

# Application Note

## DA14531 Filter for Spurious Emissions Reduction

### AN-B-073

#### **Abstract**

*This document contains guidelines for implementing a RFIO filter to reduce conducted and radiated spurious emissions in Bluetooth low energy applications using Dialog's DA14531 System-on-Chip.*

---

## Contents

<b>Abstract</b> .....	<b>1</b>
<b>Contents</b> .....	<b>2</b>
<b>Figures</b> .....	<b>2</b>
<b>Tables</b> .....	<b>2</b>
<b>1 Terms and Definitions</b> .....	<b>3</b>
<b>2 References</b> .....	<b>3</b>
<b>3 Introduction</b> .....	<b>4</b>
<b>4 Filter Configuration</b> .....	<b>4</b>
4.1 Pi Filter .....	4
4.2 Simulated Performance.....	5
4.3 Measured Performance.....	5
<b>5 Conducted Performance</b> .....	<b>6</b>
5.1 TX Measurements .....	6
5.1.1 Conducted Limits .....	6
5.1.2 Measurement Results .....	6
5.2 RX Measurements .....	6
5.2.1 Conducted Limits .....	6
5.2.2 Measurement Results .....	6
<b>6 Radiated Performance</b> .....	<b>7</b>
6.1 TX Measurements .....	8
6.2 RX Measurements .....	9
<b>7 Other Remarks</b> .....	<b>9</b>
7.1 Impact on Power Consumption .....	9
7.2 Impact on Link Budget .....	9
<b>8 Conclusions</b> .....	<b>10</b>
<b>Revision History</b> .....	<b>11</b>

## Figures

Figure 1: Pi Filter Topology .....	4
Figure 2: Transfer Function and Return Loss of Pi Filter .....	5
Figure 3: Measurement Results of the Pi-filter .....	5
Figure 4: DUT on a Turning Table.....	7
Figure 5: Experiment Setup for Measuring Radiated Performance .....	7
Figure 6: ETSI EN 300 328 - Transmitter Unwanted Emissions in the Spurious Domain .....	8
Figure 7: Part 15.247 - Spurious Emissions Radiated at from 1 GHz to 18 GHz .....	8
Figure 8: ETSI EN 300 328 - Receiver Spurious Emissions .....	9
Figure 9: Schematic of Example Implementation of Pi Filter to DA14531 .....	10

## Tables

Table 1: Specification Limits for Conducted TX Measurements .....	6
Table 2: Fundamental Power and Harmonics, Conducted Mode, PA in 3 dBm Mode .....	6
Table 3: Specification Limits for Conducted RX Measurements .....	6
Table 4: LO Leakage in Conducted Mode Results .....	6

## 1 Terms and Definitions

SoC	System on Chip
BLE	Bluetooth Low Energy
DUT	Device under Test
SDK	Software Development Kit

## 2 References

- [1] [UM-B-083](#), SmartSnippets™ Toolbox, User Manual, Dialog Semiconductor.
- [2] [UM-B-119](#), DA14585/DA14531 SW Platform Reference Manual, Dialog Semiconductor.

### 3 Introduction

This document provides information on implementing a 3-component Pi filter for Dialog's DA14531 System-on-Chip (SoC) in 2.4 GHz Bluetooth low energy (BLE) applications. It specifically addresses the conducted performance in the spurious domain.

### 4 Filter Configuration

A range of different filter configurations have been considered and assessed in terms of performances, costs, and sizes. The assessment concluded that the best configuration was a Pi filter. The Pi filter configuration was chosen because it gave the best harmonic suppression with minimal power loss at fundamental frequencies. Lower cost solutions were eliminated because they did not deliver the same level of suppression whilst having greater impact on power loss. The size of the components is not critical, but to implement a small footprint, filter 0201 components have been used.

#### 4.1 Pi Filter

The filter topology is shown in [Figure 1](#).

