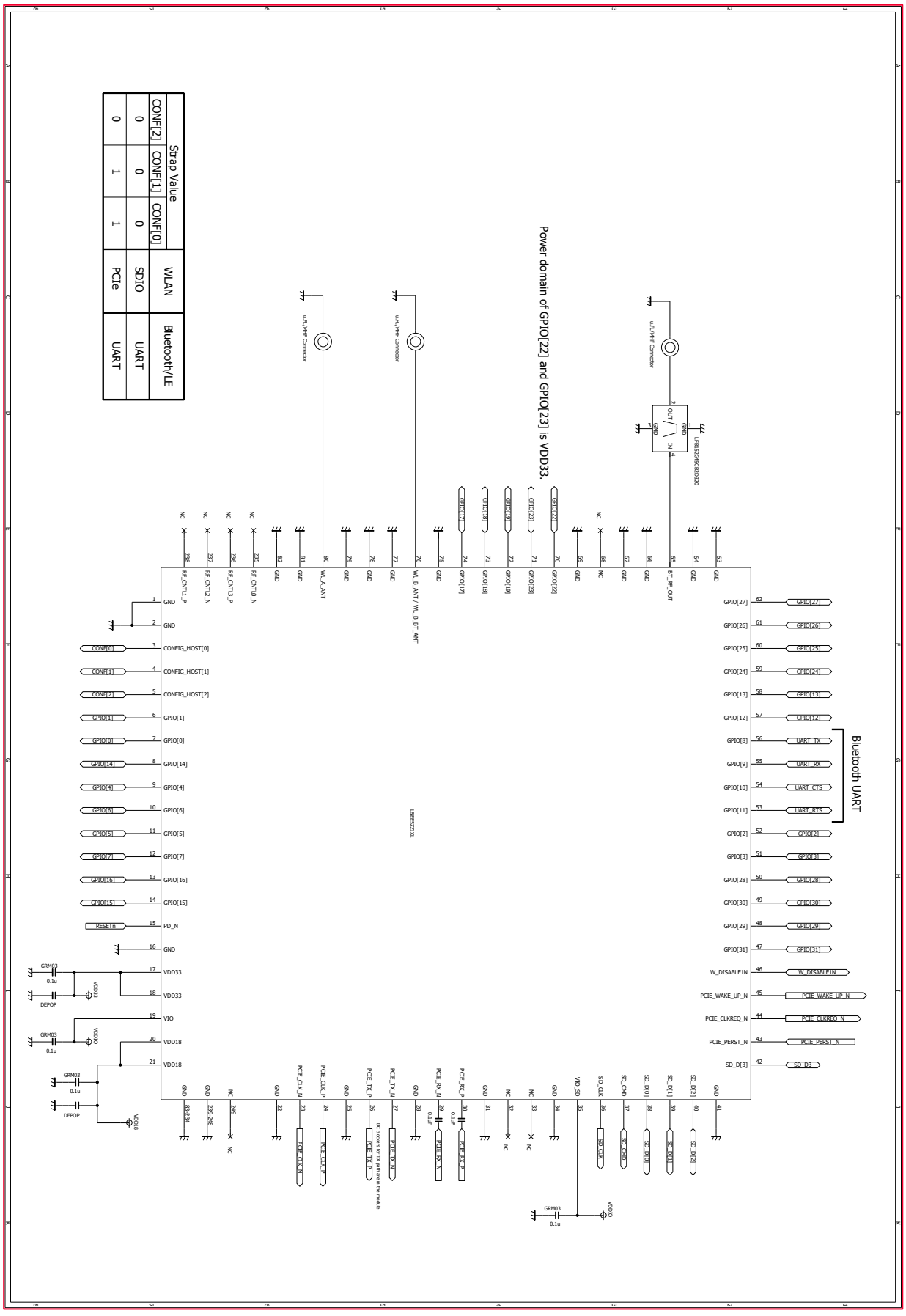


Figure 4 shows the reference circuit design for Type 2XS.

When interfacing WLAN-PCIE, DC blocker 0.1 µF capacitors on both PCIE_RX_P and PCIE_RX_N signals should be located very close to the transmission point – i.e. close to the host processor PCIe transmit lines. This applies to both 1XL and 2XS reference circuits.

