EFR32FG14 2400/490 MHz Dual Band 19 dBm Radio Board BRD4258A Reference Manual

The BRD4258A Flex Gecko Radio Board enables developers to develop proprietary wireless applications. The board contains a dual-band Flex Gecko Wireless System-on-Chip and it is optimized for operating at 19 dBm output power. For the 2.4 GHz band with the on-board printed antenna and UFL connector, radiated and conducted testing is supported. For the 490 MHz band, the on-board SMA connector enables conducted testing and attachment of external whip antenna for radiated tests.

The BRD4258A Flex Gecko Radio Board plugs into the Wireless Starter Kit Mainboard, which is included with the Flex Gecko Starter Kit and gives access to display, buttons and additional features from Expansion Boards. With the supporting Simplicity Studio suite of tools, developers can take advantage of graphical wireless application development and visual energy profiling and optimization. The board also serves as an RF reference design for applications targeting 2.4 GHz and 490 MHz dual band wireless operation with 19 dBm output power.

This document contains a brief introduction and description of the BRD4258A Radio Board features, focusing on the RF sections and performance.

RADIO BOARD FEATURES

- Wireless SoC: EFR32FG14P233F256GM48
  - CPU core: ARM Cortex®-M4 with FPU
  - Flash memory: 256 kB
  - RAM: 32 kB
- Operation frequency: 2.4 GHz + 490 MHz
- Transmit power: 19 dBm
- 2.4 GHz: Integrated PCB antenna, UFL connector (optional)
- 490 MHz: Single SMA connector both for transmit and receive
- Crystals for LFXO and HFXO: 32.768 kHz and 38.4 MHz
- 8 Mbit low-power serial flash for over-the-air updates

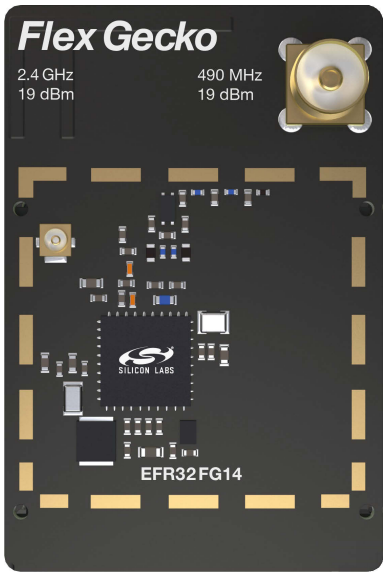


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1. Introduction

The EFR32 Flex Gecko Radio Boards provide a development platform (together with the Wireless Starter Kit Mainboard) for the Silicon Labs EFR32 Flex Gecko Wireless System-on-Chips and serve as reference designs for the matching networks of the RF interfaces.

The BRD4258A Radio Board supports dual-band operation with its integrated sub-GHz ISM band and 2.4 GHz band transceivers. The sub-GHz section is designed to operate in the AMR 470-510 MHz band with an external whip antenna, the 2.4 GHz section is designed to operate at the 2400-2483.5 MHz band with the on-board printed antenna. The matching networks are optimized for operating at 19 dBm output power.

To develop and/or evaluate the EFR32 Flex Gecko, the BRD4258A Radio Board can be connected to the Wireless Starter Kit Mainboard to get access to display, buttons and additional features from Expansion Boards and also to evaluate the performance of the RF interfaces.

2. Radio Board Connector

2.1 Introduction

The board-to-board connector scheme allows access to all EFR32FG14 GPIO pins as well as the RESETn signal. For more information on the functions of the available pins, see the EFR32FG14 data sheet.

2.2 Radio Board Connector Pin Associations

The figure below shows the mapping between the connector and the EFR32FG14 pins and their function on the Wireless Starter Kit Mainboard.

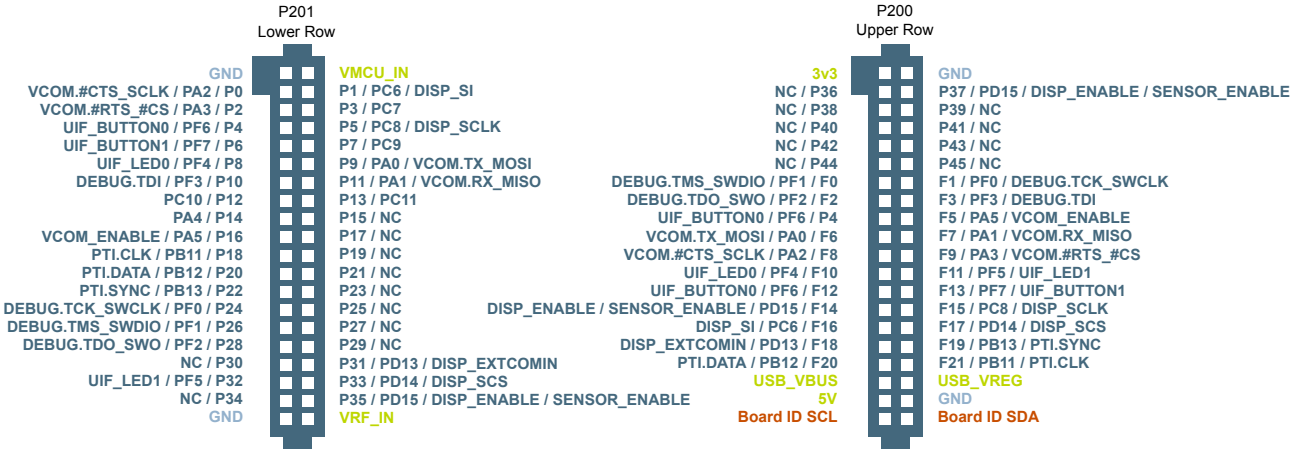


Figure 2.1. BRD4258A Radio Board Connector Pin Mapping

3. Radio Board Block Summary

3.1 Introduction

This section gives a short introduction to the blocks of the BRD4258A Radio Board.

3.2 Radio Board Block Diagram

The block diagram of the BRD4258A Radio Board is shown in the figure below.

