UG415: Thunderboard™ EFR32BG22 User's Guide

The Thunderboard™ EFR32BG22 is a low cost, small form factor prototype and development platform for the EFR32BG22 Wireless Gecko System-on-Chip.

The board is a small and cost effective, feature rich, prototype and development platform based on the EFR32™ Wireless Gecko System-on-Chip. The Thunderboard EFR32BG22 is an ideal platform for developing energy-friendly connected IoT devices.

The Thunderboard EFR32BG22 ships with a Bluetooth demo that works with a cloud connected smartphone app, showcasing easy collection of environmental and motion sensor data, as well as button and LED control.

A built in SEGGER J-Link debugger ensures easy debugging through the USB Micro-B connector.

TARGET DEVICE

- EFR32 Wireless Gecko System-on-Chip (EFR32BG22C224F512IM40)
  - 32-bit ARM® Cortex®-M33 with 76.8 MHz maximum operating frequency
  - 512 kB flash and 32 kB RAM
  - Energy-efficient radio core with low active and sleep currents
  - Bluetooth 5.2 Direction Finding
  - Integrated PA with up to 6 dBm (2.4 GHz) TX power
  - Secure Boot with Root of Trust and Secure Loader (RTSL)

KIT FEATURES

- 2.4 GHz ceramic chip antenna
- Power control of on-board peripherals for ultra low power operation
- Relative humidity and temperature sensor
- UV index and ambient light sensor
- Hall effect sensor
- 6-axis inertial sensor
- 8 Mbit flash for OTA programming and data logging
- User LED and push button
- 20-pin 2.54 mm breakout pads
- SEGGER J-Link on-board debugger
- Virtual COM port
- Packet Trace Interface (PTI)
- Mini Simplicity connector for AEM and packet trace using external Silicon Labs debugger
- USB or coin cell battery powered.

SOFTWARE SUPPORT

- Simplicity Studio™

Table of Contents

1. Introduction

The Thunderboard EFR32BG22 (OPN: SLTB010A) has been designed to inspire customers to make battery operated IoT devices with the Silicon Labs EFR32BG22 Wireless Gecko System-on-Chip. The highlights of the board include four different environmental sensors accessible to the EFR32BG22 wireless MCU. The peripherals can be turned on and off by the application code as needed.

Programming the Thunderboard EFR32BG22 is easily done using a USB Micro-B cable and the on-board J-Link debugger. A USB virtual COM port provides a serial connection to the target application, and the Packet Trace Interface (PTI) offers invaluable debug information about transmitted and received packets in wireless links. Included on the board is an 8 Mbit serial flash that can be used for Over-The-Air (OTA) firmware upgrade, or as a general purpose non-volatile memory. The Thunderboard EFR32BG22 is supported in Simplicity Studio™, and a Board Support Package (BSP) is provided to give application developers a flying start.

Energy profiling and advanced wireless network analysis and debugging tools are available through the provided Mini Simplicity Connector using an external Silicon Labs debugger.

Connecting external hardware to the Thunderboard EFR32BG22 can be done using the 20 breakout pads which present peripherals from the EFR32BG22 Wireless Gecko such as I^2C, SPI, UART and GPIOs. The breakout pads follow the same pinout as the expansion headers (EXP) on other Silicon Labs Starter Kits.

1.1 Kit Contents

The following items are included in the box:
- 1x Thunderboard EFR32BG22 board (BRD4184A)

1.2 Getting Started

Detailed instructions for how to get started with your new Thunderboard EFR32BG22 can be found on the Silicon Labs web pages:

https://www.silabs.com/support/getting-started/thunderboard

1.3 Hardware Content

The following key hardware elements are included on the Thunderboard EFR32BG22:
- EFR32BG22 Wireless Gecko SoC with 76.8 MHz operating frequency, 512 kB kB flash and 32 kB RAM
- 2.4 GHz ceramic antenna for wireless transmission
- Silicon Labs Si7021 relative humidity and temperature sensor
- Silicon Labs Si1133 UV index and ambient light sensor
- Silicon Labs Si7210 hall effect sensor
- TDK InvenSense ICM-20648 6-axis inertial sensor
- Macronix ultra low power 8 Mbit SPI flash (MX25R8035F)
- One LED and one push button
- Power enable signals and isolation switches for ultra low power operation
- On-board SEGGER J-Link debugger for easy programming and debugging, which includes a USB virtual COM port and Packet Trace Interface (PTI)
- Mini Simplicity connector for access to energy profiling and advanced wireless network debugging
- Breakout pads for GPIO access and connection to external hardware
- Reset button
- Automatic switchover between USB and battery power
- CR2032 coin cell holder