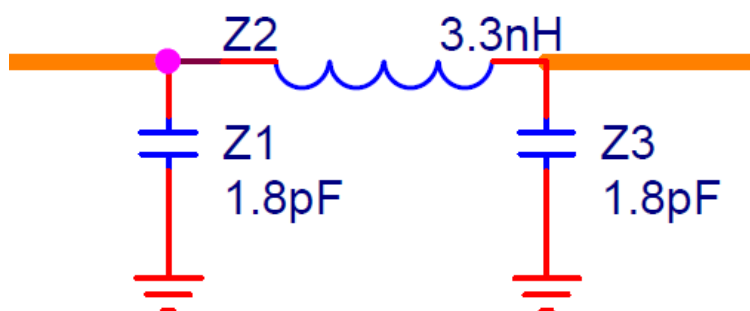


Figure 1: Pi Filter Topology

The components used include:

- Capacitors: 1.8 pF, 0201, Murata, PN: GRM0335C1H1R8CA01
- Inductor: 3.3 nH, 0201, Murata, PN: LQP03TN3N3B02

### 4.2 Simulated Performance

Transfer function and return loss are shown in Figure 2.

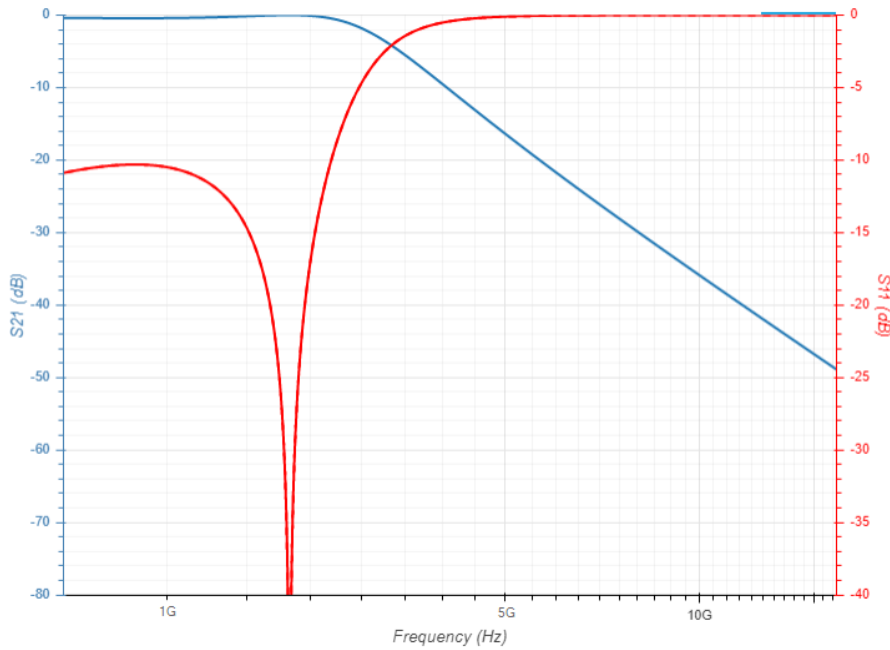


Figure 2: Transfer Function and Return Loss of Pi Filter

The simulated loss at fundamental power is ~0.35 dB while providing a second harmonic suppression of ~15 dB.

### 4.3 Measured Performance

The influence of the daughter board on the filter function was measured with a calibrated network analyzer connected via SMA connectors to the filter on the daughter board.

