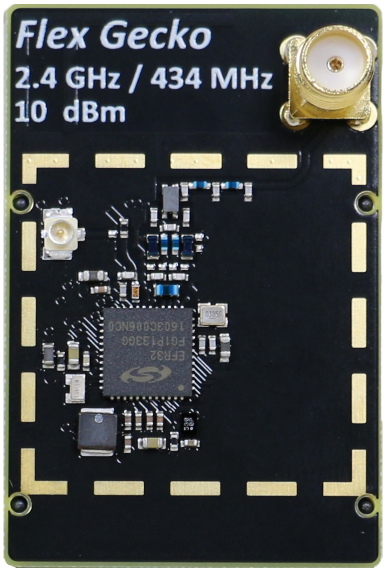
EFR32FG 2.4 GHz / 434 MHz Dual Band 10 dBm Radio Board BRD4251B Reference Manual

The EFR32FG family of Wireless SoCs deliver a high performance, low energy wireless solution integrated into a small form factor package.

By combining high performance sub-GHz RF and 2.4 GHz RF transceivers with an energy efficient 32-bit MCU, the family provides designers the ultimate in flexibility with a family of pin-compatible devices that scale from 128/256 kB of flash and 16/32 kB of RAM. The ultra-low power operating modes and fast wake-up times of the Silicon Labs energy friendly 32-bit MCUs, combined with the low transmit and receive power consumption of the sub-GHz and 2.4 GHz radios result in a solution optimized for battery powered applications.

To develop and/or evaluate the EFR32 Flex Gecko the BRD4251B Radio Board can be connected to the Wireless Starter Kit Mainboard to get access to display, buttons and additional features from Expansion Boards.



RADIO BOARD FEATURES

- Wireless SoC: EFR32FG1P133F256GM48
- CPU core: ARM Cortex-M4 with FPU
- Flash memory: 256 kB
- RAM: 32 kB
- Operation frequency: 2.4 GHz + 434 MHz
- Transmit power: 10 dBm
- Integrated PCB antenna, UFL connector (optional).
- Crystals for LFXO and HFXO: 32.768 kHz and 38.4 MHz.

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 BRD4251B 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 the operate in the European ETSI 433.05-434.79 MHz band with an external whip antenna, the 2.4 GHz section is designed to operate at the 2400-2483.5 MHz band band with the on-board printed antenna. The matching networks are optimized to 10 dBm output power.

To develop and/or evaluate the EFR32 Flex Gecko the BRD4251B 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 EFR32FG1 GPIO pins as well as the RESETn signal. For more information on the functions of the available pin functions, we refer you to the EFR32FG1 Datasheet.

2.2 Radio Board Connector Pin Associations

The figure below shows the pin mapping on the connector to the radio pins and their function on the Wireless Starter Kit Mainboard.

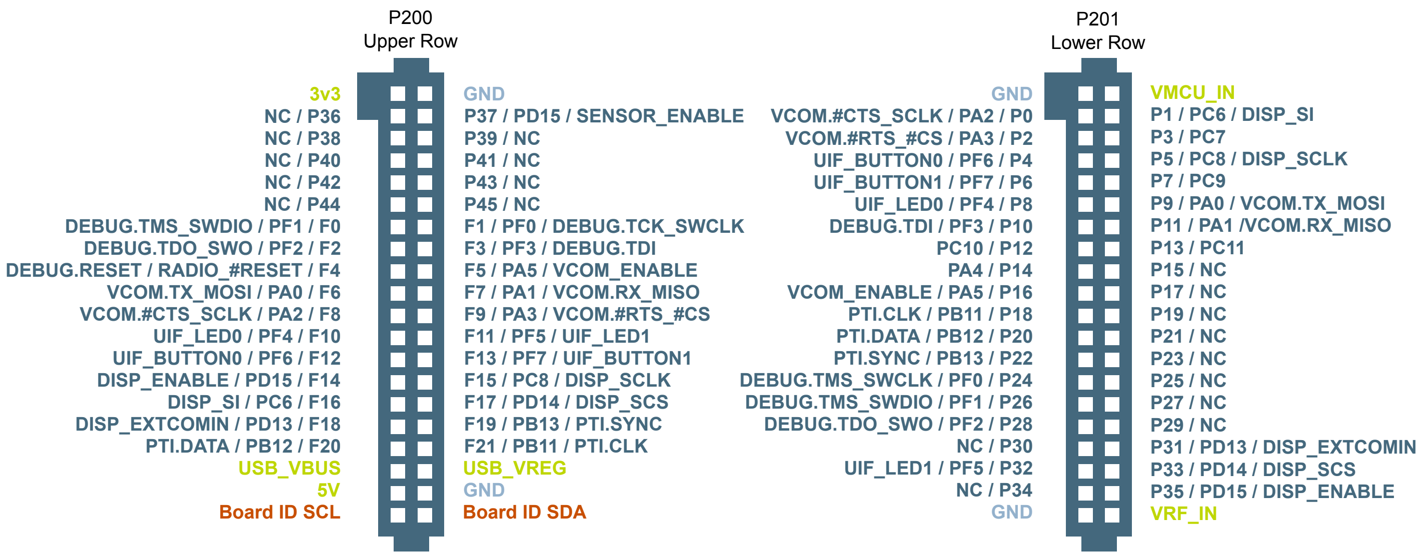


Figure 2.1. BRD4251B Radio Board Connector Pin Mapping

3. Radio Board Block Summary

3.1 Introduction

This section gives a short introduction to the blocks of the BRD4251B Radio Board.

3.2 Radio Board Block Diagram

The block diagram of the BRD4251B Radio Board is shown in the figure below.