Figure 3: Reference Circuit - Type 1XL

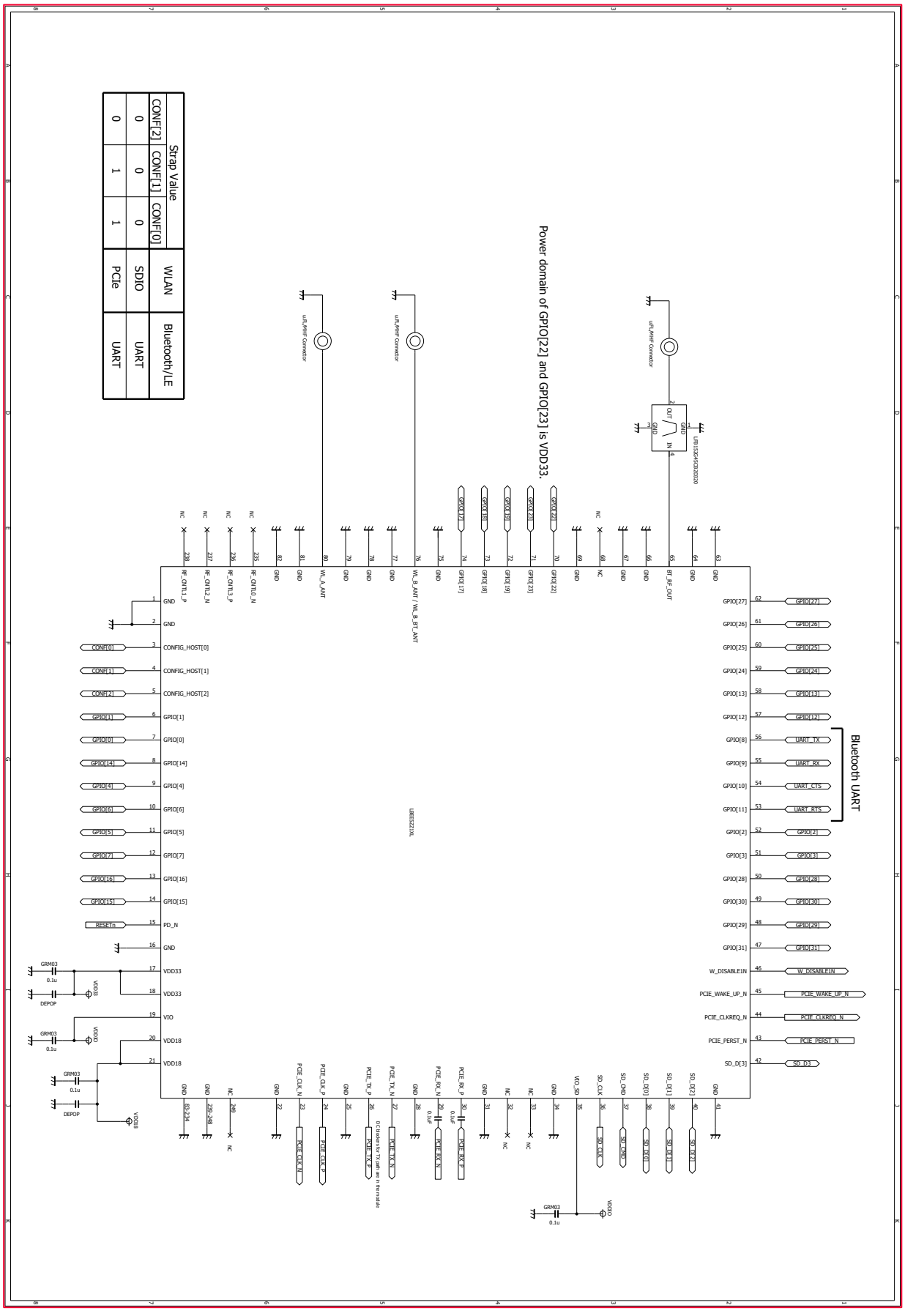
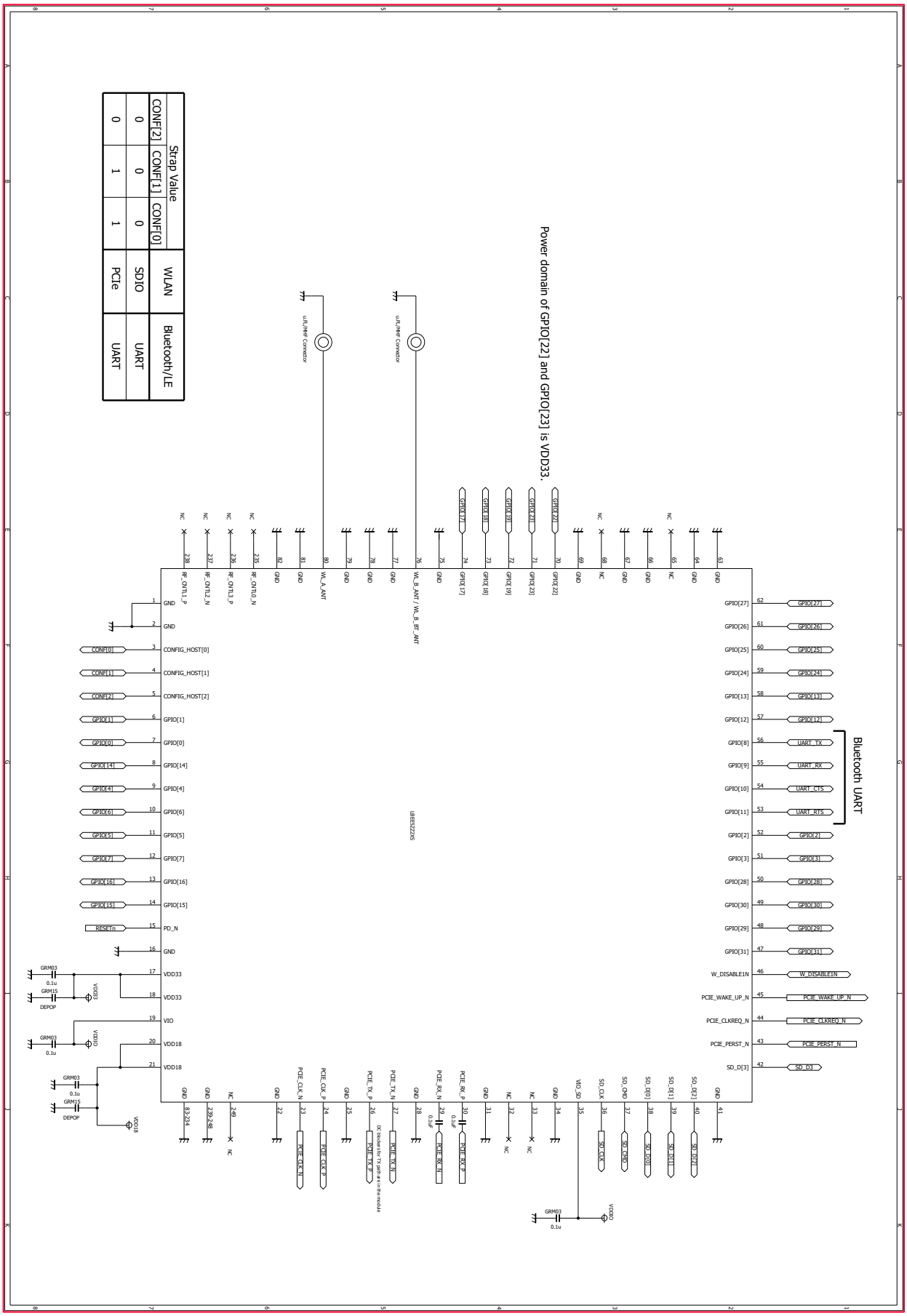