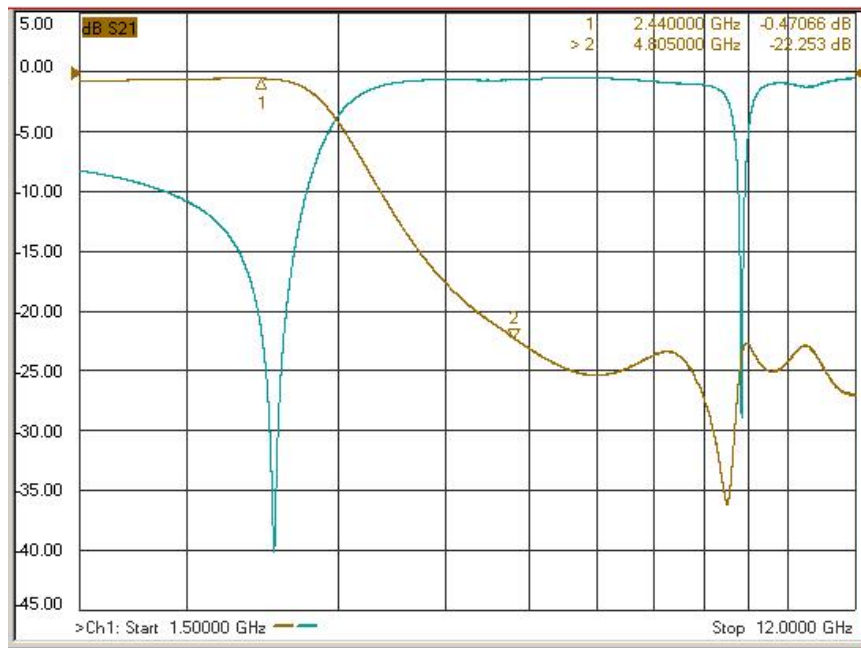


Figure 3: Measurement Results of the Pi-filter

## 5 Conducted Performance

The measurements are performed using a calibrated spectrum analyzer and RF cables. The levels are measured at the SMA output of the device under test (DUT). All measurements are calibrated for cable losses.

The production test software (`prod_test.hex`) from Dialog's DA14531 SDK is used to set the device into BLE TX and RX mode. This can be done with RF master of [SmartSnippets](#) Toolbox or with `prodtest.exe` using the commands "`cont_pkt_tx`" and "`start_pkt_rx`" (see [\[1\]](#) and [Appendix J](#) in [\[2\]](#)).

### 5.1 TX Measurements

#### 5.1.1 Conducted Limits

There are different limits specified for the conducted TX measurements. [Table 1](#) shows the limits for ETSI, FCC, and Japan.

**Table 1: Specification Limits for Conducted TX Measurements**

Measurement	ETSI	FCC	Japan
TX Conducted	-30 dBm	-20 dBc	-26 dBm

#### 5.1.2 Measurement Results

The test is performed at 2402 MHz, room temperature, and normal operating conditions. Measurements are done in burst mode, modulated signal.

**Table 2: Fundamental Power and Harmonics, Conducted Mode, PA in 3 dBm Mode**

	Fundamental	2nd harm	3rd harm	4th harm	5th harm
Without RFIO filter	2.2	-40.16	-40.75	-47.58	-39.26
With RFIO filter	1.54	-58.99	-61.27	-68.95	-56.15

**Note 1** All values in dBm.

### 5.2 RX Measurements

#### 5.2.1 Conducted Limits

Limits for the conducted RX measurements can be found in [Table 3](#).

**Table 3: Specification Limits for Conducted RX Measurements**

Measurement	ETSI	Japan	Korea
RX conducted	-47 dBm	-47 dBm	-54 dBm

#### 5.2.2 Measurement Results

The test is performed at 2402 MHz and the measurement frequency is 4805 MHz ( $2 \times 2402 + 1$  MHz).

**Table 4: LO Leakage in Conducted Mode Results**

Measurement	Without RFIO filter	With RFIO filter
LO Leakage Power	-41.33 dBm	-58.78 dBm

## 6 Radiated Performance

The measurements are performed in an anechoic chamber using a standard wideband horn antenna at the reference receiver. The DUT is placed on a turning table 3 meters away from the antenna. The measurements include the DUT board in horizontal and vertical position and both vertical and horizontal polarizations are measured. The maximum value is recorded.

All measurements are calibrated for antenna gain, amplifier gain, cable losses and path losses.