1.4 Kit Hardware Layout

The layout of the Thunderboard EFR32BG22 is shown below.
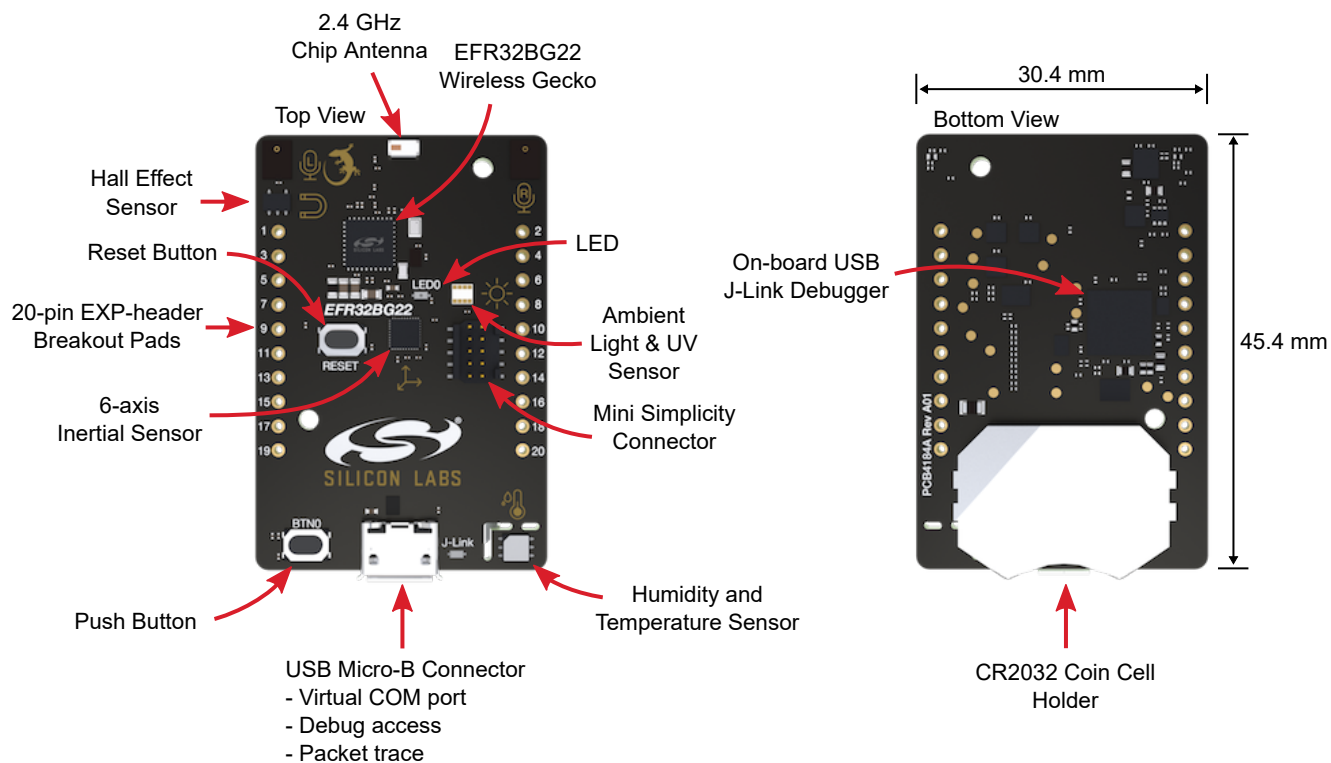
Figure 1.1.   Thunderboard EFR32BG22 Hardware Layout

2. Specifications

2.1 Recommended Operating Conditions

Parameter	Symbol	Min	Typ	Max	Unit
USB Supply Input Voltage	V_{USB}	-	+5.0	-	V
Battery Supply Input Voltage	V_{VBAT}	-	+3.0	-	V
Supply Input Voltage (VMCU supplied externally)	V_{VMCU}	-	+3.0	-	V
Operating Temperature	T_{OP}	-	+20	-	˚C

2.2 Current Consumption

The operating current of the board greatly depends on the application. The table below attempts to give some indication of how different features of the board contribute to the overall power consumption. Please note that the numbers are taken from the datasheets for the devices. For a full overview of the conditions that apply for a specific number from a datasheet, the reader is encouraged to read the specific datasheet.

Table 2.1. Current Consumption

Parameter	Symbol	Condition	Typ	Unit
EFR32 Current Consumption[1]	I_{EFR32}	MCU current consumption in EM0 mode with all peripherals disabled (DC-DC converter at 3.0 V input and 1.8 V output, VSCALE1, 38.4 MHz crystal, CPU running Prime from flash at 25 ˚C)	28	µA/MHz
		Radio system current consumption in receive mode, active packet reception (DC-DC converter at 3.0 V input and 1.8 V output, MCU in EM1 and all MCU peripherals disabled, HCLK = 38.4 MHz, 1Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE1 at 25 ˚C)	3.8	mA
		Radio system current consumption in transmit mode (DC-DC converter at 3.0 V input and 1.8 V output, MCU in EM1 and all MCU peripherals disabled, HCLK = 38.4 MHz, f = 2.4 GHz, CW, 6 dBm output power, VSCALE1 at 25 ˚C)	8.4	mA
UV/ALS Current Consumption [2]	I_{Si1133}	Standby	0.125	µA
		ADC Conversion in Progress	0.525	µA
		Responding to commands and calculating results	4.5	mA
RH/Temp Sensor Current Consumption [3]	I_{Si7021}	Standby, -40 to +85˚C	0.06	µA
		RH conversion in progress	150	µA
		Temperature conversion in progress	90	µA
		Peak I_{DD} during I^2C operations	3.5	mA
IMU Current Consumption [4]	I_{IMU}	Full-chip sleep mode at 1.8 V supply	8	µA
		Gyroscope Only, 102.3 Hz update rate at 1.8 V supply	1.23	mA
		Accelerometer only, 102.3 Hz update rate at 1.8 V supply	68.9	µA
		Gyroscope + Accelerometer, 102.3 Hz update rate at 1.8 V supply	1.27	mA
On-board Debugger Sleep Current Consumption [5]	I_{DBG}	On-board debugger current consumption when USB cable is not inserted (EFM32GG12 EM4S mode current consumption)	80	nA

Note:

1. From EFR32BG22 Wireless Gecko SoC datasheet.
2. From Si1133 datasheet.
3. From Si7021-A20 datasheet.
4. From ICM-20648 datasheet.
5. From EFM32GG12 datasheet.

3. Hardware

The core of the Thunderboard EFR32BG22 is the EFR32BG22 Wireless Gecko System-on-Chip. The board also contains several peripherals connected to the EFR32BG22. For placement and layout of the hardware components the reader is referred to section 1.4 Kit Hardware Layout.