Figure 4: Reference Circuit - Type 2XS



3.2 Requirements for High-Speed Digital Signals

- SDIO: SDIO traces should be isometric zero delay routing with 50 Ω impedance.
- PCIe: TxP/N, RxP/N and CLKP/N signals should be differential 100 Ω impedance. DC blockers are necessary on RxP/N (these should be located very close to the transmission point – i.e. close to the host processor PCIe transmit lines).

3.3 Requirements for Unused Signals

Any pull-up/down is not necessary (floating) for GPIO [0..31] if these signals are not used.

3.4 Module Footprint Design

Refer to dimensions in the Type 1XL Datasheet / Type 2XS Datasheet. The DXF file of Type 1XL module footprint is provided via the website.

3.5 Recommended Antenna

This module is certified with two types of antenna solution by regulatory certification body. To use Murata's regulatory certification, any user must follow below instructions. The DXF file file for Type 1XL module is provided via the website.

3.5.1 PCB Type Di-pole Antenna with Co-axial Connector

- Any users must use recommended antennas. However, user can use any equivalent type of antenna with less antenna gain than antenna gain of recommended antennas for US and EU under approval of Class I Permissive Change by Murata.

Table 2: Cable Options for Antenna Gains

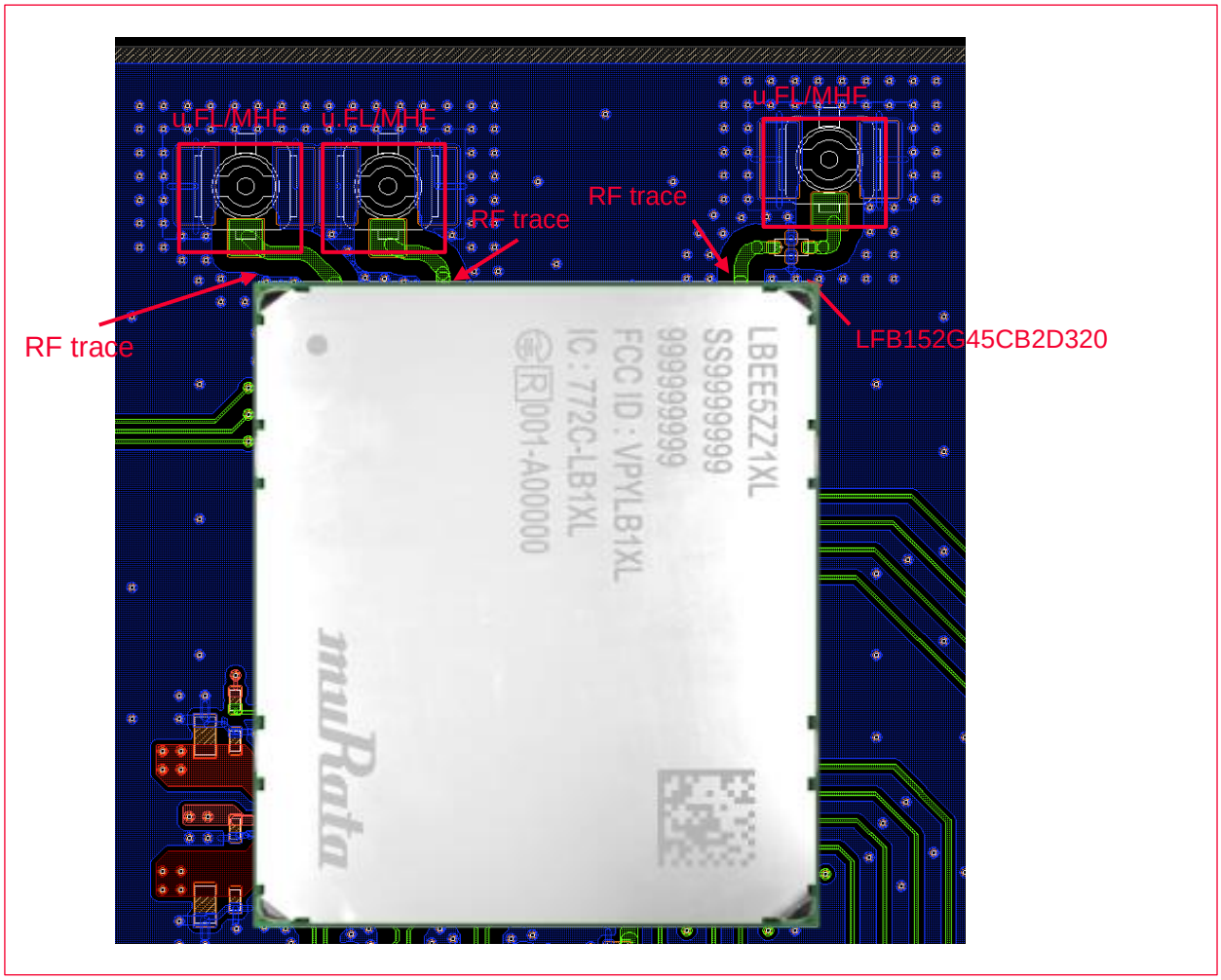
P/N	Vendor	Form factor	Type	2.4 GHz Gain	5 GHz Gain	Cable Options
146153	Molex	U.FL/PCB	Di-pole	3.2 dBi	4.25 dBi	050 (50 mm) or longer cable
WT32D1-KX	Unictron	U.FL/PCB	Di-pole	3 dBi	4 dBi	150 mm (H2B1WD1A3B0200)

206994: Only for Japan

- Any users must copy RF trace to u.FL/MHF connector from the trace layout file provided by Murata; adhering to below guidelines on:
  - Trace width accuracy within +/- 0.25 mm.
  - Stack height between GND layer and RF trace of 230 ~ 240 um (Exclude inaccuracy of PCB).
  - Passive component location matching Murata design.
  - Necessary "Keep out" area around U.FL/MHF connector.

Figure 5 shows the PCB type di-pole antenna for 1XL module. The PCB di-pole antenna for 2XS module is similar to Type 1XL module.

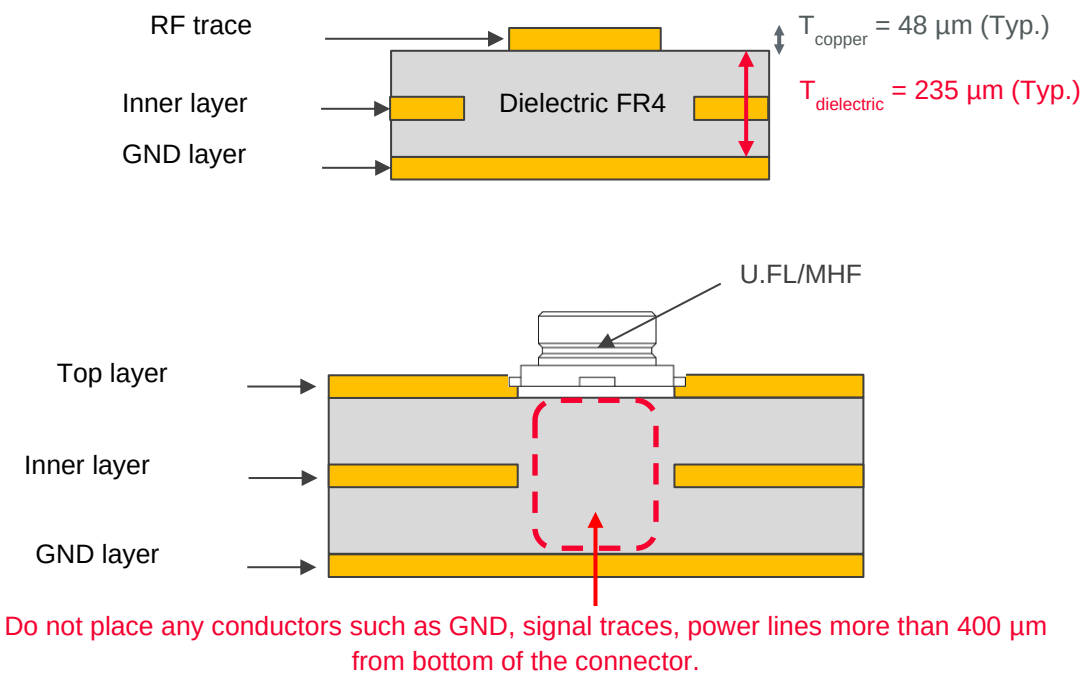
Figure 5: PCB Type Di-pole Antenna - Type1XL



3.5.2 PCB Stack-Up

This section describes the PCB Stack-up layers.