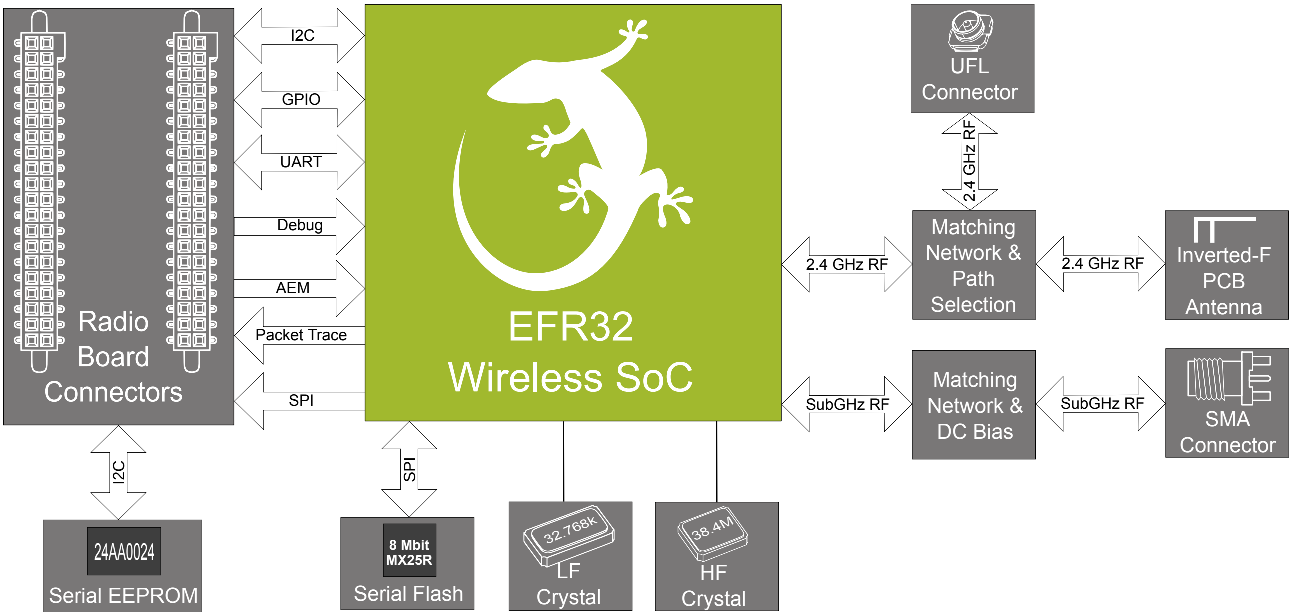


Figure 3.1. BRD4251B Block Diagram

3.3 Radio Board Block Description

3.3.1 Wireless MCU

The BRD4251B EFR32 Flex Gecko Radio Board incorporates an EFR32FG1P133F256GM48 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 19.5 dBm. For additional information on the EFR32FG1P133F256GM48, refer to the EFR32FG1 Data Sheet.

3.3.2 LF Crystal Oscillator (LFXO)

The BRD4251B Radio Board has a 32.768 kHz crystal mounted.

3.3.3 HF Crystal Oscillator (HFXO)

The BRD4251B Radio Board has a 38.4 MHz crystal mounted.

3.3.4 Matching Network for Sub-GHz

The BRD4251B Radio Board incorporates a sub-GHz matching network which connects both the sub-GHz TX and RX pins of the EFR32FG1 to the one SMA connector to be able to transmit and receive with one antenna. The component values were optimized for the 434 MHz band RF performace and current consumption with 10 dBm output power.

For 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 BRD4251B Radio Board incorporates a 2.4 GHz matching network which connects the 2.4 GHz TRX pin of the EFR32FG1 to the one on-board printed Inverted-F antenna. The component values were optimized for the 2.4 GHz band RF performace and current consumption with 10 dBm output power.

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

3.3.6 Inverted-F Antenna

The BRD4251B 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.

3.3.7 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.

3.3.8 UFL Connector

To be able to perform conducted measurements Silicon Labs added an 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 Schematic of the RF Matching Network for further details).

3.3.9 Radio Board Connectors

Two dual-row, 0.05” pitch polarized connectors make up the BRD4251B Radio Board interface to the Wireless Starter Kit Mainboard.

For more information on the pin mapping between the EFR32FG1P133F256GM48 and the Radio Board Connector refer to Chapter 2.2 Radio Board Connector Pin Associations.

4. RF Section

4.1 Introduction

This section gives a short introduction to the RF section of the BRD4251B.

4.2 Schematic of the RF Matching Network

The schematic of the RF section of the BRD4251B Radio Board is shown in the following figure.