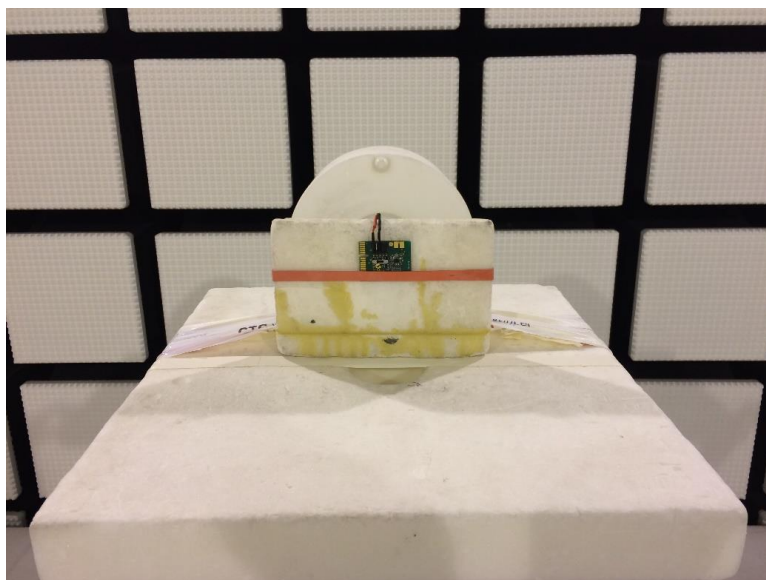


Figure 4: DUT on a Turning Table

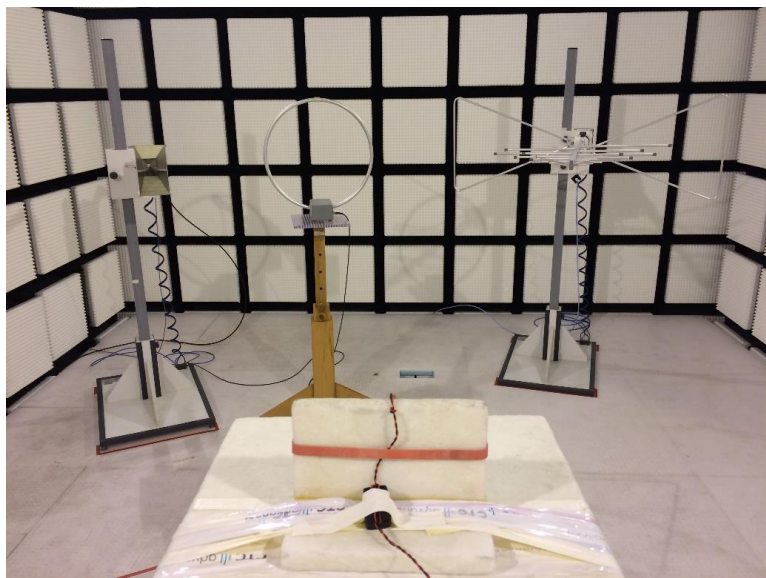


Figure 5: Experiment Setup for Measuring Radiated Performance

### 6.1 TX Measurements

The test is performed at 2402 MHz, room temperature, and normal operating conditions. The carrier signal is notched with a 2.4 GHz band rejection filter. The red lines in Figure 6 and Figure 7 indicate the specification limits. The DUT with the Pi filter has good margins towards the limits.

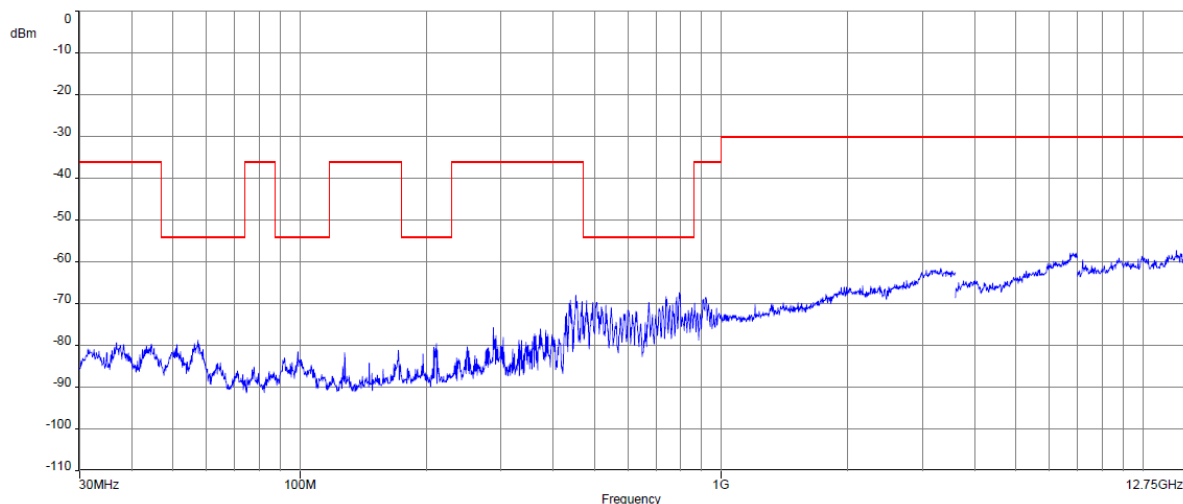


Figure 6: ETSI EN 300 328 - Transmitter Unwanted Emissions in the Spurious Domain