Figure 6: PCB Stack-Up Layers



4 Setup Configuration Files

To enable Murata's regulatory certification, below configuration file shall be loaded initially. Murata will provide configuration files via Murata's GitHub.

4.1 WLAN Configuration Files for Linux

The files listed in **Table 3** shall be used to satisfy regulatory requirements if user wants to use Murata regulatory certification. For more regulatory information, refer to section 11 of Linux User Guide.

Table 3: WLAN Configuration Files — Linux

Names	Country	Country Code	Configuration Files
WLAN Tx power configuration files	USA	US	txpower_US.bin
	Canada	CA	txpower_CA.bin
	Europe	DE	txpower_EU.bin
	Japan	JP	txpower_JP.bin
WLAN Carrier Sense / Adaptivity threshold configuration file			ed_mac.bin
WLAN regulatory limitation configuration file			db.txt

NXP IC based module shall use CRDA mechanism which is provided by Linux-wireless. Compile the new regulatory.bin file from "db.txt" which is provided by Murata with following manner of wireless-regdb.

4.2 Bluetooth configuration files for Linux

Bluetooth Tx power configuration script file shall be loaded after Bluetooth device initialization.

- Bluetooth Tx power configuration files
  - bt_power_config_1.sh
    - Command example:

```
# sh bt_power_config_1.sh
```

    - Content of shell script file "bt_power_config_1.sh"

```
hcitool -i hci0 cmd 0x3f 0x00ee 0x01
```

Bluetooth Tx power is configured by using hcitool.

5 Reference Performance Data

This section describes the reference performance data.

5.1 Typical Rx Minimum Sensitivity Level at Module Antenna port

This section describes the Typical Rx Minimum Sensitivity Level at module antenna port for WLAN and Bluetooth.

5.1.1 WLAN

- Conditions
  - VDD33 = 3.3V, VDD18 = 1.8V, VIO = 1.8V
  - Combo FW: 17.80.200.p204

Table 4 and **Table 5** describe the typical Rx minimum sensitivity level at module antenna port for WLAN at 2.4 GHz for 20 MHz and 40 MHz bandwidth. **Table 6**, **Table 7** and **Table 8** describe the typical Rx minimum sensitivity level at module antenna port for WLAN at 5 GHz for 20 MHz, 40 MHz and 80 MHz bandwidth.

Table 4: Rx Minimum Sensitivity Level - WLAN 2.4 GHz (20 MHz)

Frequency in MHz	Rx Minimum Sensitivity Level [dBm]							
	11b		11g		11n (HT 20)		11ax (HE 20)	
	1 Mbps	11 Mbps	6 Mbps	54 Mbps	MCS0	MCS7	MCS0	MCS11
2412	-97	-89	-91	-75	-90	-72	-90	-62
2442	-97	-88	-91	-74	-90	-72	-90	-62
2472	-96	-88	-90	-74	-90	-72	-90	-62

Table 5: Rx Minimum Sensitivity Level - WLAN 2.4 GHz (40 MHz)

Frequency in MHz	Rx Minimum Sensitivity Level [dBm]			
	11n (HT 40)		11ax (HE 40)	
	MCS0	MCS7	MCS0	MCS11
2422	-88	-70	-88	-60
2442	-88	-70	-88	-59
2462	-88	-70	-88	-59

Table 6: Rx Minimum Sensitivity Level - WLAN at 5 GHz (20 MHz)

Frequency in MHz	Rx Minimum Sensitivity Level [dBm]							
	11a		11n (HT 20)		11ac (VHT 20)		11ax (HE 20)	
	6 Mbps	54 Mbps	MCS0	MCS7	MCS0	MCS8	MCS0	MCS11
5180	-88	-72	-88	-70	-88	-66	-88	-60
5500	-88	-72	-88	-70	-88	-66	-88	-60
5825	-88	-72	-88	-70	-88	-66	-88	-60

Table 7: Rx Minimum Sensitivity Level - WLAN at 5 GHz (40 MHz)

Frequency in MHz	Rx Minimum Sensitivity Level [dBm]					
	11n (HT 40)		11ac (VHT 40)		11ax (HE 40)	
	MCS0	MCS7	MCS0	MCS9	MCS0	MCS11
5190	-86	-68	-86	-62	-86	-57
5510	-86	-68	-86	-62	-86	-57
5795	-86	-68	-86	-62	-86	-57

Table 8: Rx Minimum Sensitivity Level - WLAN at 5 GHz (80 MHz)

Frequency in MHz	Rx Minimum Sensitivity Level [dBm]			
	11ac (VHT 80)		11ax (HE 80)	
	MCS0	MCS9	MCS0	MCS11
5210	-83	-59	-83	-55
5530	-83	-59	-83	-55
5775	-82	-59	-83	-55

5.1.2 Bluetooth

- Conditions
  - VDD33 = 3.3V, VDD18 = 1.8V, VIO = 1.8V
  - Combo FW: 17.80.200.p204

Table 9 describes the typical Rx minimum sensitivity level for Bluetooth.