3.1 Block Diagram

An overview of the Thunderboard EFR32BG22 is illustrated in the figure below.
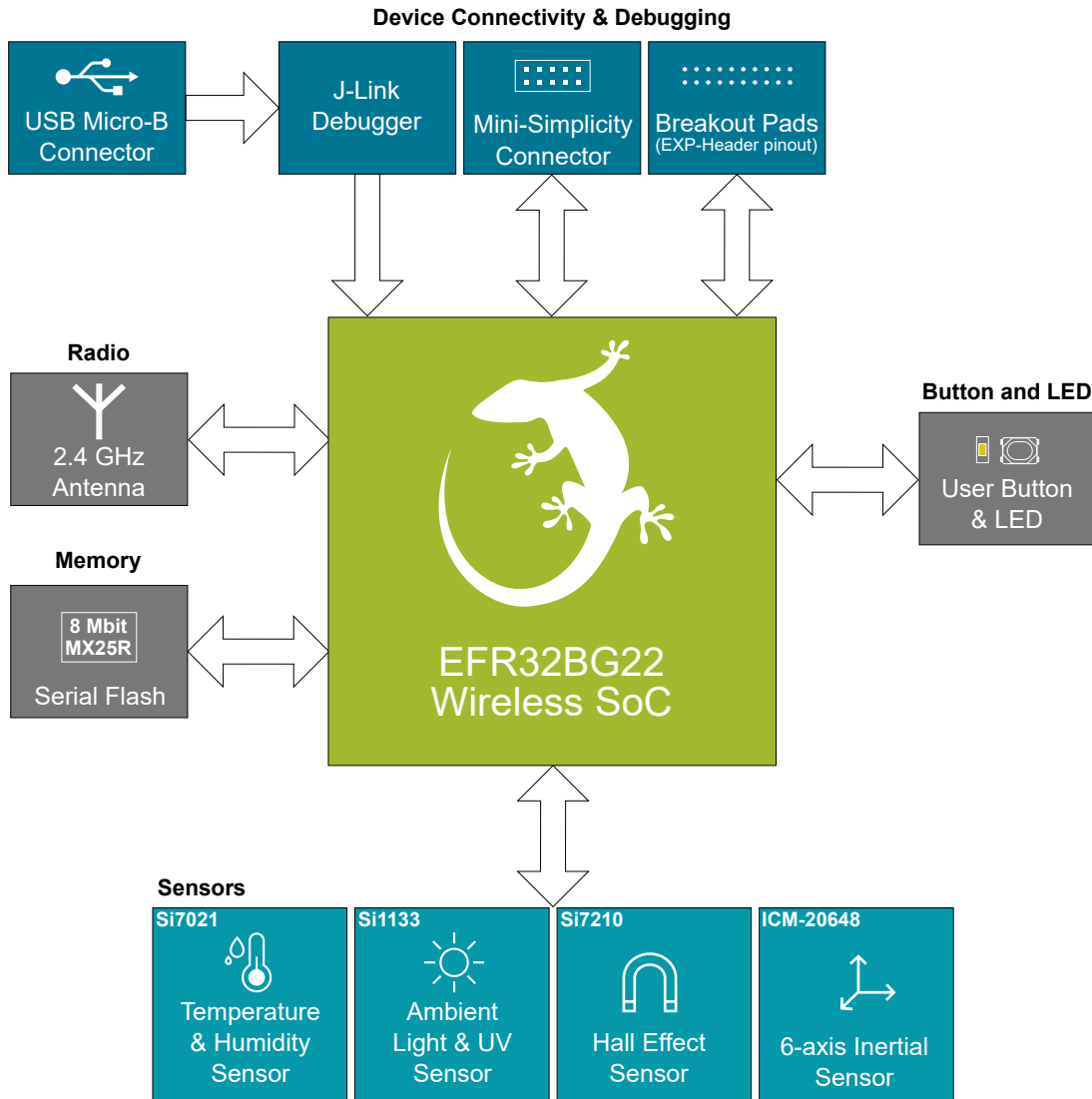

Figure 3.1.   Kit Block Diagram

3.2 Power Supply

The kit can be powered by one of these sources:

- The debug USB cable
- A 3 V coin cell battery
- Mini Simplicity connector (requires that no other power sources are present on the kit).

The figure below shows the power options available on the kit and illustrates the main system power architecture.
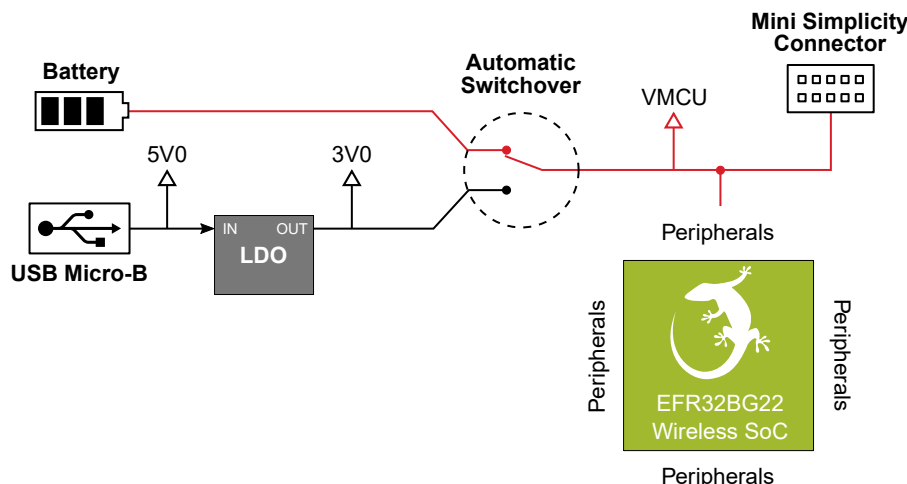

Figure 3.2. Thunderboard EFR32BG22 Power Options

Power is normally applied using either a USB cable connected to a power source or a battery inserted in the CR2032 coin cell holder. The 5 volt power net on the USB bus is regulated down to 3.0 V using a low-dropout regulator. An automatic switchover circuit switches the main system power from battery power to USB power when the USB cable is inserted, and prevents charging of the battery.

For more advanced operations, power can be applied through the Mini Simplicity connector. This option requires that no other power sources are present on the kit, as power is injected directly to the VMCU net. Failure to obey this can cause power conflicts and back-feeding of the battery. Powering the Thunderboard EFR32BG22 through the Mini Simplicity connector allows current measurements using the Advanced Energy Monitoring (AEM) as described in section 4.2 External Debugger.

> **Important:** When powering the board through the Mini Simplicity connector, the USB and battery power sources must be removed.

The power supply options are summarized in the table below.