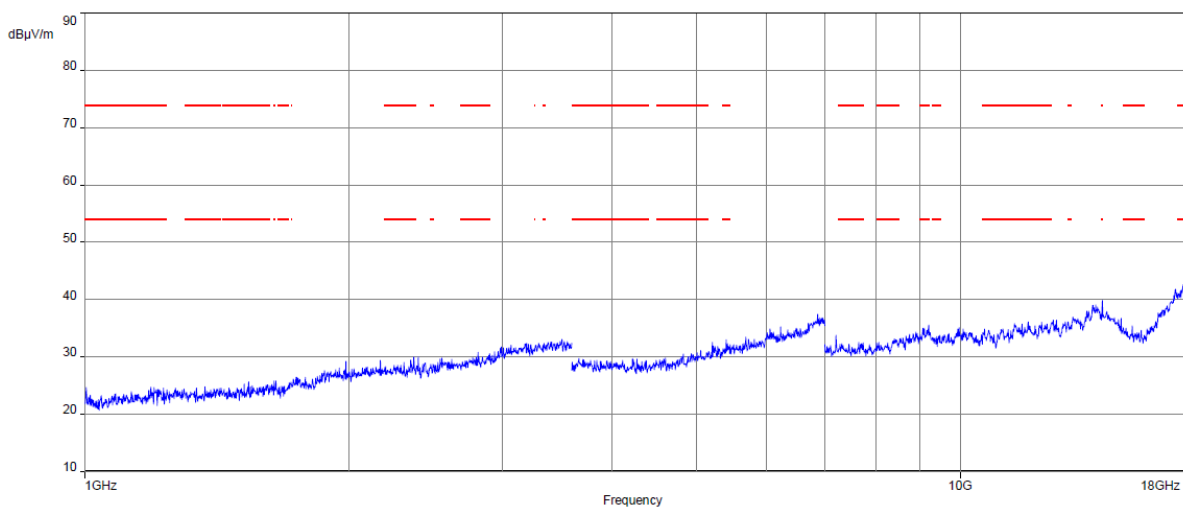


Figure 7: Part 15.247 - Spurious Emissions Radiated at from 1 GHz to 18 GHz



## 6.2 RX Measurements

The test is performed at 2402 MHz, room temperature, and normal operating conditions. The red line in Figure 8 indicates the specification limit. The DUT with the Pi filter has a good margin towards the limit.