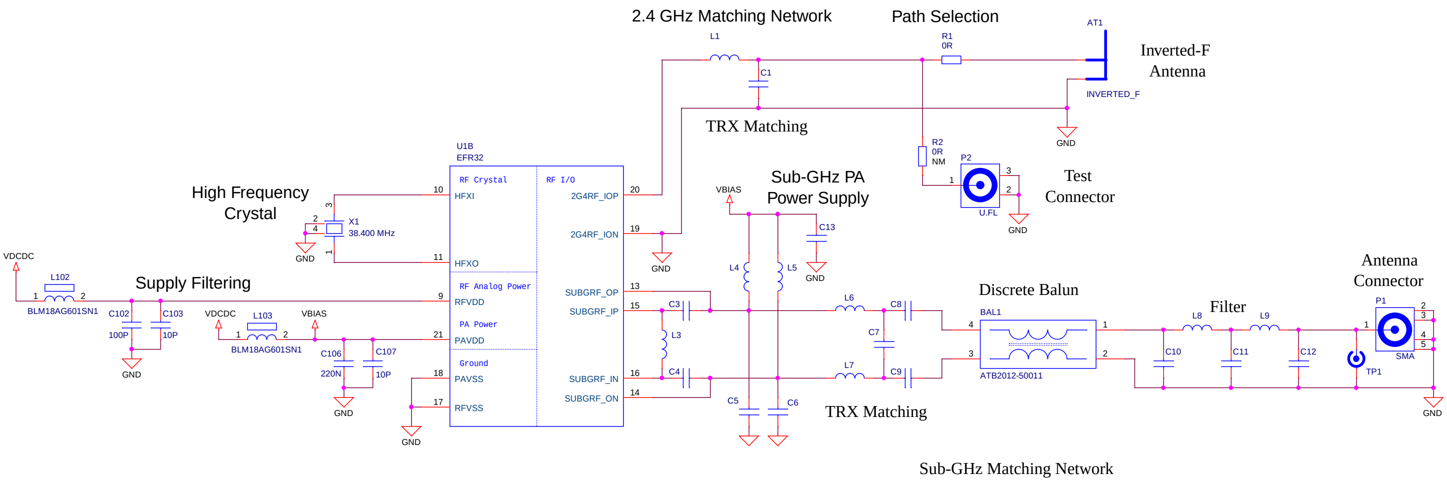


Figure 4.1. Schematic of the RF Section of the BRD4251B

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 10 dBm at 434 MHz.

4.2.2 Description of the 2.4 GHz RF Matching

The 2.4 GHz matching connects the RFIO_P pin to the on-board printed Inverted-F Antenna. The RFIO_N pin is connected to ground. For lower output powers (under 13 dBm) additional harmonic filtering is not required as the harmonic levels are below the regulation limits (see Chapter 7.1.2 Conducted Measurements in the 2.4 GHz band). Thus the matching network comprises only a two-element impedance matching circuitry. The targeted output power is 10 dBm.

For conducted measurements the output of the matching network can also be connected to the UFL connector by relocating the series R1 0 Ohm resistor to the R2 position between the output of the matching and the UFL connector.

4.3 RF Section Power Supply

On the BRD4251B Radio Board the supply for the radio (RFVDD) and the power amplifiers (VBIAS) is connected to the on-chip DC-DC converter. This way, by default, the DC-DC converter provides 1.8 V for the entire RF section (for details, see the schematic of the BRD4251B).

4.4 Bill of Materials for the sub-GHz Matching

The Bill of Materials of the sub-GHz matching network of the BRD4251B Radio Board is shown in the following table.

Table 4.1. Bill of Materials for the BRD4251B 434 MHz 10 dBm RF Matching Network

Component name	Value	Manufacturer	Part Number
BAL1	Balun	TDK Corporation	ATB2012-50011
C3	1.6 pF	Murata	GRM1555C1H1R6WA01
C4	1.6 pF	Murata	GRM1555C1H1R6WA01
C5	Not mounted	-	-
C6	Not mounted	-	-
C7	4.7 pF	Murata	GRM1555C1H4R7WA01
C8	270 pF	Murata	GRM1555C1H271FA01
C9	270 pF	Murata	GRM1555C1H271FA01
C10	6.2 pF	Murata	GRM1555C1H6R2BA01
C11	11 pF	Murata	GRM1555C1H110GA01
C12	5.6 pF	Murata	GRM1555C1H5R6WA01
C13	270 pF	Murata	GRM1555C1H271FA01
L3	75 nH	Murata	LQW18AN75NG00
L4	470 nH	Murata	LQW18CNR47J00
L5	470 nH	Murata	LQW18CNR47J00
L6	18 nH	Murata	LQW15AN18NG00
L7	18 nH	Murata	LQW15AN18NG00
L8	24 nH	Murata	LQW15AN24NG00
L9	24 nH	Murata	LQW15AN24NG00

4.5 Bill of Materials for the 2.4 GHz Matching

The Bill of Materials of the 2.4 GHz matching network of the BRD4251B Radio Board is shown in the following table.

Table 4.2. Bill of Materials for the BRD4251B 2.4 GHz 10 dBm RF Matching Network

Component name	Value	Manufacturer	Part Number
C1	2.0 pF	Murata	GRM1555C1H2R0WA01
C2	1.0 pF	Murata	GRM1555C1H1R0WA01
L1	1.8 nH	Murata	LQP15MN1N8W02
L2	3.0 nH	Murata	LQP15MN3N0W02

4.6 Inverted-F Antenna

The BRD4251B 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 thus 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 better than -10 dB) for the entire 2.4 GHz band.