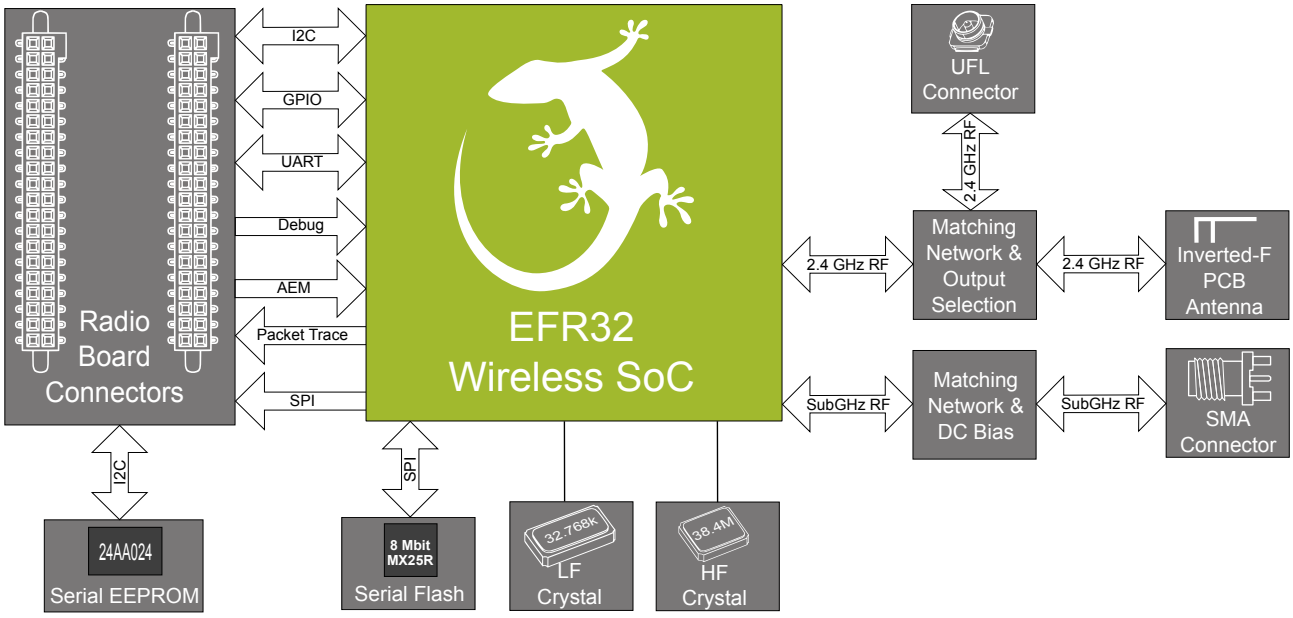


Figure 3.1. BRD4258A Block Diagram

3.3 Radio Board Block Description

3.3.1 Wireless MCU

The BRD4258A Flex Gecko Radio Board incorporates an EFR32FG14P233F256GM48 Wireless System-on-Chip featuring 32-bit Cortex®-M4 with FPU core, 256 kB of flash memory, 32 kB of RAM, an integrated 2.4 GHz band and an integrated sub-GHz ISM band transceiver with output power up to 19 dBm. For additional information on the EFR32FG14P233F256GM48, refer to the EFR32FG14 Data Sheet.

3.3.2 LF Crystal Oscillator (LFXO)

The BRD4258A Radio Board has a 32.768 kHz crystal mounted. For details regarding the crystal configuration, refer to Application Note "AN0016: Oscillator Design Considerations".

3.3.3 HF Crystal Oscillator (HFXO)

The BRD4258A Radio Board has a 38.4 MHz crystal mounted. For details regarding the crystal configuration, refer to Application Note "AN0016: Oscillator Design Considerations".

3.3.4 Matching Network for Sub-GHz

The BRD4258A Radio Board incorporates a sub-GHz matching network which connects both the sub-GHz TX and RX pins of the EFR32FG14 to the SMA connector to be able to transmit and receive with one antenna. The component values have been optimized for the 490 MHz band RF performance and current consumption with 19 dBm output power.

For a detailed description of the matching network see Chapter 4.2.1 Description of the Sub-GHz RF Matching.

3.3.5 Matching Network for 2.4 GHz

The BRD4258A Radio Board incorporates a 2.4 GHz matching network which connects the 2.4 GHz TRX pin of the EFR32FG14 to the one on-board printed inverted-F antenna. The component values have been optimized for the 2.4 GHz band RF performance and current consumption with 19 dBm output power.

For a detailed description of the matching network, see Chapter 4.2.2 Description of the 2.4 GHz RF Matching.

3.3.6 SMA Connector

To be able to perform conducted measurements or mount external antenna for radiated measurements, range tests etc., Silicon Labs added an SMA connector to the Radio Board. The connector allows an external 50 Ohm cable or antenna to be connected during design verification or testing.

3.3.7 UFL Connector

To be able to perform conducted measurements, Silicon Labs added a UFL connector to the Radio Board. The connector allows an external 50 Ohm cable or antenna to be connected during design verification or testing.

Note: By default, the output of the matching network is connected to the printed inverted-F antenna by a series component. It can be connected to the UFL connector as well through a series 0 Ohm resistor, which is not mounted by default. For conducted measurements through the UFL connector, the series component to the antenna should be removed and the 0 Ohm resistor should be mounted (see Chapter 4.2.2 Description of the 2.4 GHz RF Matching for further details).

3.3.8 Radio Board Connectors

Two dual-row, 0.05” pitch polarized connectors make up the BRD4258A Radio Board interface to the Wireless Starter Kit Mainboard.

For more information on the pin mapping between the EFR32FG14P233F256GM48 and the Radio Board Connector, refer to Chapter 2.2 Radio Board Connector Pin Associations.

3.3.9 Inverted-F Antenna

The BRD4258A Radio Board includes a printed inverted-F antenna (IFA) tuned to have close to 50 Ohm impedance at the 2.4 GHz band.

For detailed description of the antenna, see Chapter 4.6 Inverted-F Antenna.

3.3.10 Serial Flash

The BRD4258A Radio Board is equipped with an 8 Mbit Macronix MX25R SPI flash that is connected directly to the EFR32FG14 to support over-the-air (OTA) updates. For additional information on the pin mapping see the schematic of the BRD4258A.