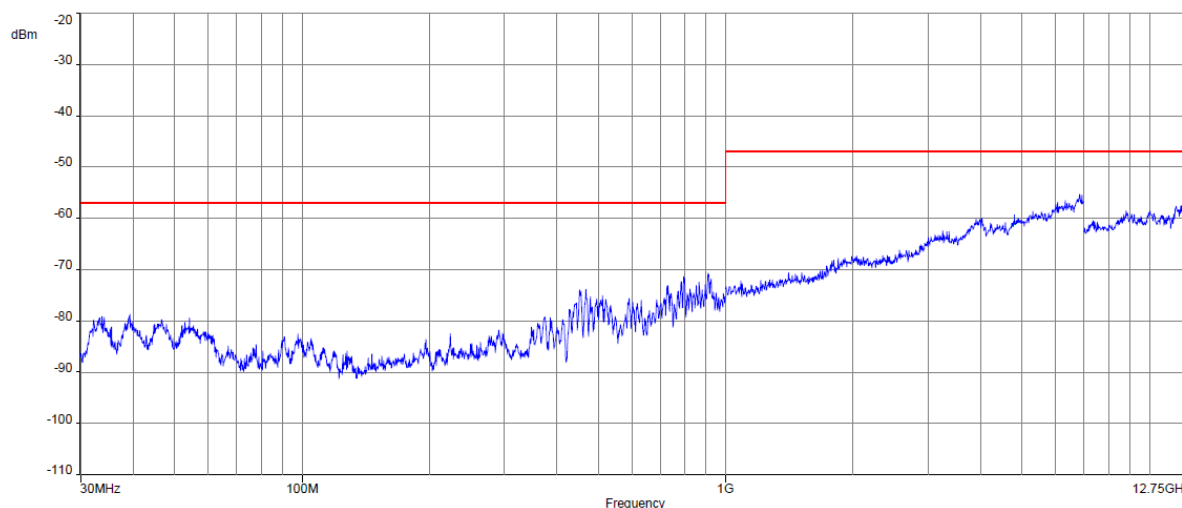


Figure 8: ETSI EN 300 328 - Receiver Spurious Emissions

## 7 Other Remarks

### 7.1 Impact on Power Consumption

The Pi filter shows no impact on the power consumption of DA14531 SoC.

### 7.2 Impact on Link Budget

The additional filter introduces <math><0.5\text{ dB}</math> loss on the fundamental power and the same loss is incurred on sensitivity. The total impact on link budget is <math><1\text{ dB}</math>.

## 8 Conclusions

The RFIO filter provides a good harmonic suppression with a minimal loss at fundamental frequencies. Dialog recommends that users include the described filter in the DA14531 design in order to pass the tests from regulatory bodies. The filter should be placed as close as possible to the RFIOp port. A schematic of an example implementation can be found in [Figure 9](#). The shown antenna matching is chosen to match the implemented antenna to 50 Ω and will change if a different antenna is used. Experienced RF designers should be able to combine the antenna matching with the needed filtering.

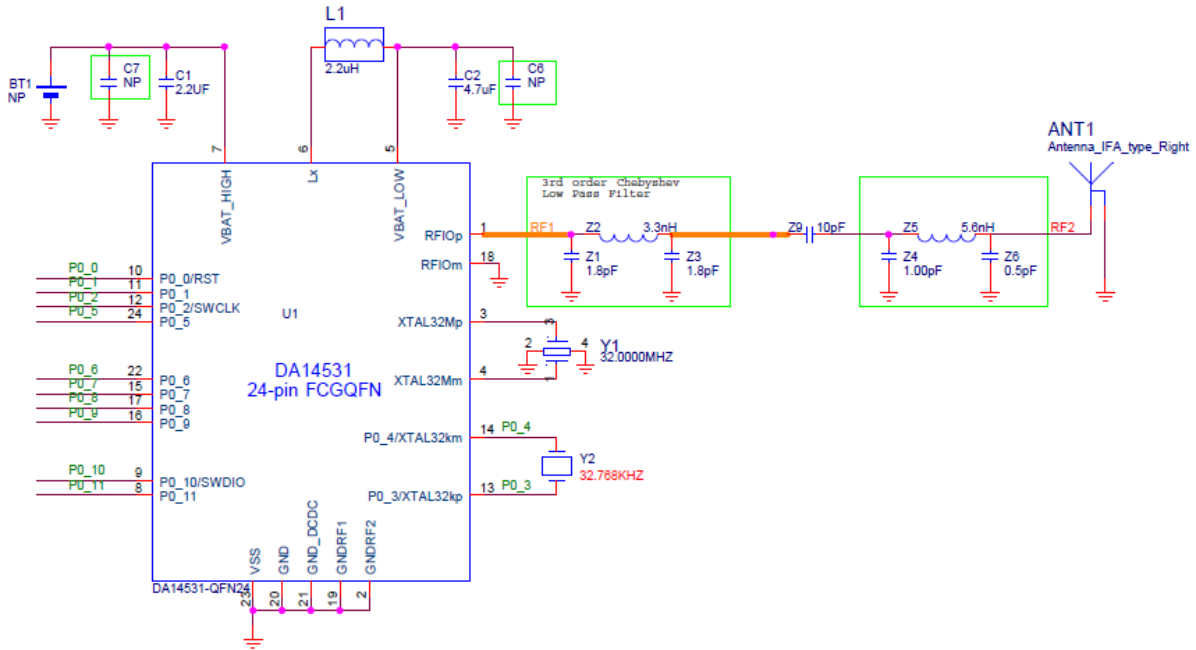


Figure 9: Schematic of Example Implementation of Pi Filter to DA14531

**Revision History**

<b>Revision</b>	<b>Date</b>	<b>Description</b>
1.0	09-Jul-2019	Initial version.
1.1	25-Oct-2019	Editorial changes
1.2	30-Oct-2019	Link changed