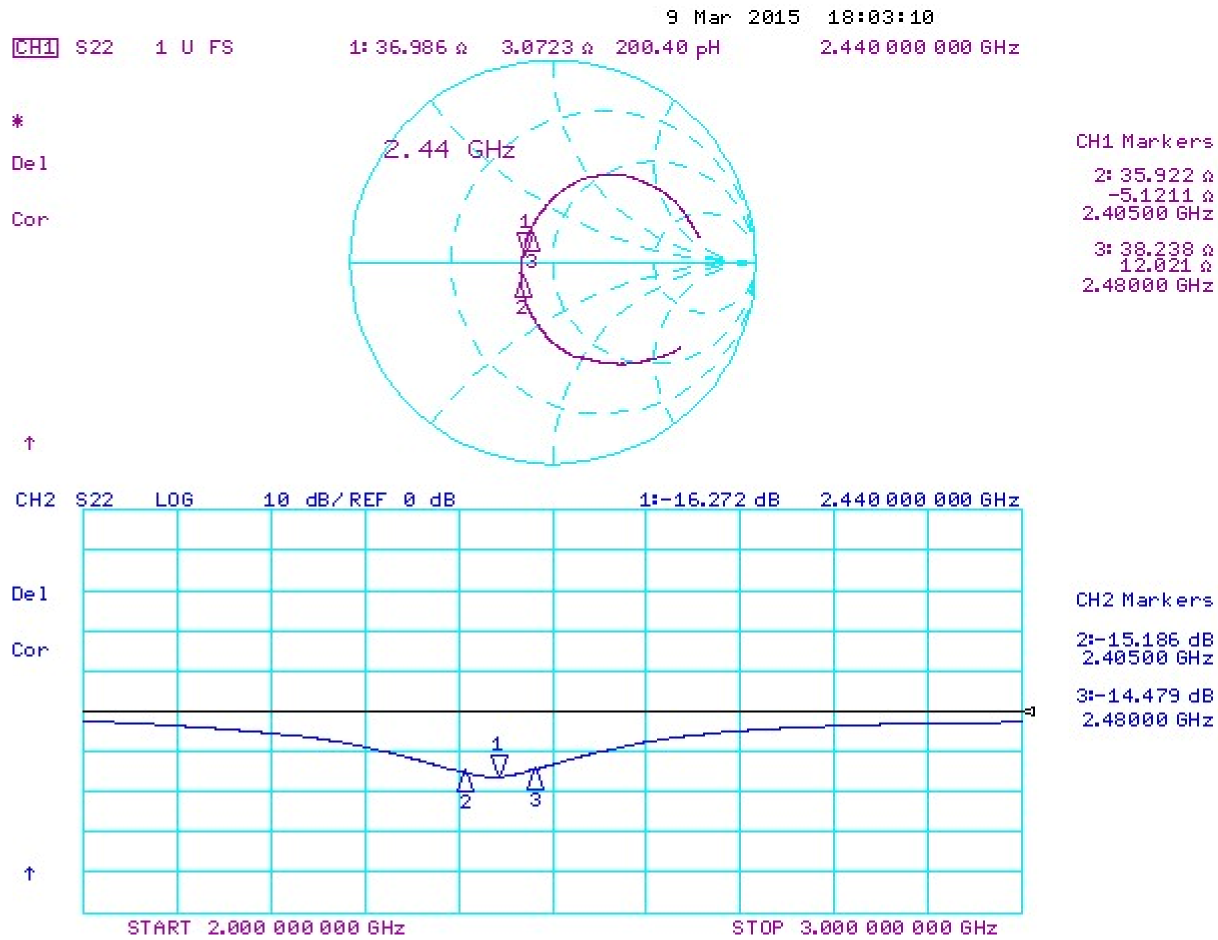


Figure 4.2. Impedance and Reflection of the Inverted-F Antenna of the BRD4251B

5. Mechanical Details

The BRD4251B EFR32 Flex Gecko Radio Board is illustrated in the figures below.

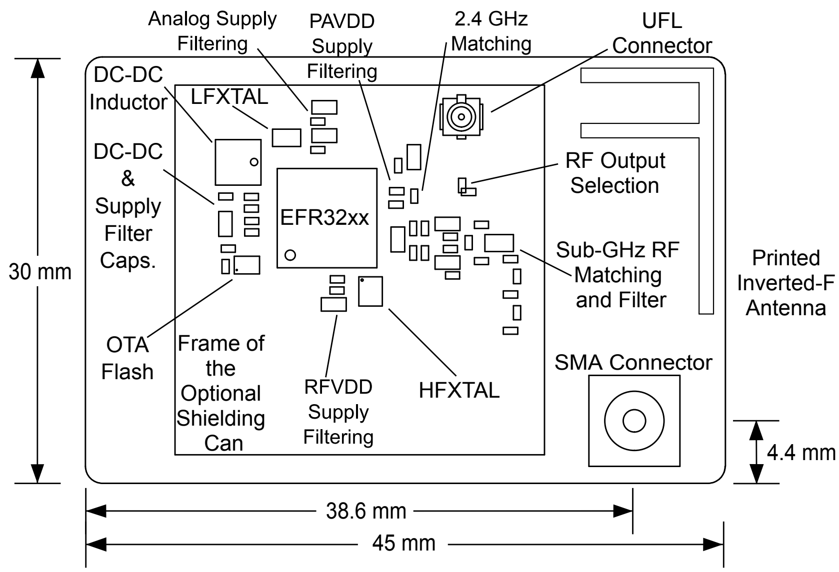


Figure 5.1. BRD4251B Top View

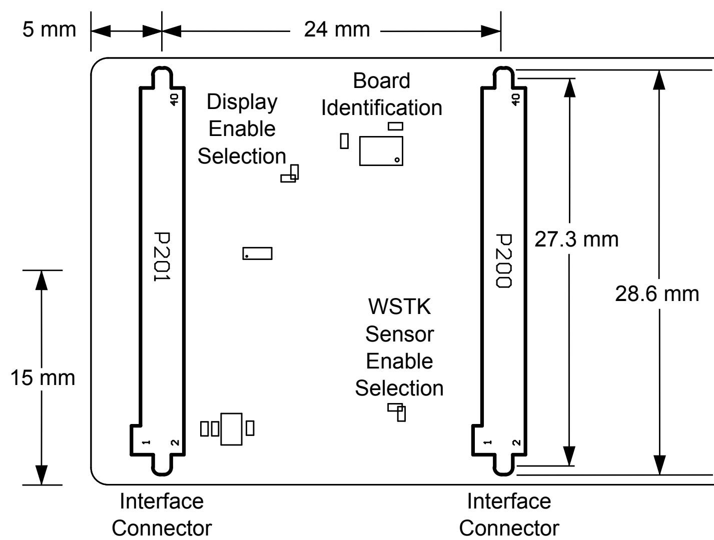


Figure 5.2. BRD4251B Bottom View

6. EMC Compliance

6.1 Introduction

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

- 434 MHz:
  - ETSI EN 300-220-1
- 2.4 GHz:
  - ETSI EN 300-328
  - FCC 15.247

6.2 EMC Regulations for 434 MHz

6.2.1 ETSI EN 300-200-1 Emission Limits for the 433.050-434.790 MHz Band

Based on ETSI EN 300-220-1 the allowed maximum fundamental power for the 433.050-434.790 MHz band is 10 mW (+10 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 limits and measurement results. The 10 mW e.r.p radiated limit is equivalent to 12.1 dBm EIRP.