Table 3.1. Thunderboard EFR32BG22 Power Options

Supply mode	VIN (typ)	VMCU	3V0	5V0
USB power	5.0 V	On-board regulator	On-board regulator	USB VBUS
CR2032 battery	3.0 V	Battery voltage	Turned off and isolated	No voltage present
Mini Simplicity	3.3 V	Debugger dependent	Turned off and isolated	No voltage present

3.3 EFR32BG22 Reset

The EFR32BG22 can be reset by a few different sources:
- A user pressing the RESET button.
- The on-board debugger pulling the #RESET pin low.
- An external debugger pulling the #RESET pin low.

3.4 Peripherals

The Thunderboard EFR32BG22 contains a set of peripherals that can be accessed from the EFR32BG22. All the peripherals have enable signals which can be used to completely turn off the peripherals that are not in use, or they can be put into a state that draws minuscule amount of power. This allows for the lowest possible power consumption in every application. The following peripherals are accessible to the EFR32BG22:

- One Silicon Labs Si7021 relative humidity & temperature sensor
- One Silicon Labs Si1133 UV index & ambient light sensor
- One Silicon Labs Si7210 hall effect sensor
- One TDK InvenSense ICM-20648 6-axis inertial measurement sensor
- One Macronix MX25R8035F ultra low power 8 Mbit SPI flash
- One LED and one push button

The figure below gives an overview of the peripherals that are connected to the EFR32BG22. Note that some of the peripherals share the same interface and enable signals. As the enable signals does not have external pull-down resistors on the board, it is recommended to actively drive the signals either low or high in the application code to prevent the lines from floating.
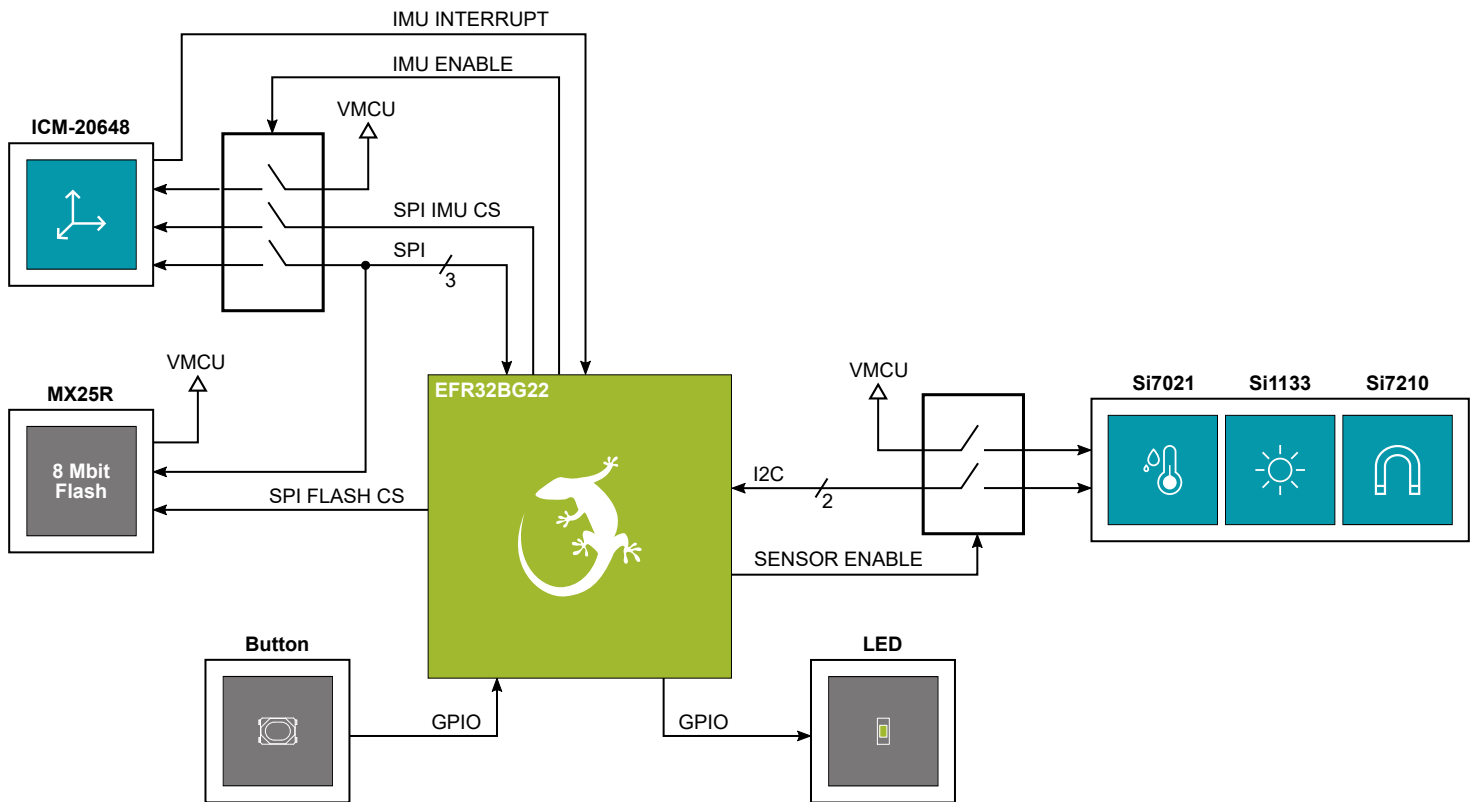
Figure 3.3. Peripherals

3.4.1 Si7021 Relative Humidity and Temperature Sensor

The Si7021 I^{2}C relative humidity and temperature sensor is a monolithic CMOS IC integrating humidity and temperature sensor elements, an analog-to-digital converter, signal processing, calibration data, and an I^{2}C interface. The patented use of industry-standard, low-K polymeric dielectrics for sensing humidity enables the construction of low-power, monolithic CMOS Sensor ICs with low drift and hysteresis, and excellent long term stability. The Si7021 offers an accurate, low-power, factory-calibrated digital solution ideal for measuring humidity, dew-point, and temperature, in applications ranging from HVAC/R and asset tracking to industrial and consumer platforms.