3.3.11 Serial EEPROM

The BRD4258A Radio Board is equipped with a serial I^2C EEPROM for board identification and to store additional board related information.

4. RF Section

4.1 Introduction

This section gives a short introduction to the RF section of the BRD4258A Radio Board.

4.2 Schematic of the RF Matching Network

The schematic of the RF section of the BRD4258A Radio Board is shown in the following figure.

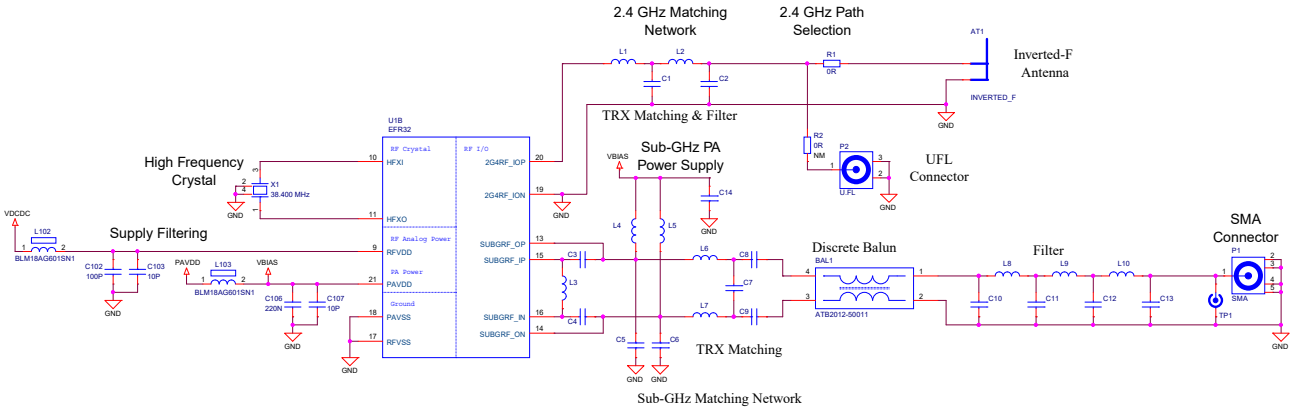


Figure 4.1. Schematic of the RF Section of the BRD4258A

4.2.1 Description of the Sub-GHz RF Matching

The sub-GHz matching network connects the differential TX outputs and RX inputs of the sub-GHz RF port to the SMA connector while transforming the impedances to 50 Ohm. Careful design procedure was followed to ensure that the RX input circuitry does not load down the TX output path while in TX mode and that the TX output circuitry does not degrade receive performance while in RX mode.

The matching includes a differential impedance matching circuitry, a discrete balanced-unbalanced transformer and a filter section. The targeted output power is 19 dBm at 490 MHz.

4.2.2 Description of the 2.4 GHz RF Matching

The 2.4 GHz matching connects the 2G4RF_IOP pin to the on-board printed Inverted-F Antenna. The 2G4RF_ION pin is connected to ground. For higher output powers (13 dBm and above) beside the impedance matching circuitry it is recommended to use additional harmonic filtering as well at the RF output. The targeted output power of the BRD4258A board is 19 dBm. Therefore, the RF output of the IC is connected to the antenna through a four-element impedance matching and harmonic filter circuitry.

For conducted measurements, the output of the matching network can also be connected to the UFL connector by relocating the series R1 resistor to the R2 resistor position between the output of the matching and the UFL connector.

4.3 RF Section Power Supply

On the BRD4258A Radio Board the supply pin of the radio (RFVDD) is connected directly of the output of the on-chip DC-DC converter while the supply for the sub-GHz and 2.4 GHz power amplifiers (SUBGRF_ON, SUBGRF_OP and PAVDD pins) is provided directly by the Motherboard. This way, by default, the DC-DC converter provides 1.8 V for the RF analog section, the Motherboard provides 3.3 V for the PAs (for details, see the schematic of the BRD4258A).

4.4 Bill of Materials for the sub-GHz Matching

The Bill of Materials of the sub-GHz matching network of the BRD4258A Radio Board is shown in the following table.

Table 4.1. Bill of Materials for the BRD4258A Sub-GHz RF Matching Network

Component Name	Value	Manufacturer	Part Number
L3	62 nH	Murata	LQW18AN62NG00D
L4	470 nH	Murata	LQW18CNR47J00D
L5	470 nH	Murata	LQW18CNR47J00D
L6	9.1 nH	Murata	LQW15AN9N1G00D
L7	9.1 nH	Murata	LQW15AN9N1G00D
L8	22 nH	Murata	LQW15AN22NG00D
L9	22 nH	Murata	LQW15AN22NG00D
L10	0 Ohm	-	-
C3	1.6 pF	Murata	GRM1555C1H1R6WA01D
C4	1.6 pF	Murata	GRM1555C1H1R6WA01D
C5	Not Mounted	-	-
C6	Not Mounted	-	-
C7	3.3 pF	Murata	GRM1555C1H3R3WA01D
C8	220 pF	Murata	GRM1555C1H221GA01D
C9	220 pF	Murata	GRM1555C1H221GA01D
C10	6.2 pF	Murata	GRM1555C1H6R2BA01D
C11	10 pF	Murata	GRM1555C1H100GA01D
C12	6.2 pF	Murata	GRM1555C1H6R2BA01D
C13	Not Mounted	-	-
C14	220 pF	Murata	GRM1555C1H221GA01D

4.5 Bill of Materials for the 2.4 GHz Matching

The Bill of Materials of the 2.4 GHz matching network of the BRD4258A Radio Board is shown in the following table.

Table 4.2. Bill of Materials for the BRD4258A 2.4GHz RF Matching Network

Component Name	Value	Manufacturer	Part Number
L1	1.8 nH	Murata	LQP15MN1N8W02D
L2	3.0 nH	Murata	LQP15MN3N0W02D
C1	2.0 pF	Murata	GRM1555C1H2R0WA01D
C2	1.0 pF	Murata	GRM1555C1H1R0WA01D

4.6 Inverted-F Antenna

The BRD4258A Radio Board includes an on-board printed inverted-F antenna tuned for the 2.4 GHz band. Due to the design restrictions of the Radio Board, the input of the antenna and the output of the matching network can't be placed directly next to each other. Therefore, a 50 Ohm transmission line was necessary to connect them. The resulting impedance and reflection measured at the output of the matcing network are shown in the following figure. As it can be observed, the impedance is close to 50 Ohm (the reflection is around or better than -10 dB) for the entire 2.4 GHz band.