For the unwanted emission limits see the table below.

Table 6.1. ETSI EN 300-220-1 Spurious Domain Emission Limits in e.r.p. (and EIRP)

Frequency	47 MHz to 74 MHz 87.5 MHz to 118 MHz 174 MHz to 230 MHz 470 MHz to 862 MHz	Other frequencies below 1000 MHz	Frequencies above 1000 MHz
Operating	4 nW (-54 dBm e.r.p. = -51.8 dBm EIRP)	250 nW (-36 dBm e.r.p. = -33.9 dBm EIRP)	1 uW (-30 dBm e.r.p. = -27.9 dBm EIRP)
Standby	2 nW (-57 dBm e.r.p. = -54.8 dBm EIRP)	2 nW (-57 dBm e.r.p. = -54.8 dBm EIRP)	20 nW (-47 dBm e.r.p. = -44.8 dBm EIRP)

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

6.3 EMC Regulations for 2.4 GHz

6.3.1 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.

6.3.2 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 emmissions 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 (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. So practically the -41.2 dBm limit can be modified to -37.6 dBm.

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

6.3.3 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. Besides that, Silicon Labs applies those to the conducted spectrum i.e. it is assumed that in case of a custom board an antenna is used which has 0 dB gain at the fundamental and the harmonic frequencies. In that theoretical case, based on the conducted measurement, the compliance with the radiated limits can be estimated.

The overall applied limits are shown in the table below.

Table 6.2. 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 BRD4251B 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 434 MHz band

The BRD4251B Radio Board was connected directly to a Spectrum Analyzer through its SMA connector. The supply for the radio (RFVDD) and the power amplifier (VBIAS) was 1.8 V provided by the on-chip DC-DC converter (for details, see the schematic of the BRD4251B). The transceiver was operated in continuous carrier transmission mode. The output power of the radio was set to 10 dBm.

The typical output spectrum is shown in the following figure.

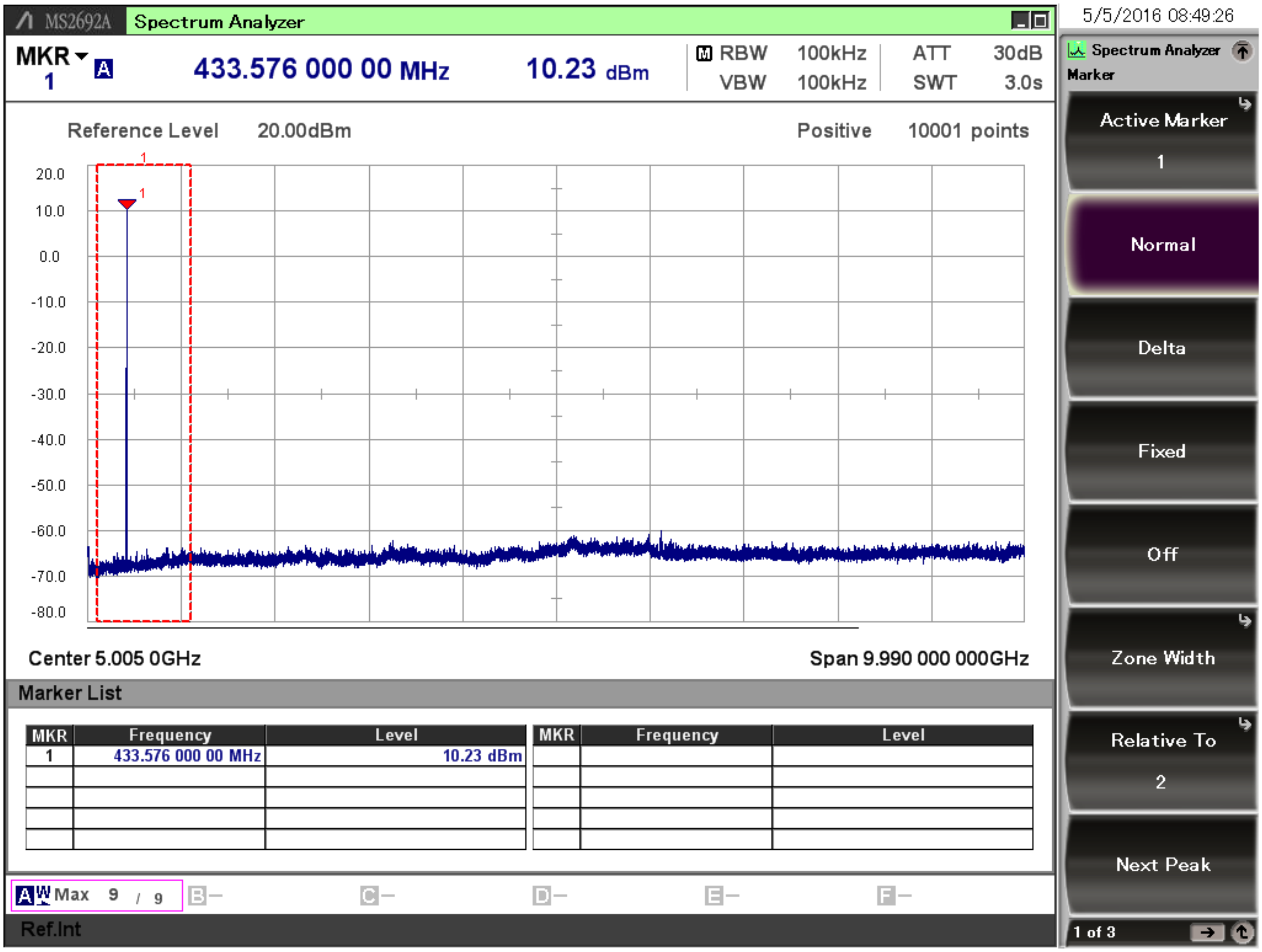


Figure 7.1. Typical Output Spectrum of the BRD4251B

As it can be observed the fundamental is slightly above 10 dBm but still under the 12.1 dBm fundamental limit and the unwanted emissions are under the Spectrum Analyzer noise level (<-60 dBm). So the conducted spectrum is compliant with the regulation limits.

