AN14463

Antenna Diversity

Rev. 1.0 — 24 January 2025 Application note

Document information

Information	Content
Keywords	Antenna, Wi-Fi, Bluetooth, Bluetooth LE, 802.15.4, diversity, single antenna, dual antenna, front-end, radio performance
Abstract	Explains antenna diversity feature, single antenna design, and dual antenna design.

1 About this document

Antenna diversity feature is used to improve and optimize the signal quality. The front-end design includes two or more antennas to reduce the effects of interference. This document explains the different types of RF front-end antenna configurations with and without antenna diversity. Each design has specific benefits related to cost, radio priority, and more. Contact your NXP representative for more information and guidance on which design is best suited to your application.

1.1 Supported devices

This document applies to the following wireless SoCs:

- IW416
- IW610
- AW611
- IW611
- IW612
- 88W8987
- RW610
- RW612
- 88W8801

2 Wi-Fi antenna diversity algorithm

Antenna diversity is used to determine the best suited antenna for real time performance. The feature can be enabled by firmware when the NXP wireless SoC is in client mode. The firmware must evaluate and compare each antenna at a set evaluation interval to determine which antenna best fits the environmental condition. At every evaluation interval, the firmware checks the performance of each antenna for the following parameters:

- TX frame error rate (FER)
- RX signal to noise ratio (SNR)
- Number of missed beacons

The evaluation interval is user configurable and dynamic. By default, the evaluation interval is set to trigger every 6 seconds but the interval may scale with the SNR measured on the current antenna.

- 10 < SNR < 40: user configured time (the default is 6 seconds)
- SNR ≤ 10: 0.5x of user configured time (the default is 3 seconds)
- SNR ≤ 5: 0.25x of user configured time (the default is 1.5 seconds)
- SNR ≥ 40: 2x of user configured time (the default is 12 seconds)

The firmware compares the measurement of each antenna parameters (FER, SNR, and number of missed beacons), and selects the best antenna based on the following:

- If the difference between the two antenna FER values is greater than 5% over 100 TX attempts, the antenna with the lowest FER is selected.
- If the difference between the two antenna SNR is greater than 3 dB, the antenna with the highest SNR is selected.
- If the difference between the number of missed beacons between the two antennas is greater than five beacons, the antenna with the lowest number of missed beacons is selected.

The selected antenna is used until the next evaluation interval, when the evaluation and comparison cycle is repeated.

Figure 1 illustrates the antenna diversity algorithm.

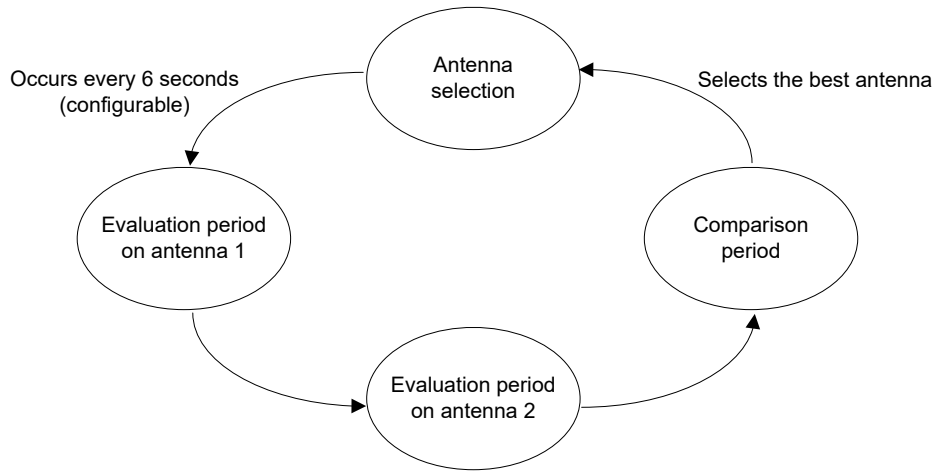

Figure 1. Illustration of antenna diversity algorithm

3 Front-end configurations

The antenna diversity setup depends on the front-end design. This document covers the following front-end designs:

- Single-antenna design
- Dual-antenna design

3.1 Single-antenna design

In a single-antenna design, the Wi-Fi and Bluetooth/802.15.4 radios share the same antenna.

- A single pole double throw (SPDT) switch is used between the 2.4 GHz Wi-Fi and Bluetooth/802.15.4 radios.
- A diplexer is used between the 5 GHz Wi-Fi radio and SPDT switch.

Figure 2 illustrates a single-antenna design without diversity.