On Thunderboard EFR32BG22, the Si7021 is powered down and isolated through an analog switch. The analog switch must therefore be enabled by setting PA04 high before it can be used by the application. This enables power to the Si7021 and connects the I^{2}C lines used for the sensor to the EFR32BG22 I^{2}C bus. The figure below shows how the Si7021 is connected to the EFR32BG22.
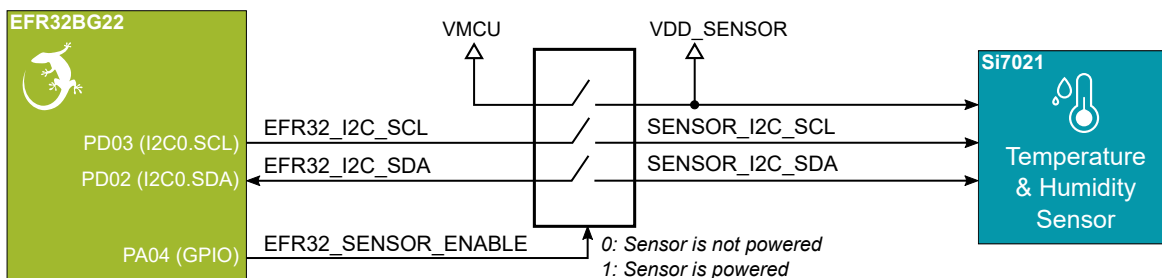
Figure 3.4. Si7021 Relative Humidity and Temperature Sensor

Note: Although measures have been taken to thermally isolated the sensor from the board, temperature readings will be influenced when power is dissipated on the board. More accurate temperature measurements are achieved when powering the board with a battery or through the Mini Simplicity connector as self-heating from the on-board LDO is eliminated and the on-board debugger is put in a low power state.

3.4.2 Si7210 Hall Effect Sensor

The Si7210 family of Hall effect sensors from Silicon Labs combines a chopper-stabilized Hall element with a low-noise analog amplifier, 13-bit analog-to-digital converter, and an I^{2}C interface. Leveraging Silicon Labs' proven CMOS design techniques, the Si7210 family incorporates digital signal processing to provide precise compensation for temperature and offset drift. The 13-bit magnetic field strength can be read through the I^{2}C interface at any time. Applications for the Si7210 include mechanical position sensing in consumer, industrial and automotive applications, reed switch replacement, fluid level measurement, speed sensing and control knobs and switches.

On Thunderboard EFR32BG22, the Si7210 is powered down and isolated through an analog switch. The analog switch must therefore be enabled by setting PA04 high before it can be used by the application. This enables power to the Si7210 and connects the I^{2}C lines used for the sensor to the EFR32BG22 I^{2}C bus. The figure below shows how the Si7210 is connected to the EFR32BG22.
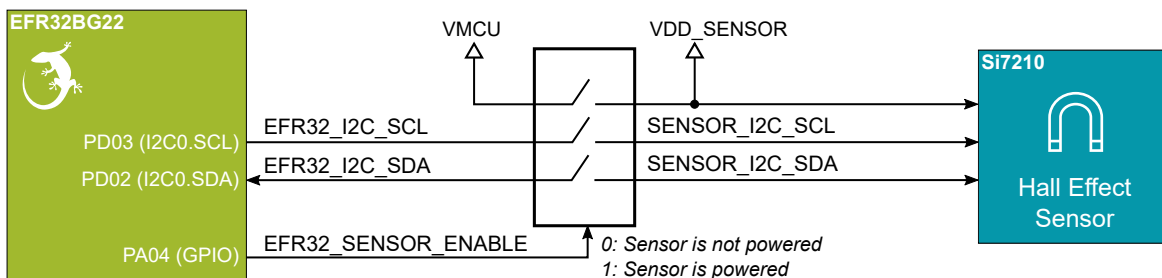
Figure 3.5. Hall Effect Sensor

3.4.3 Si1133 UV Index and Ambient Light Sensor

The Si1133 is a UV index and ambient light sensor with I^2C digital interface and programmable event interrupt output. This sensor IC includes dual 23-bit analog-to-digital converters, integrated high-sensitivity array of UV, visible and infrared photodiodes, and digital signal processor.

On Thunderboard EFR32BG22, the Si1133 is powered down and isolated through an analog switch. The analog switch must therefore be enabled by setting PA04 high before it can be used by the application. This enables power to the Si1133 and connects the I^2C lines used for the sensor to the EFR32BG22 I^2C bus. The figure below shows how the Si1133 is connected to the EFR32BG22.
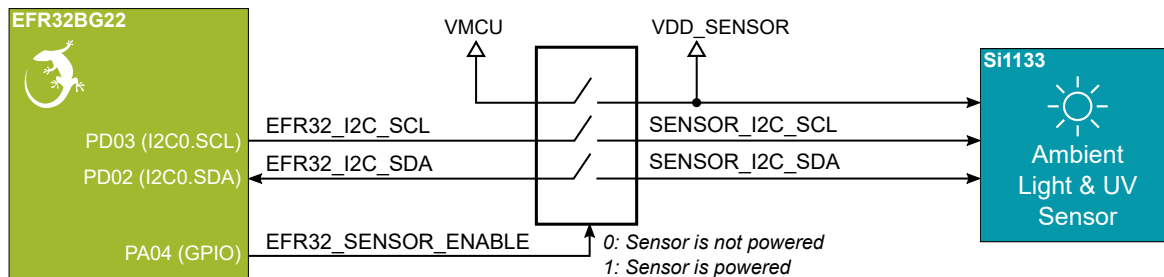

Figure 3.6. Si1133 UV and Ambient Light Sensor

3.4.4 ICM-20648 6-Axis Inertial Sensor

The ICM-20648 is a 6-axis inertial sensor consisting of a 3-axis gyroscope and a 3-axis accelerometer. The sensor detects acceleration and angular rate in and around the X-, Y- and Z-axes with integrated 16-bit ADCs and programmable digital filters. The device supports both the SPI and I^2C interface.