### Status Definitions

Status	Definition
DRAFT	The content of this document is under review and subject to formal approval, which may result in modifications or additions.
APPROVED or unmarked	The content of this document has been approved for publication.

### Disclaimer

Unless otherwise agreed in writing, the Dialog Semiconductor products (and any associated software) referred to in this document are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of a Dialog Semiconductor product (or associated software) can reasonably be expected to result in personal injury, death or severe property or environmental damage. Dialog Semiconductor and its suppliers accept no liability for inclusion and/or use of Dialog Semiconductor products (and any associated software) in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

Information in this document is believed to be accurate and reliable. However, Dialog Semiconductor does not give any representations or warranties, express or implied, as to the accuracy or completeness of such information. Dialog Semiconductor furthermore takes no responsibility whatsoever for the content in this document if provided by any information source outside of Dialog Semiconductor.

Dialog Semiconductor reserves the right to change without notice the information published in this document, including, without limitation, the specification and the design of the related semiconductor products, software and applications. Notwithstanding the foregoing, for any automotive grade version of the device, Dialog Semiconductor reserves the right to change the information published in this document, including, without limitation, the specification and the design of the related semiconductor products, software and applications, in accordance with its standard automotive change notification process.

Applications, software, and semiconductor products described in this document are for illustrative purposes only. Dialog Semiconductor makes no representation or warranty that such applications, software and semiconductor products will be suitable for the specified use without further testing or modification. Unless otherwise agreed in writing, such testing or modification is the sole responsibility of the customer and Dialog Semiconductor excludes all liability in this respect.

Nothing in this document may be construed as a license for customer to use the Dialog Semiconductor products, software and applications referred to in this document. Such license must be separately sought by customer with Dialog Semiconductor.

All use of Dialog Semiconductor products, software and applications referred to in this document is subject to Dialog Semiconductor's [Standard Terms and Conditions of Sale](http://www.dialog-semiconductor.com), available on the company website ([www.dialog-semiconductor.com](http://www.dialog-semiconductor.com)) unless otherwise stated.

Dialog, Dialog Semiconductor and the Dialog logo are trademarks of Dialog Semiconductor Plc or its subsidiaries. All other product or service names and marks are the property of their respective owners.

© 2019 Dialog Semiconductor. All rights reserved.

## Contacting Dialog Semiconductor

#### United Kingdom (Headquarters)

*Dialog Semiconductor (UK) LTD*  
Phone: +44 1793 757700

#### Germany

*Dialog Semiconductor GmbH*  
Phone: +49 7021 805-0

#### The Netherlands

*Dialog Semiconductor B.V.*  
Phone: +31 73 640 8822

#### Email:

[enquiry@diasemi.com](mailto:enquiry@diasemi.com)

#### North America

*Dialog Semiconductor Inc.*  
Phone: +1 408 845 8500

#### Japan

*Dialog Semiconductor K. K.*  
Phone: +81 3 5769 5100

#### Taiwan

*Dialog Semiconductor Taiwan*  
Phone: +886 281 786 222

#### Web site:

[www.dialog-semiconductor.com](http://www.dialog-semiconductor.com)

#### Hong Kong

*Dialog Semiconductor Hong Kong*  
Phone: +852 2607 4271

#### Korea

*Dialog Semiconductor Korea*  
Phone: +82 2 3469 8200

#### China (Shenzhen)

*Dialog Semiconductor China*  
Phone: +86 755 2981 3669

#### China (Shanghai)

*Dialog Semiconductor China*  
Phone: +86 21 5424 9058