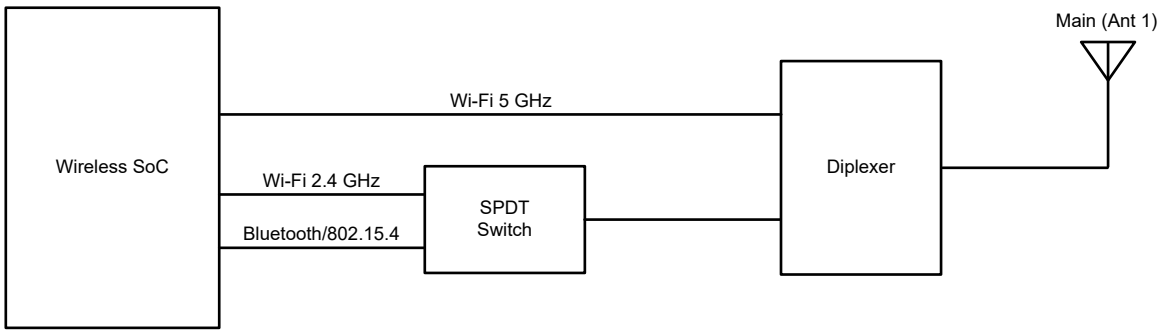

Figure 2. Single-antenna design without diversity

To enable antenna diversity on a single antenna design, an additional SPDT diversity switch and auxiliary antenna are required. The additional SPDT switch is used to select the best antenna based on the firmware algorithm (Section 2).

Figure 3 illustrates a single-antenna design with diversity.

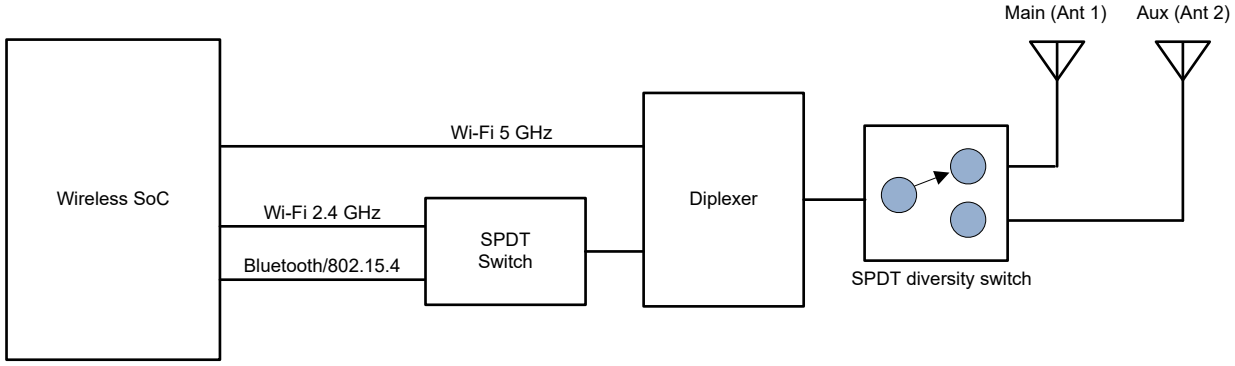

Figure 3. Single antenna design with diversity

3.2 Dual-antenna design

In a dual-antenna design, the Wi-Fi and Bluetooth/802.15.4 radios use separate antennas. The operation of the Wi-Fi and Bluetooth/802.15.4 radios is simultaneous given the appropriate antenna isolation.

- The diplexer between the Wi-Fi radio and the antenna is used for the 2.4 GHz and 5 GHz RF paths.
- The Bluetooth/802.15.4 radio uses a separate antenna.

Figure 4 illustrates a dual-antenna design without diversity.