On Thunderboard EFR32BG22, the inertial sensor is located close to the geometrical center of the board. The coordinate system and rotation of the sensor follows the right-hand rule, and the spatial orientation of the board is shown in the figure below.
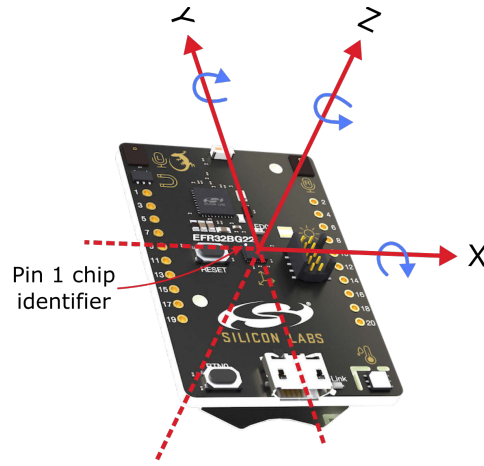

Figure 3.7. Thunderboard EFR32BG22 Spatial Orientation

On Thunderboard EFR32BG22, the ICM-20648 is powered down and isolated through an analog switch. The analog switch must therefore be enabled by setting PB04 high before it can be used by the application. This enables power to the ICM-20648 and connects the SPI lines used for the sensor to the EFR32BG22 SPI bus. Note the presence of the external pull-up resistor on the interrupt line as this can cause back powering if not handled correctly in software. The figure below shows how the ICM-20648 is connected to the EFR32BG22.
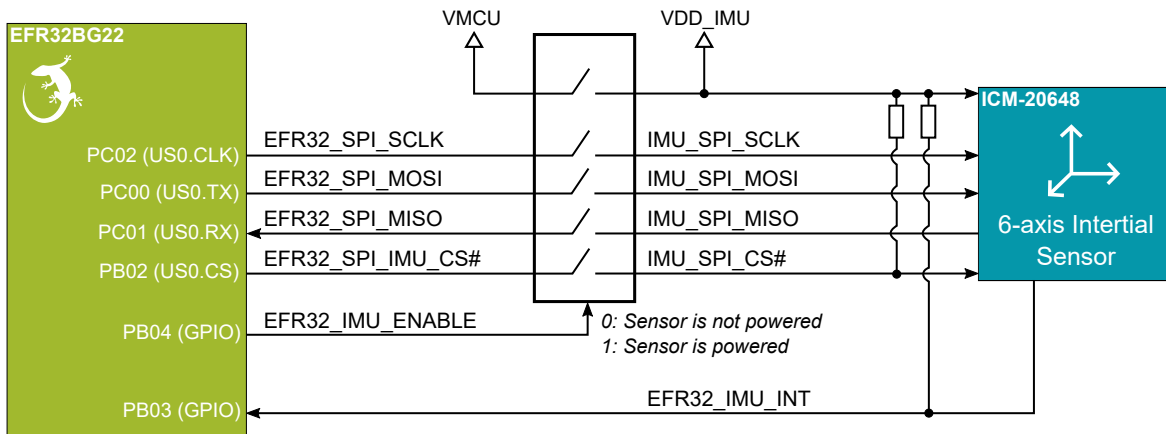

Figure 3.8. ICM-20648 Nine-axis Inertial Sensor

3.4.5 Push Button and LED

The kit has one user push button marked BTN0 that is connected to a GPIO on the EFR32BG22. The button is connected to pin PB01 and it is debounced by an RC filter with a time constant of 1 ms. The logic state of the button is high while the button is not being pressed, and low when the button is pressed.

The kit also features one yellow LED marked LED0 that is controlled by a GPIO pin on the EFR32BG22. The LED is connected to pin PB00 in an active-high configuration.
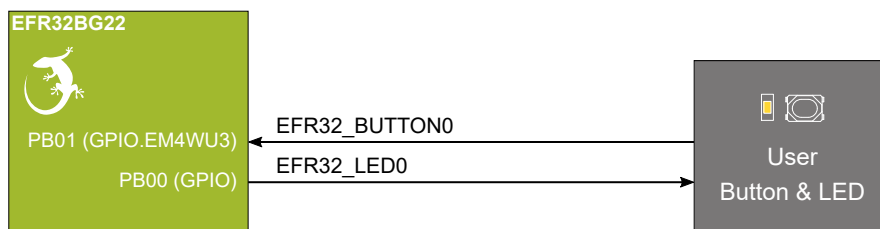
Figure 3.9. Button and LED

3.4.6 External Memory

The Thunderboard EFR32BG22 is equipped with an 8 Mbit Macronix SPI Flash that is connected directly to the EFR32BG22 Wireless Gecko. The MX25R series are ultra low power serial flash devices, so there is no need for a separate enable switch to keep current consumption down. However, it is important that the flash is always put in deep power down mode when not used. This is done by issuing a command over the SPI interface. In deep power down, the MX25R typically adds approximately 100 nA to the current consumption. The figure below shows how the serial flash is connected to the EFR32BG22.
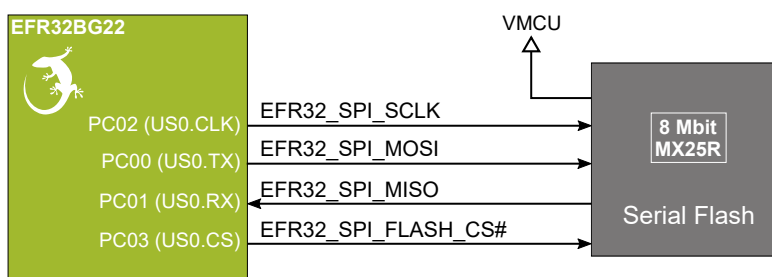
Figure 3.10. Serial Flash

3.5 On-board Debugger

The Thunderboard EFR32BG22 contains a microcontroller separate from the EFR32BG22 Wireless Gecko that provides the user with a on-board J-Link debugger through the USB Micro-B port. This microcontroller is referred to as the "on-board debugger", and is not programmable by the user. When the USB cable is removed, the on-board debugger goes into a very low power shutoff mode (EM4S), consuming around 80 nA typically (EFM32GG12 datasheet number).

In addition to providing code download and debug features, the on-board debugger also presents a virtual COM port for general purpose application serial data transfer. The Packet Trace Interface (PTI) is also supported which offers invaluable debug information about transmitted and received packets in wireless links.