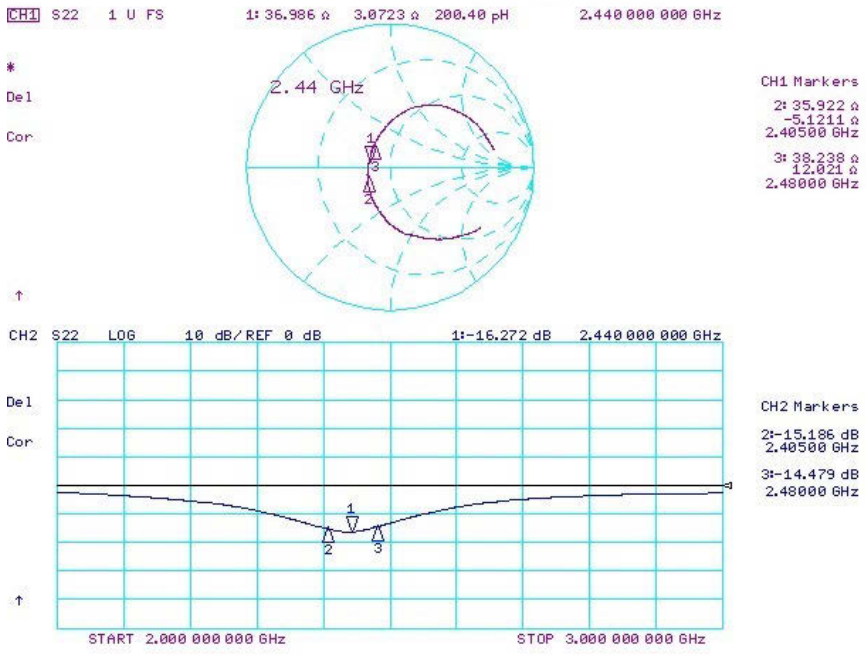


Figure 4.2. Impedance and Reflection of the Inverted-F Antenna of the BRD4258A Board Measured from the Matching Output

5. Mechanical Details

The BRD4258A Radio Board is illustrated in the figures below.

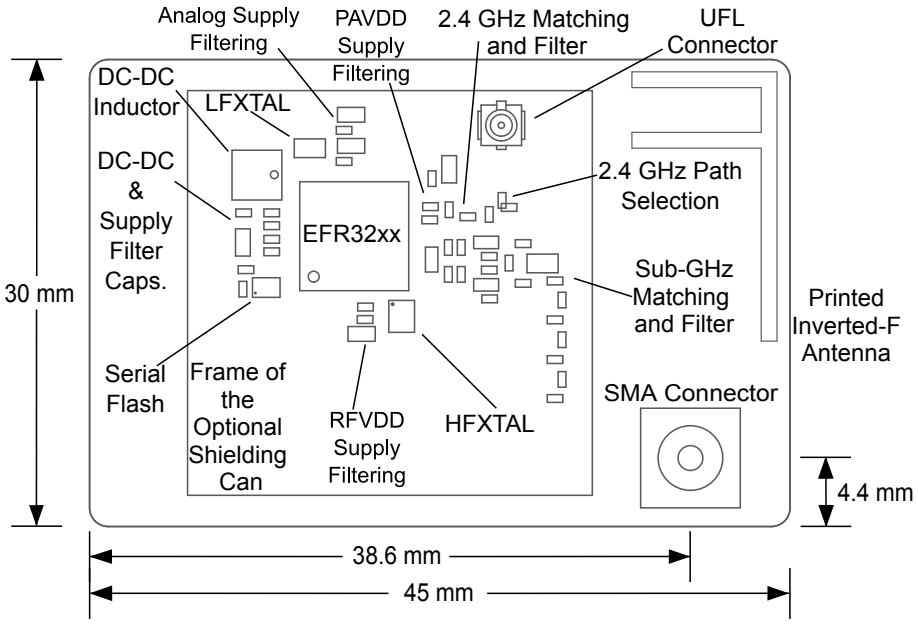


Figure 5.1. BRD4258A Top View

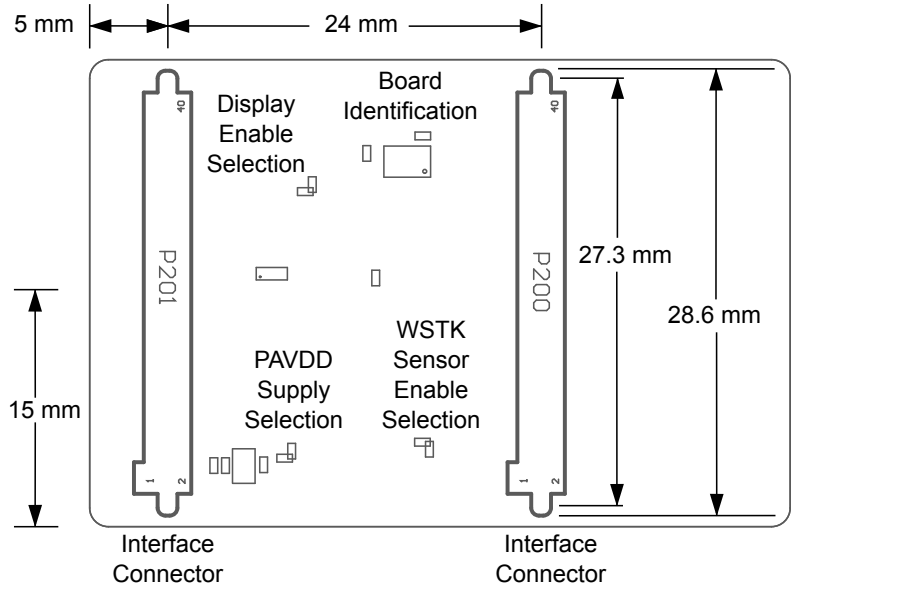


Figure 5.2. BRD4258A Bottom View

6. EMC Compliance

6.1 Introduction

Compliance of the fundamental and harmonic levels of the BRD4258A Radio Board is tested against the following standards:

- 490 MHz:
  - AMR
- 2.4 GHz:
  - ETSI EN 300-328
  - FCC 15.247

6.2 EMC Regulations for 490 MHz

6.2.1 AMR Emission Limits for the 470-510 MHz Band

Based on the AMR regulation, the allowed maximum fundamental power for the 470-510 MHz band is 50 mW (17 dBm) e.r.p. both for conducted and radiated measurements.