7.1.2 Conducted Measurements in the 2.4 GHz band

The BRD4251B Radio Board was connected directly to a Spectrum Analyzer through its UFL connector (the 0 Ohm resistor was removed from the R1 position and was soldered to the R2 position). The supply for the radio (RFVDD) and the power amplifier (PAVDD) was 1.8 V provided by the on-chip DC-DC converter (for details, see the schematic of the BRD4251B). The transceiver was operated in continuous carrier transmission mode. The output power of the radio was set to 10 dBm.

The typical output spectrum is shown in the following figure.

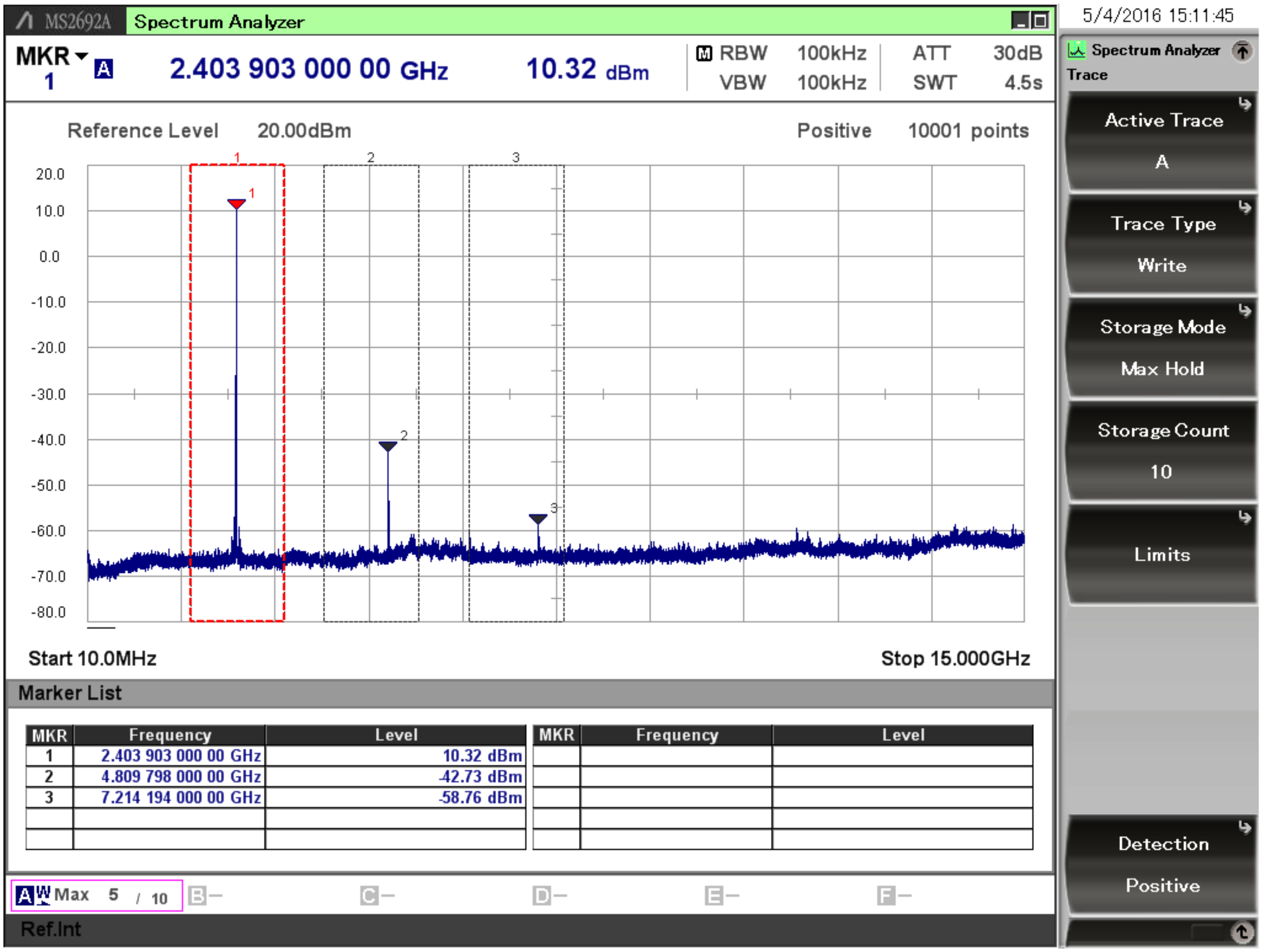


Figure 7.2. Typical Output Spectrum of the BRD4251B

As it can be observed the fundamental is slightly above 10 dBm and the strongest unwanted emission is the double-frequency harmonic but with its with -42.73 dBm level it is under the -37.6 dBm applied limit with ~5 dB margin. So the conducted spectrum is compliant with the applied limits.

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 approx. 0.3 dB insertion loss.

7.2 Radiated Power Measurements

During measurements the BRD4251B 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 DUT in 360 degree with horizontal and vertical reference antenna polarizations in the XY, XZ and YZ cuts. The measurement axes are as shown in the figure below.