Figure 3.11 On-Board Debugger Connections on page 15 shows the connections between the target EFR32BG22 device and the on-board debugger. The figure also shows the presence of the Mini Simplicity Connector, and how this is connected to the same I/O pins.

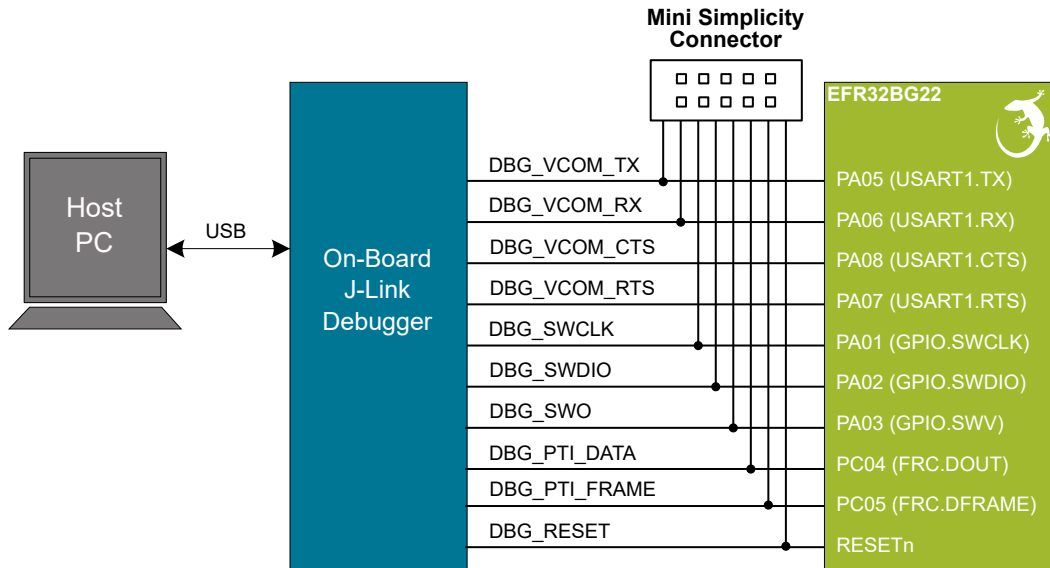Please refer to chapter 4. Debugging for more details on debugging.

Figure 3.11. On-Board Debugger Connections

3.6 Connectors

Featured on the Thunderboard EFR32BG22 is a Mini Simplicity Connector, a USB Micro-B connector and 20 breakout pads that follow the expansion header pinout. The connectors are placed on the top side of the board, and their placement and pinout can be seen in Figure 3.12 Thunderboard EFR32BG22 Connectors on page 16. For additional information on the connectors see the following sub chapters.
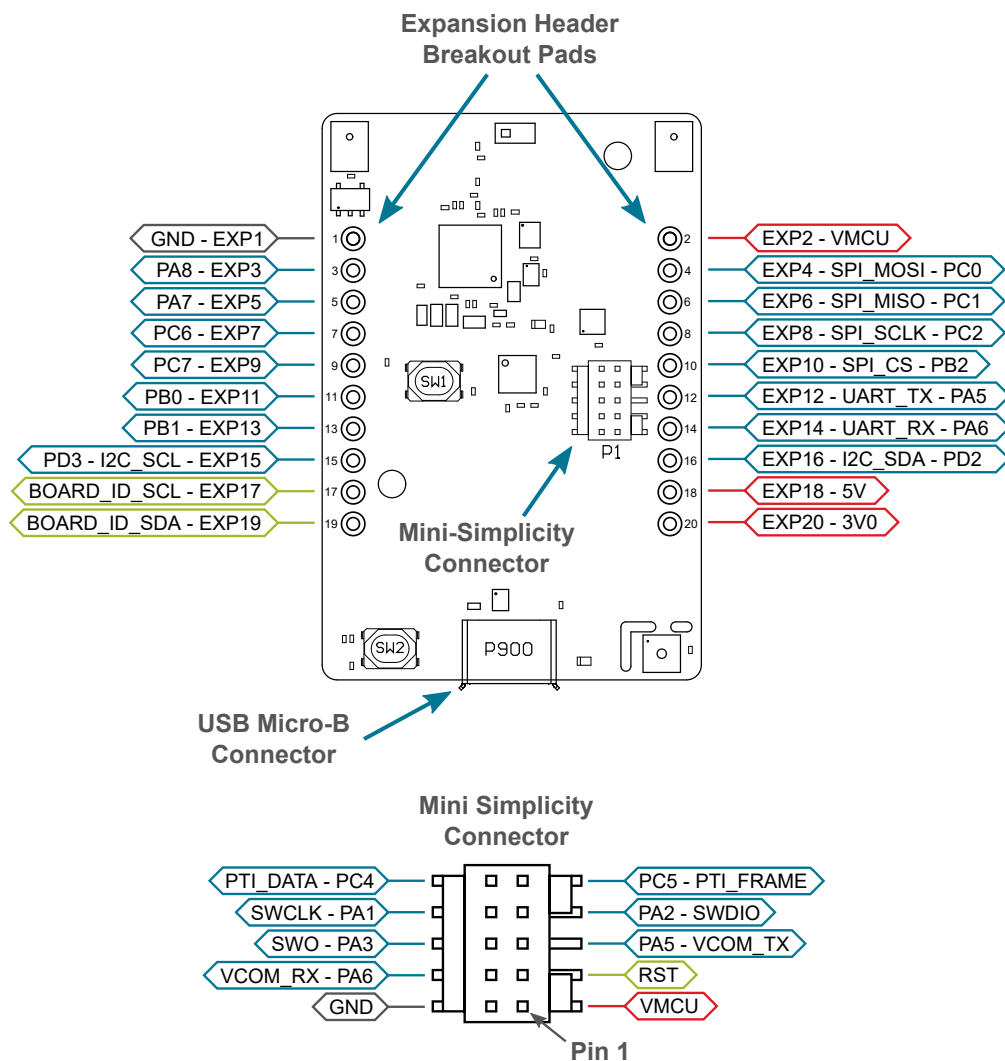
Expansion Header Breakout Pads