Note: Further in this document EIRP (Effective Isotropic Radiated Power) will be used instead of e.r.p. (Effective Radiated Power) for the comparison of the radiated limits and measurement results. The 50 mW e.r.p radiated limit is equivalent to 19.1 dBm EIRP.

For the unwanted emissions, AMR specifies the following limits:

- For frequencies between 30 MHz and 1 GHz, the limit is -36 dBm in e.r.p (-33.9 dBm in EIRP).
- For frequencies above 1 GHz, the limit is -30 dBm in e.r.p (-27.9 dBm in EIRP).

6.3 ETSI EN 300-328 Emission Limits for the 2400-2483.5 MHz Band

Based on ETSI EN 300-328, the allowed maximum fundamental power for the 2400-2483.5 MHz band is 20 dBm EIRP. For the unwanted emissions in the 1 GHz to 12.75 GHz domain the specified limit is -30 dBm EIRP.

6.4 FCC15.247 Emission Limits for the 2400-2483.5 MHz Band

FCC 15.247 allows conducted output power up to 1 Watt (30 dBm) in the 2400-2483.5 MHz band. For spurious emissions the limit is -20 dBc based on either conducted or radiated measurement, if the emission is not in a restricted band. The restricted bands are specified in FCC 15.205. In these bands the spurious emission levels must meet the levels set out in FCC 15.209. In the range from 960 MHz to the frequency of the 5th harmonic it is defined as 0.5 mV/m at 3 m distance which equals to -41.2 dBm in EIRP.

Additionally, for spurious frequencies above 1 GHz, FCC 15.35 allows duty-cycle relaxation to the regulatory limits. For the EmberZNet PRO the relaxation is 3.6 dB. Therefore, the -41.2 dBm limit can be modified to -37.6 dBm.

If operating in the 2400-2483.5 MHz band the 2nd, 3rd and 5th harmonics can fall into restricted bands. As a result, for those harmonics the -37.6 dBm limit should be applied. For the 4th harmonic the -20 dBc limit should be applied.

6.5 Applied Emission Limits for the 2.4 GHz Band

The above ETSI limits are applied both for conducted and radiated measurements.

The FCC restricted band limits are radiated limits only. In addition, Silicon Labs applies the same restrictions to the conducted spectrum. By doing so, in case of a custom board, assuming that an antenna is used which has 0 dB gain at the fundamental and the harmonic frequencies, the compliance with the radiated limits can be estimated based on the conducted measurement.

The overall applied limits are shown in the table below.

Table 6.1. Applied Limits for Spurious Emissions for the 2.4 GHz Band

Harmonic	Frequency	Limit
2nd	4800~4967 MHz	-37.6 dBm
3rd	7200~7450.5 MHz	-37.6 dBm
4th	9600~9934 MHz	-30 dBm
5th	12000~12417.5 MHz	-37.6 dBm

7. RF Performance

7.1 Conducted Power Measurements

During measurements, the BRD4258A Radio Board was attached to a Wireless Starter Kit Mainboard which was supplied by USB. The voltage supply for the Radio Board was 3.3 V.

7.1.1 Conducted Measurements in the 490 MHz Band

The BRD4258A Radio Board was connected directly to a Spectrum Analyzer through its SMA connector. The supply for the RF section (RFVDD) was 1.8 V provided by the on-chip DCDC converter, the supply for the sub-GHz power amplifier (SUBGRF_ON, SUBGRF_OP) was 3.3 V provided by the mainboard (VBIAS through the discrete balun); for details, see the schematic of the BRD4258A. The transceiver was operated in continuous carrier transmission mode. The output power of the radio was set to 19 dBm.

The typical output spectrum is shown in the following figure.