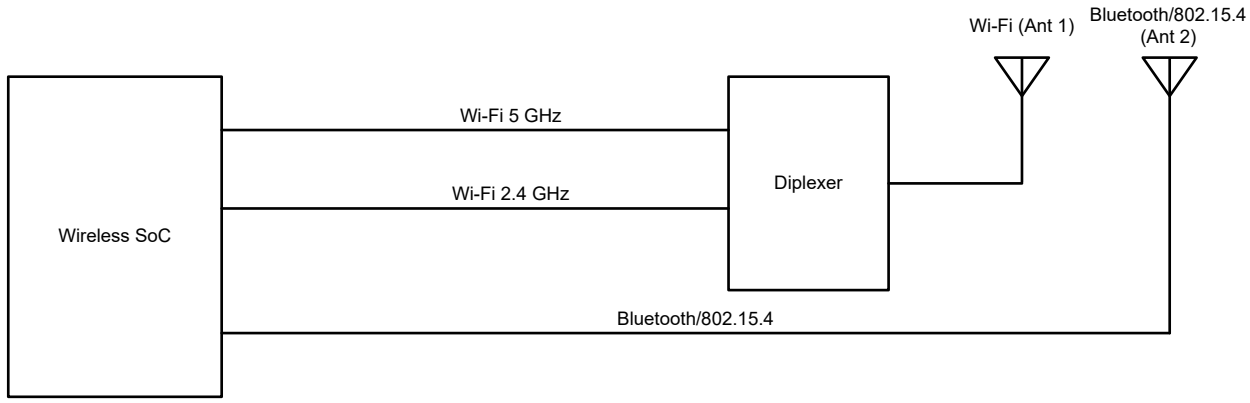

Figure 4. Dual-antenna design without diversity

To enable antenna diversity on a dual-antenna design, an additional double pole double throw (DPDT) switch is added after the diplexer. The DPDT switch is used to select the best antenna based on the antenna diversity algorithm. When the Wi-Fi and Bluetooth/802.15.4 radios operate simultaneously, the firmware allocates the best antenna to the Wi-Fi radio. The DPDT switch allocates the other antenna to the Bluetooth/802.15.4 radio.

Figure 5 illustrates a dual-antenna design with diversity.

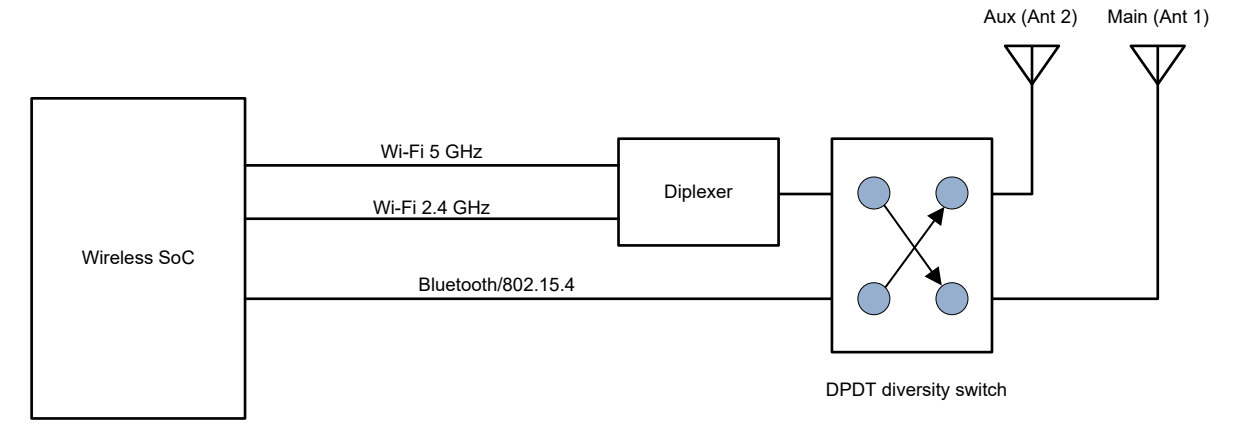

Figure 5. Dual-antenna design with diversity

The dual-antenna design can also include an auxiliary Wi-Fi antenna that supports diversity, and a separate antenna for Bluetooth/802.15.4 radio without antenna diversity. In this configuration, the Wi-Fi and Bluetooth/802.15.4 radios can operate simultaneously given the appropriate antenna isolation.

- An SPDT diversity switch is used to select the best antenna for Wi-Fi.
- The Bluetooth/802.15.4 radio operates on a separate antenna.

Figure 6 illustrates the dual-antenna design with the auxiliary Wi-Fi antenna thaht supports diversity.