Table 9: Rx Minimum Sensitivity Level - Bluetooth

Frequency in MHz	Rx Minimum Sensitivity Level[dBm]						
	DH5	2DH5	3DH5	LE 125K	LE 500K	LE 1M	LE 2M
2402	-92	-92	-86	-106	-104	-100	-98
2441	-92	-92	-86	-105	-104	-100	-98
2480	-91	-90	-84	-103	-102	-99	-97

5.2 Typical Tx/Rx Current Consumption

This section describes the typical Tx/Rx current consumption for WLAN and Bluetooth.

5.2.1 WLAN

- Conditions
  - VDD33 = 3.3V, VDD18 = 1.8V, VIO = 1.8V
  - Combo FW: 17.80.200.p204
  - Current definition

Figure 7: Typical Tx/Rx Current Consumption for WLAN

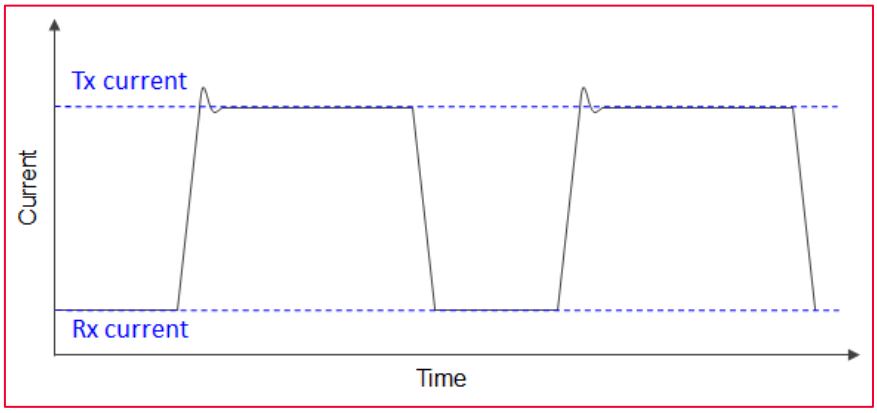


Table 10 and **Table 11** describes the typical Tx/Rx current consumption for WLAN at 2.4 GHz.

Table 10: Typical Tx/Rx Current Consumption - WLAN at 2.4 GHz (1SS)

Mode	Data Rate	Setting Tx Power [dBm]	Current [mA]			
			Tx		Rx	
			VDD18	VDD33	VDD18	VDD33
11b	1 Mbps	18	280	210	280	0.2
11g	6 Mbps	17	300	200	280	0.2
11n (HT20)	MCS0	16	300	190	280	0.2
11ax (HE20)	MCS0	16	300	190	280	0.2
11n (HT40)	MCS0	14	310	150	300	0.2
11ax (HE40)	MCS0	14	310	160	300	0.2

Table 11: Typical Tx/Rx Current Consumption - WLAN at 2.4 GHz (2SS)

Mode	Data Rate	Setting Tx Power [dBm]	Current [mA]			
			Tx		Rx	
			VDD18	VDD33	VDD18	VDD33
11b	1 Mbps	18	370	450	300	0.2
11g	6 Mbps	17	410	450	300	0.2
11n (HT20)	MCS0	16	410	380	300	0.2
11ax (HE20)	MCS0	16	420	390	300	0.2
11n (HT40)	MCS0	14	430	330	320	0.2
11ax (HE40)	MCS0	14	430	330	320	0.2

Table 12 and **Table 13** describes the typical Tx/Rx current consumption for WLAN at 5 GHz.

Table 12: Typical Tx/Rx Current Consumption - WLAN at 5 GHz (1SS)

Mode	Data Rate	Setting Tx Power [dBm]	Current [mA]			
			Tx		Rx	
			VDD18	VDD33	VDD18	VDD33
11a	6 Mbps	17	430	260	320	0.2
11n (HT20)	MCS0	16	400	250	320	0.2
11ac (VHT20)	MCS0	16	400	250	320	0.2
11ax (HE20)	MCS0	16	400	250	320	0.2
11n (HT40)	MCS0	16	410	250	320	0.2
11ac (VHT40)	MCS0	16	410	250	320	0.2
11ax (HE40)	MCS0	16	420	250	320	0.2
11ac (VHT80)	MCS0	15	400	230	350	0.2
11ax (HE80)	MCS0	15	400	230	350	0.2