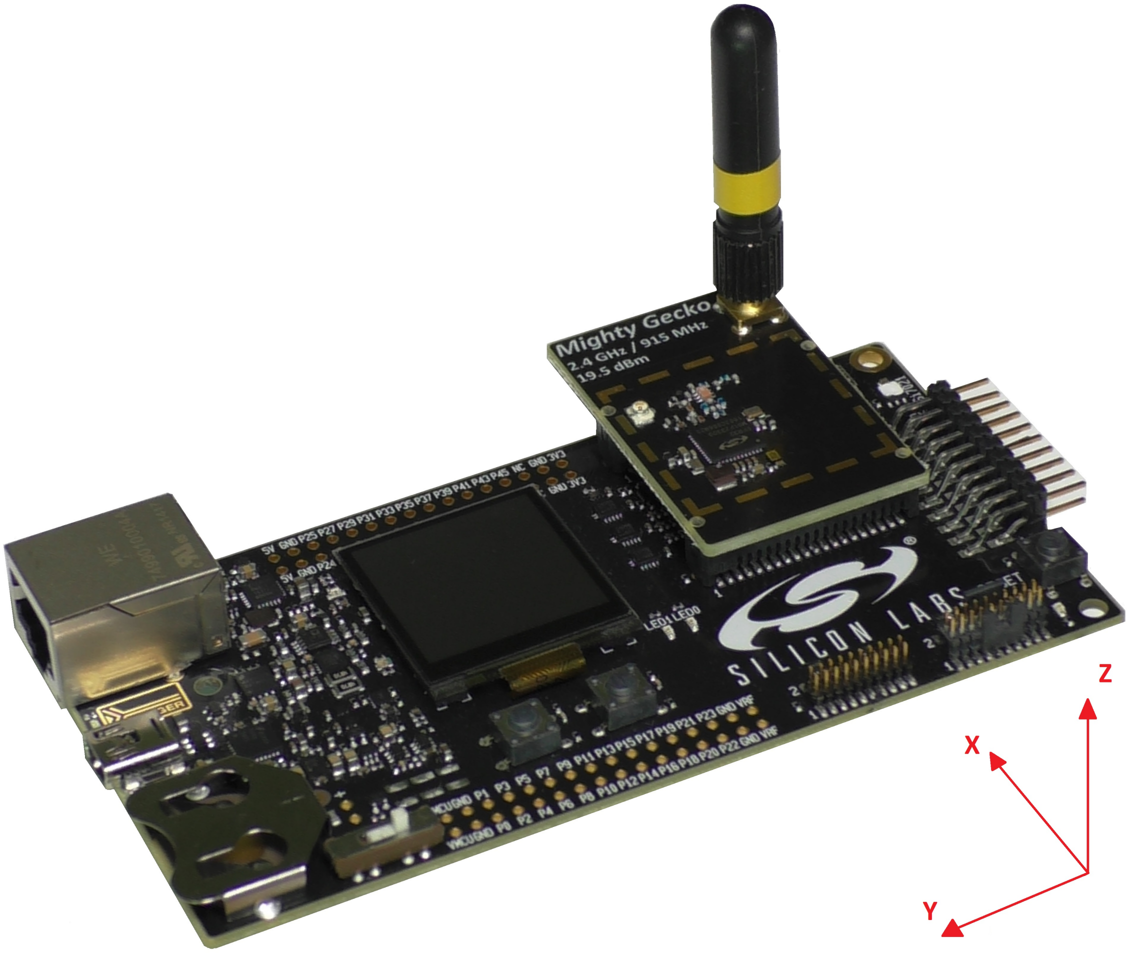


Figure 7.3. DUT: Radio Board with the Wireless Starter Kit Mainboard (Illustration)

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 etc.) therefore the absolute levels and margins of the final application is recommended to be verified in a licensed EMC testhouse!

7.2.1 Radiated Measurements in the 434 MHz band

For the 434 MHz radiated power measurements an external whip antenna (P/N: ANT-433-CW-QW-SMA) was used as a transmitter antenna. It was connected to the SMA connector of the BRD4251B Radio Board. The supply for the radio (RFVDD) and the power amplifier (VBIAS) was 1.8 V provided by the on-chip DC-DC converter (for details, see the schematic of the BRD4251B). The transceiver was operated in continuous carrier transmission mode. The output power of the radio was set to 10 dBm.

The measured radiated powers are shown in the table below.

Table 7.1. Maximums of the Measured Radiated Powers of BRD4251B at 434 MHz

434 MHz	EIRP [dBm]	Orientation	Margin [dB]	Limit in EIRP [dBm]
Fund	9.8	XY/V	2.3	12.1
2nd	-58.6	YZ/H	24.7	-33.9
3rd	-60.1	YZ/H	32.2	-27.9
4th	-49.0	XZ/H	21.1	-27.9
5th	-60.8	XZ/V	32.9	-27.9
6th	-49.9	XY/H	22.0	-27.9
7th	<-50*	-/-	>20	-27.9
8th	-46.0	XZ/V	18.1	-27.9
9th	<-50*	-/-	>20	-27.9
10th	<-50*	-/-	>20	-27.9
* Signal level is below the Spectrum Analyzer noise floor.				

As it can be observed the fundamental is below the regulation limit by approx. 2 dB, the harmonic levels are also compliant with large margins.

7.2.2 Radiated Measurements in the 2.4 GHz band

For the transmitter antenna the on-board printed Inverted-F antenna of the BRD4251B board was used (the R1 resistor was mounted). The supply for the radio (RFVDD) and the power amplifier (PAVDD) was 1.8 V provided by the on-chip DC-DC converter (for details, see the schematic of the BRD4251B). During the measurement the sub-GHz antenna (P/N: ANT-433-CW-QW-SMA) was attached to the SMA connector. The transceiver was operated in continuous carrier transmission mode. The output power of the radio was set to 10 dBm.

The results are shown in the table below.