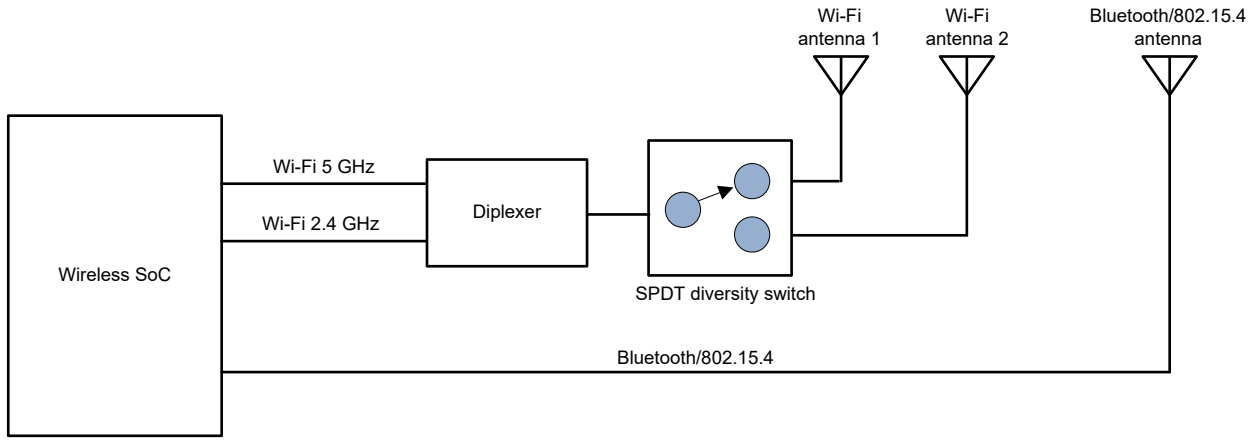

Figure 6. Dual-antenna design with auxiliary Wi-Fi antenna and diversity

4 RF Front-end (FE) switch setting configuration

The Wi-Fi and Bluetooth/802.15.4 front-end parameters are configurable using the calibration data. The front-end parameters are used:

- To enable antenna diversity.
- To configure the RF controls of the SPDT or DPDT switch.

Use additional parameters in the calibration data to optimize the radio transmit power and reduce TX frame error rate (FER), RX signal to noise ratio (SNR), and the number of missed beacons. Refer to [1], [2], [3], [4], [5], or [6].

5 Enabling antenna diversity

Antenna diversity is enabled by software during runtime. The procedure depends on the operating system of the host device.

5.1 Linux and Android

To enable antenna diversity on an NXP wireless SoC with a Linux/Android host platform:

- Wait for the firmware download to complete.
- Go to the directory with the configuration file of the wireless SoC. The path is */proc/mwlan/adapter0/config*.
- Issue the command to set the antenna configuration.

```
echo "antcfg=<Antenna mode> <Evaluation interval (ms)>" > /proc/mwlan/adapter0/config
```

Table 1. Command parameters

Parameter	Description
`Antenna mode`	Antenna mode for TX/RX 0x1 = RF path set to Antenna 1 (disable antenna diversity) 0x2 = RF path set to Antenna 2 (disable antenna diversity) 0xffff = Enable antenna diversity
`Evaluation interval`	Evaluation interval in milliseconds (ms) Enter interval as a hexadecimal number The default value is 0x1770 (6000 ms) ***Note:*** *This parameter is only needed when* `Antenna mode` *is set to 0xffff.*

Example of command to enable antenna diversity with a 6 second evaluation interval:

```
echo "antcfg=0xffff" > /proc/mwlan/adapter0/config
```

Example of command to disable antenna diversity and set TX/RX path to Antenna 1:

```
echo "antcfg=1" > /proc/mwlan/adapter0/config
```

Command to readback the antenna diversity configuration:

```
cat /proc/mwlan/adapter0/config
```

Example of command readback:

```
hardware_status=0
netlink_num=31
drv_mode=7
hssetpara=7,0xff,200,400
sdcmd52rw=0 0x0 0x00
rf_test_mode=0
antcfg=0xffff 6000 1
```

The values in bold show that antenna diversity is enabled with a 6000ms evaluation time and the current antenna is set to 1.

5.2 FreeRTOS

To enable antenna diversity on the wireless SoC with a FreeRTOS host platform:

- Wait for the firmware download to complete.
- Issue the command to set the antenna configuration.

```
wlan-set-antcfg <Antenna mode> <Evaluation interval>
```

Table 2. Command parameters

Parameter	Description
`Antenna mode`	Antenna mode for TX/RX 0x1 = RF path set to Antenna 1 (disable antenna diversity) 0x2 = RF path set to Antenna 2 (disable antenna diversity) 0xffff = enable antenna diversity
`Evaluation interval`	Evaluation interval in milliseconds (ms) Enter interval as a decimal number The default value is 6000 ***Note:*** *This parameter is only needed when* `Antenna mode` *is set to 0xffff.*

Example of command to enable antenna diversity with a 6 second evaluation interval:

```
wlan-set-antcfg 0xffff
```

Example of command to disable antenna diversity and set TX/RX path to Antenna 1:

```
wlan-set-antcfg 1
```

Command to readback the antenna diversity configuration:

```
wlan-get-antcfg
```

Example of command readback:

```
Mode of Tx/Rx path is : ffff
Evaluate time : 6000
Default diversity mode.
Current antenna is Ant1
```

The return values in bold show that antenna diversity is enabled with a 6000 ms evaluation time and current antenna set to 1.