Table 13: Typical Tx/Rx Current Consumption - WLAN at 5 GHz (2SS)

Mode	Data Rate	Setting Tx Power [dBm]	Current [mA]			
			Tx		Rx	
			VDD18	VDD33	VDD18	VDD33
11a	6 Mbps	17	610	510	320	0.2
11n (HT20)	MCS0	16	630	470	320	0.2
11ac (VHT20)	MCS0	16	640	470	320	0.2
11ax (HE20)	MCS0	16	640	480	320	0.2
11n (HT40)	MCS0	16	650	470	350	0.2
11ac (VHT40)	MCS0	16	650	470	350	0.2
11ax (HE40)	MCS0	16	660	480	350	0.2
11ac (VHT80)	MCS0	15	630	440	420	0.2
11ax (HE80)	MCS0	15	640	440	420	0.2

5.2.2 Bluetooth

- Conditions
  - VDD33 = 3.3V, VDD18 = 1.8V, VIO = 1.8V
  - Combo FW: 17.80.200.p204
  - Current definition

Figure 8: Typical Tx/Rx Current Consumption for Bluetooth

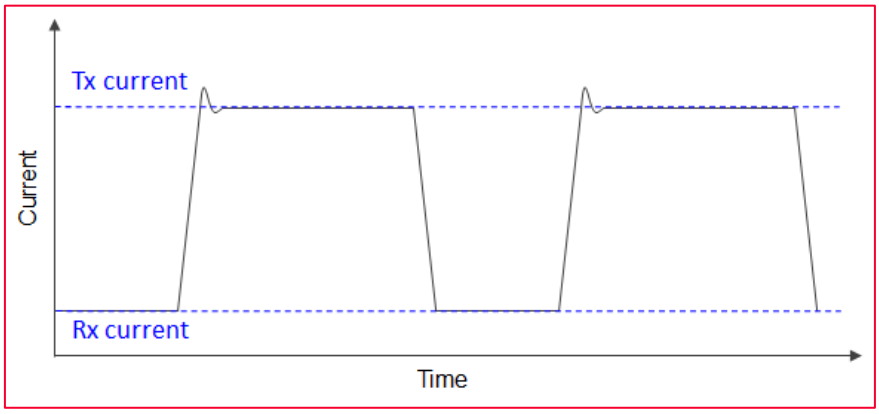


Table 14 describes the typical Tx/Rx current consumption for Bluetooth.

Table 14: Typical Tx/Rx Current Consumption - Bluetooth at 2.4 GHz

Mode	Setting Tx Power [dBm]	Current [mA]			
		Tx		Rx	
		VDD18	VDD33	VDD18	VDD33
BR (1DH5)	3	45	0.2	20	0.2
EDR (3DH5)	0	45	0.2	20	0.2
LE 125K	3	60	0.2	20	0.2
LE 500K	3	60	0.2	20	0.2
LE 1M	3	60	0.2	20	0.2
LE 2M	3	60	0.2	20	0.2

5.3 Typical Sleep Current Consumption

This section describes the typical sleep current consumption for Wi-Fi and Bluetooth.

5.3.1 WLAN

- Conditions
  - VDD33 = 3.3V, VDD18 = 1.8V, VIO = 1.8V
  - Platform: NXP MCIMX8MQuad-EVK
  - Combo FW: 17.68.1.p81
  - WLAN I/F: PCIe
  - Beacon Interval = 100 ms

Table 15 describes the typical sleep current consumption for WLAN.

Table 15: Typical Sleep Current Consumption - WLAN

Band	Mode	Current consumption VDD18 [mA]
	Chip deep sleep (L1.2)	1.21
2.4 GHz	IEEE Power Save: DTIM1	7.88
	IEEE Power Save: DTIM3	4.29
	IEEE Power Save: DTIM5	3.57
5 GHz	IEEE Power Save: DTIM1	6.41
	IEEE Power Save: DTIM3	3.80
	IEEE Power Save: DTIM5	3.28

5.3.2 Bluetooth

- Conditions
  - VDD33 = 3.3V, VDD18 = 1.8V, VIO = 1.8V
  - Platform: NXP MCIMX8MQuad-EVK
  - Combo FW: 17.26.1.p109
  - Bluetooth I/F: UART

Table 16 describes the typical sleep current consumption for Bluetooth.

Table 16: Typical Sleep Current Consumption - Bluetooth

Mode	Current consumption VDD18 [mA]
Deep Sleep (BT Only)	1.51
BT Page Scan 1.28 s	1.61
BT Page & Inquiry Scan 1.28 s	1.51
BT Master Sniff mode 1.28 s	1.79
Advertise 1 s	1.29
BLE Scan 1.28 s	1.44
LE Link Master 1 s	1.77

5.4 Throughput

This section describes the typical and concurrent throughput communications.