Table 7.2. Maximums of the Measured Radiated Powers of BRD4251B at 2.4 GHz

2.4 GHz	EIRP [dBm]	Orientation	Margin [dB]	Limit in EIRP [dBm]
Fund	12.8	XZ/H	17.2	30
2nd	-49.0	XZ/H	11.4	-37.6
3rd	-49.0	YZ/H	11.4	-37.6
4th	<-50*	-/-	>20	-30
5th	<-50*	-/-	>10	-37.6
* Signal level is below the Spectrum Analyzer noise floor.				

As it can be observed, thanks to the ~2-3 dB gain of the on-board Inverted-F antenna, the level of the fundamental is higher than 10 dBm. The harmonics are compliant with the applied limits with large margins.

8. EMC Compliance Recommendations

8.1 Recommendations for 434 MHz ETSI EN 300-220-1 Compliance

As it was shown in the previous chapter the BRD4251B EFR32 Flex Gecko Radio Board is compliant with the emission limits of the ETSI EN 300-220-1 regulation with 10 dBm output power. Although the BRD4251B Radio Board has an option for mounting a shielding can, that 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 BRD4251B EFR32 Flex Gecko Radio Board is compliant with the emission limits of the ETSI EN 300-328 regulation with 10 dBm output power. Although the BRD4251B Radio Board has an option for mounting a shielding can, that 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 BRD4251B EFR32 Flex Gecko Radio Board is comliant with the emission limits of the FCC 15.247 regulation with 10 dBm output power. Although the BRD4251B Radio Board has an option for mounting a shielding can, that is not required for the compliance.

9. Revision History

Table 9.1. Document Revision History

Revision Number	Effective Date	Change Description
1.0	20.05.2016	Initial release.

10. Board Revisions

Table 10.1. BRD4251B Radio Board Revisions

Radio Board Revision	Description
A00	Initial release.
B00	Changing board design to support dual-band operation (434 MHz/2.4 GHz). Updating sub-GHz matching network.
B01	Sub-GHz PA supplied from VBIAS (filtered PAVDD).

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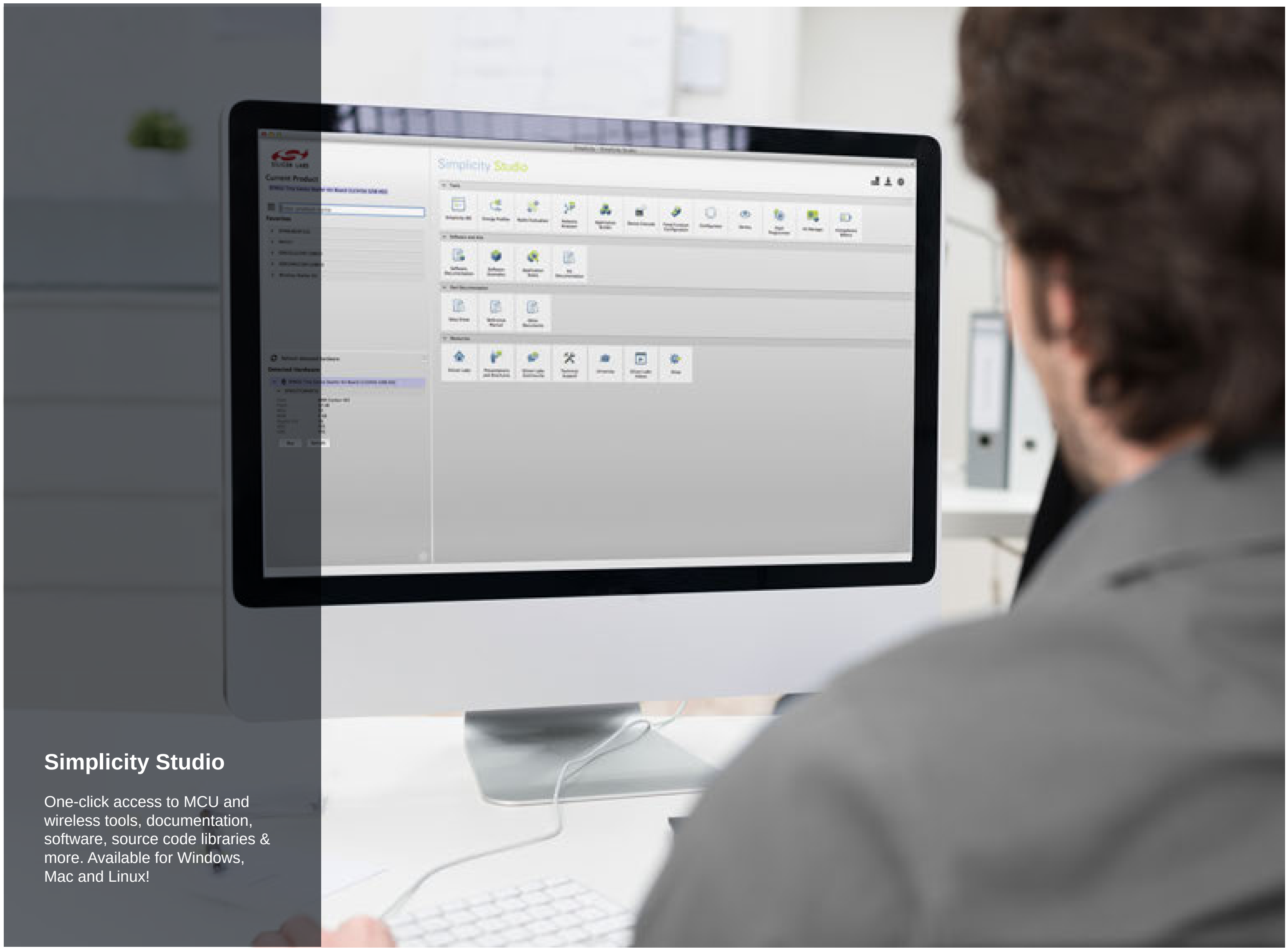

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