6 Abbreviations

Table 3. Abbreviations

Abbreviation	Definition
Ant	antenna
DPDT	double dipole pole throw
FE	front-end
FEM	front-end module
FER	frame error rate
LE	low energy
SDPT	single dipole pole throw
SNR	signal to noise ratio

7 References

[1] Application note – 88W8801 Calibration Structure (link)
[2] Application note – 88W8987 Calibration Structure (link)
[3] Application note – AN12794: IW416 Calibration Structure (link)
[4] Application note – AN13983: Calibration Structure for AW611, IW611, and IW612 (link)
[5] Application note – AN13639: Calibration Structure for RW61x
[6] Application note – AN14308: Calibration Structure for IW610 (link)

8 Note about the source code in the document

The example code shown in this document has the following copyright and BSD-3-Clause license:

Copyright 2025 NXP Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials must be provided with the distribution.
3. Neither the name of the copyright holder nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

9 Revision history

Table 4. Revision history

Document ID	Release date	Description
AN14463 v.1.0	24 January 2025	• Initial version

Legal information

Definitions

Draft — A draft status on a document indicates that the content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included in a draft version of a document and shall have no liability for the consequences of use of such information.

Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. NXP Semiconductors takes no responsibility for the content in this document if provided by an information source outside of NXP Semiconductors.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Terms and conditions of commercial sale of NXP Semiconductors.

Right to make changes — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

Terms and conditions of commercial sale — NXP Semiconductors products are sold subject to the general terms and conditions of commercial sale, as published at https://www.nxp.com/profile/terms, unless otherwise agreed in a valid written individual agreement. In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. NXP Semiconductors hereby expressly objects to applying the customer's general terms and conditions with regard to the purchase of NXP Semiconductors products by customer.

Suitability for use in automotive applications — This NXP product has been qualified for use in automotive applications. If this product is used by customer in the development of, or for incorporation into, products or services (a) used in safety critical applications or (b) in which failure could lead to death, personal injury, or severe physical or environmental damage (such products and services hereinafter referred to as "Critical Applications"), then customer makes the ultimate design decisions regarding its products and is solely responsible for compliance with all legal, regulatory, safety, and security related requirements concerning its products, regardless of any information or support that may be provided by NXP. As such, customer assumes all risk related to use of any products in Critical Applications and NXP and its suppliers shall not be liable for any such use by customer. Accordingly, customer will indemnify and hold NXP harmless from any claims, liabilities, damages and associated costs and expenses (including attorneys' fees) that NXP may incur related to customer's incorporation of any product in a Critical Application.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

HTML publications — An HTML version, if available, of this document is provided as a courtesy. Definitive information is contained in the applicable document in PDF format. If there is a discrepancy between the HTML document and the PDF document, the PDF document has priority.

Translations — A non-English (translated) version of a document, including the legal information in that document, is for reference only. The English version shall prevail in case of any discrepancy between the translated and English versions.

Security — Customer understands that all NXP products may be subject to unidentified vulnerabilities or may support established security standards or specifications with known limitations. Customer is responsible for the design and operation of its applications and products throughout their lifecycles to reduce the effect of these vulnerabilities on customer's applications and products. Customer's responsibility also extends to other open and/or proprietary technologies supported by NXP products for use in customer's applications. NXP accepts no liability for any vulnerability. Customer should regularly check security updates from NXP and follow up appropriately.

Customer shall select products with security features that best meet rules, regulations, and standards of the intended application and make the ultimate design decisions regarding its products and is solely responsible for compliance with all legal, regulatory, and security related requirements concerning its products, regardless of any information or support that may be provided by NXP.

NXP has a Product Security Incident Response Team (PSIRT) (reachable at PSIRT@nxp.com) that manages the investigation, reporting, and solution release to security vulnerabilities of NXP products.

NXP B.V. — NXP B.V. is not an operating company and it does not distribute or sell products.

Trademarks

Notice: All referenced brands, product names, service names, and trademarks are the property of their respective owners.

NXP — wordmark and logo are trademarks of NXP B.V.

Bluetooth — the Bluetooth wordmark and logos are registered trademarks owned by Bluetooth SIG, Inc. and any use of such marks by NXP Semiconductors is under license.

Tables

Figures

Contents