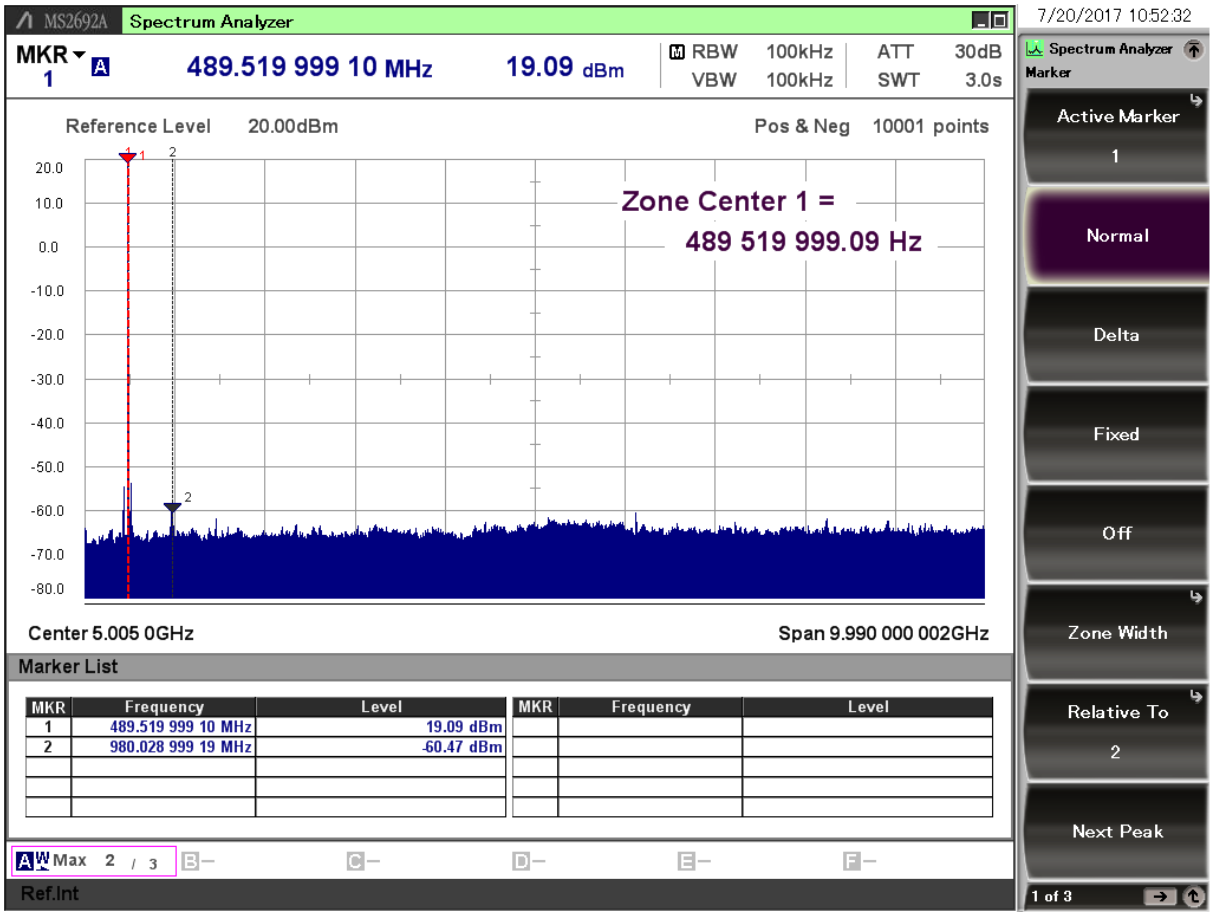


Figure 7.1. Typical Output Spectrum of the BRD4258A

As shown in the figure, the fundamental is a bit higher than 19 dBm and so just below the 19.1 dBm fundamental limit. The unwanted emissions are under -50 dBm, so the conducted spectrum is compliant with the regulation limits.

7.1.2 Conducted Measurements in the 2.4 GHz Band

The BRD4258A Radio Board was connected directly to a Spectrum Analyzer through its UFL connector (the R1 resistor was removed and a 0 Ohm resistor was soldered to the R2 resistor position). The supply for the RF section (RFVDD) and the 2.4 GHz power amplifier (PAVDD) was 1.8 V provided by the on-chip DC-DC converter; for details, see the schematic of the BRD4258A. The transceiver was operated in continuous carrier transmission mode. The output power of the radio was set to 19 dBm.

The typical output spectrum is shown in the following figure.

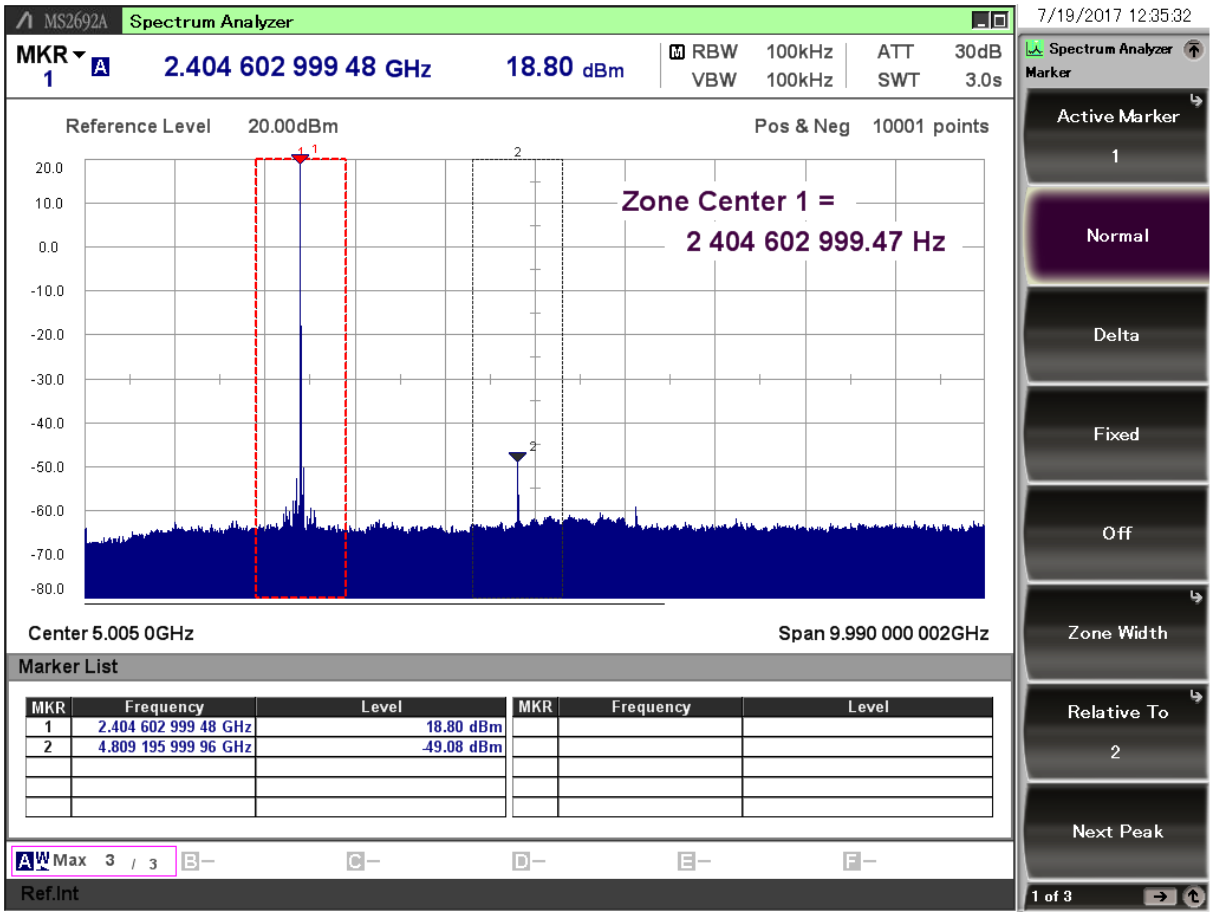


Figure 7.2. Typical Output Spectrum of the BRD4258A

As shown in the figure, the fundamental is slightly lower than 19 dBm and all of the unwanted emissions are under the -37.6 dBm applied limit.