5.4.1 Typical Throughput

The typical throughput test configurations are:

- VDD33 = 3.3V, VDD18 = 1.8V, VIO = 1.8V
- Platform: NXP MCIMX8MQuad-EVK
- Combo FW: 17.68.1.p81
- Access Point: RT-AX88U (ASUS)
- Distance between Access Point and the Target is around 3 ft.
- UDP commands：Bit rate was set at more than 20% of observed corresponding TCP throughput.

  Sample UDP command:

```
iperf3 <server-ip-addr> -u -b <20%-of-TCP>M -P1 -t 60
```

Table 17 shows the typical throughput data for the modules.

Table 17: WLAN Typical Throughput Data

Mode	TCP Throughput in Mbps		UDP Throughput in Mbps	
	Tx	Rx	Tx	Rx
2.4 GHz 11ax HE40 MIMO	318	311	340	363
5 GHz 11ax HE80 MIMO	879	668	934	947

5.4.2 Concurrent Throughput

- Conditions
  - VDD33 = 3.3V, VDD18 = 1.8V, VIO = 1.8V
  - Platform: NXP MCIMX8MQuad-EVK
  - Combo FW: 17.68.1.p81
  - Access Point: 2.4 GHz RT-AX88U (ASUS)
    5 GHz Nighthawk AX12 (NETGEAR)
  - Distance between Access Point and the Target is around 3 ft.
  - UDP commands: Bit rate was set at more than 20% of observed corresponding TCP throughput.

    Sample UDP command:

```
iperf3 <server-ip-addr> -u -b <20%-of-TCP>M -P1 -t 60
```

Table 18, Table 19, Table 20, and **Table 21** shows the WLAN concurrent throughput data for the modules.

Table 18: WLAN Concurrent Throughput: STA (2.4 GHz) - STA (5 GHz) Configuration

Mode	TCP Throughput in Mbps		UDP Throughput in Mbps	
	Tx	Rx	Tx	Rx
STA 2.4 GHz 11n HT40 MIMO	228	206	238	230
STA 5 GHz 11ax HE 80 MIMO	854	683	954	813

Table 19: WLAN Concurrent Throughput: STA (2.4 GHz) - AP (5 GHz) Configuration

Mode	TCP Throughput in Mbps		UDP Throughput in Mbps	
	Tx	Rx	Tx	Rx
STA 2.4 GHz 11n HT40 MIMO	225	226	255	202
AP 5 GHz 11ax HE 80 MIMO	709	569	915	783

Table 20: WLAN Concurrent Throughput: AP (2.4 GHz) - STA (5 GHz) Configuration

Mode	TCP Throughput in Mbps		UDP Throughput in Mbps	
	Tx	Rx	Tx	Rx
STA 2.4 GHz 11n HT40 MIMO	222	216	229	221
AP 5 GHz 11ax HE 80 MIMO	820	738	925	920

Table 21: WLAN Concurrent Throughput: AP (2.4 GHz) - AP (5 GHz) Configuration

Mode	TCP Throughput in Mbps		UDP Throughput in Mbps	
	Tx	Rx	Tx	Rx
STA 2.4 GHz 11n HT40 MIMO	219	200	219	220
AP 5 GHz 11ax HE 80 MIMO	727	680	944	889

6 References

Table 22 reviews all the key reference documents that the user may like to refer to.

Table 22: Reference Table

Support Site	Notes
Murata Type 1XL Module Datasheet	Murata Type 1XL module datasheet (type1xl.pdf)
Murata Type 2XS Module Datasheet	Murata Type 2XS module datasheet (TYPE2XS.pdf)
Murata Type 1XL Module Footprint	Murata Type 1XL module footprint (type1xl_module_footprint_topview.dxf)
Murata Type 1XL Antenna	Murata Type 1XL module antenna (Type1XL-u-FL.dxf)
Murata's GitHub	Murata GitHub link for Linux transmit power files
wireless-regdb	Regulatory database used by Linux
Linux User Guide	Murata Linux User Guide for NXP modules (Murata Wi-Fi & BT (NXP) Solution for i.MX Linux User Guide.pdf). Murata website to be updated soon.

In case Murata website does not have the updated document, please refer to the Connectivity Module page on the Murata Community Forum. This contains a pinned post with all the updated documents on top.

7 Technical Support Contacts

Table 23 lists all the support resources available for the Murata Wi-Fi/BT solution.

Table 23: List of Support Resources

Support Site	Notes
Murata Community Forum	**Primary support point for technical queries.** This is an open forum for all customers. Registration is required.
Murata i.MX Landing Page	No login credentials required. Murata documentation covering hardware, software, testing, etc. is provided here.
Murata uSD-M.2 Adapter Landing Page	Landing page for uSD-M.2 Adapter. In conjunction with Murata i.MX Landing Page, this should provide the user with comprehensive getting started documentation.
Murata Module Landing Page	No login credentials required. Murata documentation covering all Infineon-based Wi-Fi/BT modules is provided here.

Revision History

Revision Code	Date	Description	Comments
1.0	Aug 29, 2022	Initial Release	
2.0	Jan 16, 2023	Updated to new format	
3.0	Jan 26, 2023	Updated 1XL reference circuit