Note: The conducted measurement is performed by connecting the on-board UFL connector to a Spectrum Analyzer through an SMA Conversion Adapter (P/N: HRMJ-U.FLP(40)). This connection itself introduces approximately 0.3 dB insertion loss.

7.2 Radiated Power Measurements

During measurements, the BRD4258A Radio Board was attached to a Wireless Starter Kit Mainboard which was supplied by USB. The voltage supply for the Radio Board was 3.3 V. The radiated power was measured in an antenna chamber by rotating the board 360 degrees with horizontal and vertical reference antenna polarizations in the XY, XZ and YZ cuts. The measurement planes are illustrated in the figure below.

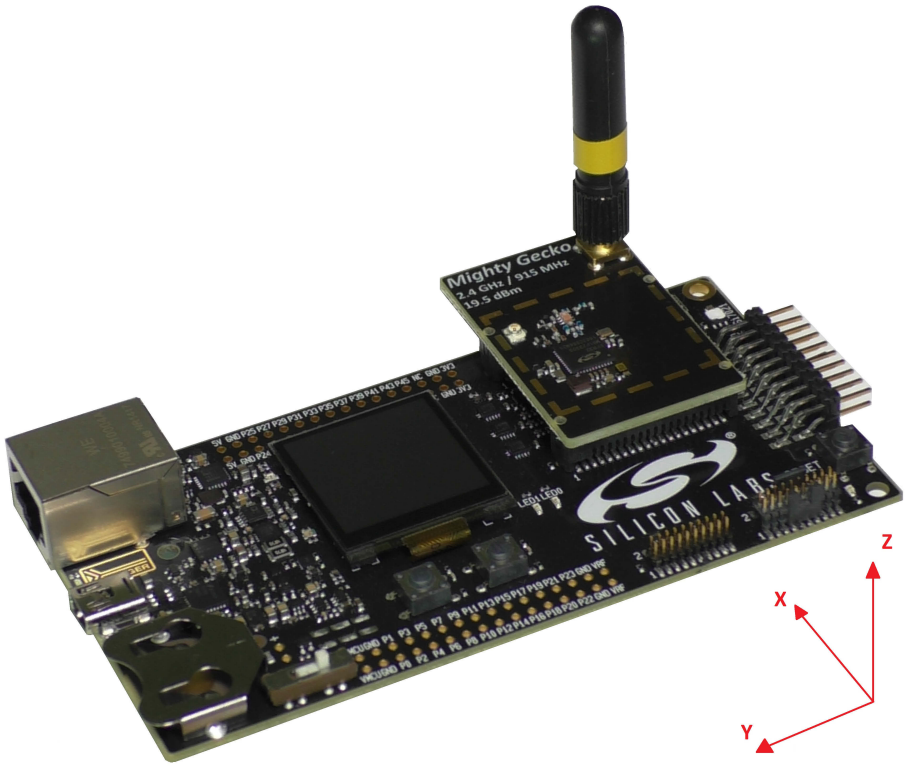


Figure 7.3. Illustration of Reference Planes with a Radio Board Plugged into the Wireless Starter Kit Mainboard

Note: The radiated measurement results presented in this document were recorded in an unlicensed antenna chamber. Also, the radiated power levels may change depending on the actual application (PCB size, used antenna, and so on). Therefore, the absolute levels and margins of the final application are recommended to be verified in a licensed EMC testhouse.

7.2.1 Radiated Measurements in the 490 MHz Band

For the 490 MHz radiated power measurements, an external whip antenna (P/N: EXC470SM (Laird Technologies)) was used as a transmitter antenna. It was connected to the SMA connector of the BRD4258A Radio Board. The supply for the RF section (RFVDD) was 1.8 V provided by the on-chip DCDC converter, the supply for the sub-GHz power amplifier (SUBGRF_ON, SUBGRF_OP) was 3.3 V provided by the mainboard (VBIAS through the discrete balun); for details, see the schematic of the BRD4258A. The transceiver was operated in continuous carrier transmission mode. The output power of the radio was set to 19 dBm.

The measured radiated powers are shown in the table below.

Table 7.1. Maximums of the Measured Radiated Powers in EIRP [dBm]

Frequency	EIRP [dBm]	Orientation	Margin [dB]	Limit in EIRP [dBm]
Fund	21	XY/V	-1.9	19.1
2nd	-38.4	YZ/H	4.5	-33.9
3rd	-44.2	YZ/V	16.3	-27.9
4th	-31.4	YZ/H	3.5	-27.9
5th	-48.1	YZ/H	20.2	-27.9
6th	-45.9	XZ/H	18	-27.9
7th	-53.4	XZ/V	25.5	-27.9
8th	-35.4	YZ/H	7.5	-27.9
9th	-55.9	YZ/H	28	-27.9
10th	-50	XZ/H	22.1	-27.9

As shown in the table, the fundamental is above the regulation limit by 2 dB so the reduction of the output power is required to comply. The harmonic levels are compliant even with 19 dBm output power.

7.2.2 Radiated Measurements in the 2.4 GHz Band

For the transmitter antenna, the on-board printed inverted-F antenna of the BRD4258A Radio Board was used (the R1 resistor was mounted). The supply for the RF section (RFVDD) and the 2.4 GHz power amplifier (PAVDD) was 1.8 V provided by the on-chip DC-DC converter; for details, see the schematic of the BRD4258A. The transceiver was operated in continuous carrier transmission mode. The output power of the radio was set to 19 dBm based on the conducted measurement. During the measurement the sub-GHz antenna (P/N: EXC470SM (Laird Technologies)) was attached to the SMA connector.

The results are shown in the table below.

Table 7.2. Maximums of the Measured Radiated Powers in EIRP [dBm]

Frequency	EIRP [dBm]	Orientation	Margin [dB]	Limit in EIRP [dBm]
Fund	21.3	XZ/H	8.7	30
2nd	-46.1	XZ/H	8.5	-37.6
3rd	<-50*	-/-	>10	-37.6
4th	<-50*	-/-	>10	-30
5th	<-50*	-/-	>10	-37.6
* Signal level is below the Spectrum Analyzer noise floor.				

As shown in the table, due to the high gain of the inverted-F antenna, the level of the fundamental is higher than 19 dBm. The harmonics are compliant with the applied limits with large margins.

8. EMC Compliance Recommendations

8.1 Recommendations for 490 MHz AMR Compliance

As it was shown in the previous chapter, the BRD4258A Flex Gecko Radio Board with 19 dBm output power violates the 19.1 dBm limit of the AMR regulation so reduction of the fundamental power is required by approximately 2 dB in order to comply. Although the BRD4258A Radio Board has an option for mounting a shielding can, it is not required for the compliance.

8.2 Recommendations for 2.4 GHz ETSI EN 300-328 Compliance

As it was shown in the previous chapter, the power of the fundamental of the BRD4258A Flex Gecko Radio Board with 19 dBm output exceeds the 20 dBm limit of the ETSI EN 300-328 regulation during the radiated power measurement due to the high antenna gain. In order to be compliant, reduction of the fundamental power is required by approximately 2.3 dB. The harmonic emissions are under the -30 dBm limit with a large margin. Although the BRD4258A Radio Board has an option for mounting a shielding can, it is not required for the compliance.

8.3 Recommendations for 2.4 GHz FCC 15.247 Compliance

As it was shown in the previous chapter, the power of the fundamental of the BRD4258A Flex Gecko Radio Board with 19 dBm output is compliant with the 30 dBm limit of the FCC 15.247 regulation. The harmonic emissions are under the -37.6 dBm applied limit with margin. Although the BRD4258A Radio Board has an option for mounting a shielding can, it is not required for the compliance.

9. Board Revision History

Table 9.1. BRD4258A Radio Board Revisions

Radio Board Revision	Description
A01	Updating EFR revision to Rev. B.
A00	Initial revision.

Note: The silkscreen marking on the board (e.g. PCBxxxx A00) denotes the revision of the PCB. The revision of the actual Radio Board is laser printed in the 'Board Info' field on the PCB. Also, it can be read from the on-board EEPROM.

10. Errata

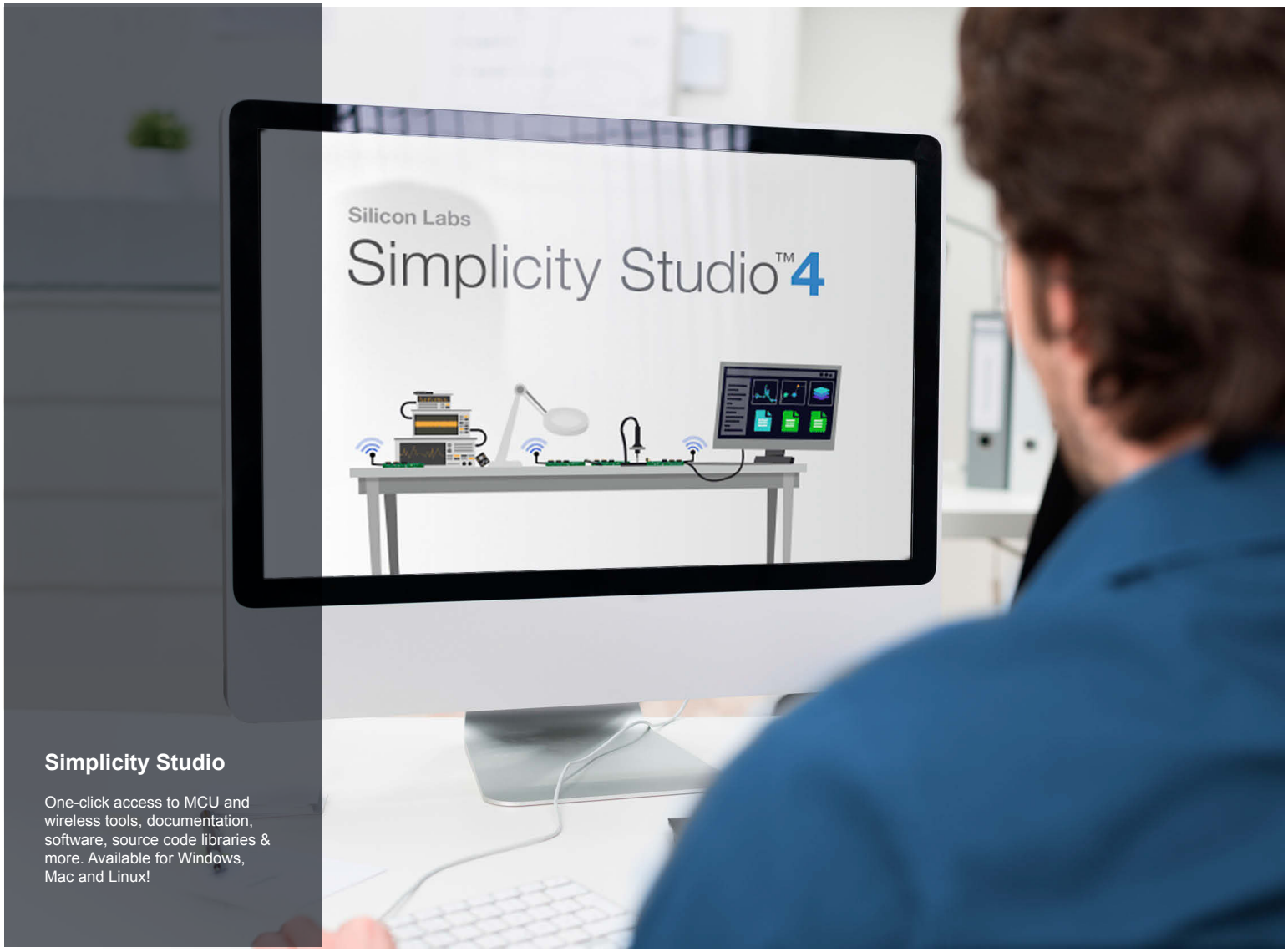
There are no known errata at present.

11. Document Revision History

Revision 1.00

2017-10-26

Initial document revision.



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