GND - EXP1	EXP2 - VMCU
PA8 - EXP3	EXP4 - SPI_MOSI - PC0
PA7 - EXP5	EXP6 - SPI_MISO - PC1
PC6 - EXP7	EXP8 - SPI_SCLK - PC2
PC7 - EXP9	EXP10 - SPI_CS - PB2
PB0 - EXP11	EXP12 - UART_TX - PA5
PB1 - EXP13	EXP14 - UART_RX - PA6
PD3 - I2C_SCL - EXP15	EXP16 - I2C_SDA - PD2
BOARD_ID_SCL - EXP17	EXP18 - 5V
BOARD_ID_SDA - EXP19	EXP20 - 3V0

Mini-Simplicity Connector

USB Micro-B Connector

Mini Simplicity Connector

PTI_DATA - PC4	PC5 - PTI_FRAME
SWCLK - PA1	PA2 - SWDIO
SWO - PA3	PA5 - VCOM_TX
VCOM_RX - PA6	RST
GND	VMCU

Pin 1

Figure 3.12. Thunderboard EFR32BG22 Connectors

3.6.1 Breakout Pads

20 breakout pads, which follow the expansion header pinout, are provided and allow connection of peripherals or add-on boards. Ten of the pads are located along the left side of the board while the remaining ten are located on the right side of the board. The breakout pads contain a number of I/O pins that can be used with most of the EFR32BG22 Wireless Gecko's features. Additionally, the VMCU (main board power rail), 3V0 (LDO regulator output) and 5V power rails are also exported.

The breakout pads are pinned out similar to the expansion header found on other Silicon Labs Starter Kits, which ensures that commonly used peripherals such as SPI, UART and I^2C buses are available on fixed locations. The rest of the pins are used for general purpose IO. This allows the definition of expansion boards that can plug into a number of different Silicon Labs starter kits.

The pin-routing on the EFR32 is very flexible, so most peripherals can be routed to any pin. However, pins may be shared between the breakout pads and other functions on the Thunderboard EFR32BG22. The table below includes an overview of the expansion header and functionality that is shared with the kit.

Table 3.2. Expansion Header Pinout

Pin	Connection	EXP Header Function	Shared Feature	Peripheral Mapping
Right Side Breakout Pins				
2	VMCU	EFR32BG22 voltage domain, included in AEM measurements.		
4	PC00	SPI_MOSI	IMU & Flash	US0_TX
6	PC01	SPI_MISO	IMU & Flash	US0_RX
8	PC02	SPI_SCLK	IMU & Flash	US0_CLK
10	PB02	SPI_CS	IMU	US0_CS
12	PA05	UART_TX	Virtual COM Port	US1_TX
14	PA06	UART_RX	Virtual COM Port	US1_RX
16	PD02	I2C_SDA	Sensor I2C bus	I2C0_SDA
18	5V	Board USB voltage		
20	3V0	Board controller supply		
Left Side Breakout Pins				
1	GND	Ground		
3	PA08	GPIO	Virtual COM Port	
5	PA07	GPIO	Virtual COM Port	
7	PC06	GPIO		
9	PC07	GPIO		
11	PB00	GPIO	LED	
13	PB01	GPIO	Button	
15	PD03	I2C_SCL	Sensor I2C bus	I2C0_SCL
17	BOARD_ID_SCL	Connected to Board Controller for identification of add-on boards.		
19	BOARD_ID_SDA	Connected to Board Controller for identification of add-on boards.		

3.6.2 Mini Simplicity Connector

The Mini Simplicity connector featured on the Thunderboard EFR32BG22 is a 10-pin 1.27 mm pitch connector that allows the use of an external debugger such as the one found on a Silicon Labs Wireless Starter Kit (WSTK) mainboard. In addition to providing serial wire debug (SWD) and virtual COM port functionality, the WSTK can also support advanced energy profiling, wireless network analysis and debugging tools. The pinout of the connector on the board is described in the table below with the names being referenced from the EFR32BG22.

Table 3.3. Mini Simplicity Connector Pin Descriptions

Pin number	Connection	Function	Description
1	VMCU	VAEM	Target voltage on the debugged application. Supplied and monitored by the AEM when powered by a WSTK with its power selection switch in the "AEM" position.
2	GND	GND	Ground.
3	EFR32BG22 reset pin	DBG_RST	Reset.
4	PA06	VCOM_RX	Virtual COM Rx.
5	PA05	VCOM_TX	Virtual COM Tx.
6	PA03	DBG_SWO	Serial Wire Output.
7	PA02	DBG_SWDIO	Serial Wire Data.
8	PA01	DBG_SWCLK	Serial Wire Clock.
9	PC05	PTI_FRAME	Packet Trace Frame Signal.
10	PC04	PTI_DATA	Packet Trace Data Signal.

3.6.3 Debug USB Micro-B Connector

The debug USB port can be used for uploading code, debugging, and as a Virtual COM port. More information is available in section 4. Debugging.

4. Debugging

The Thunderboard EFR32BG22 contains an on-board SEGGER J-Link Debugger that interfaces to the target EFR32BG22 using the Serial Wire Debug (SWD) interface. The debugger allows the user to download code and debug applications running in the target EFR32BG22. Additionally, it also provides a virtual COM port (VCOM) to the host computer that is connected to the target device's serial port, for general purpose communication between the running application and the host computer. The Packet Trace Interface (PTI) is also supported by the on-board debugger which offers invaluable debug information about transmitted and received packets in wireless links. The on-board debugger is accessible through the USB Micro-B connector.

An external debugger can be used instead of the on-board debugger by connecting it to the Mini Simplicity Connector. This allows advanced debugging features as described in section 4.2 External Debugger. When using an external debugger it is very important to make sure that there is no power source present on the Thunderboard EFR32BG22 if the external debugger is also sourcing a voltage on VMCU. Failure to do so will create power conflicts and there is no protection against backfeeding the on-board LDO or the battery.

> **Important:** When connecting an external debugger that sources voltage to the VMCU net, the USB and battery must be removed. Failure to do so will create power conflicts and there is no protection against backfeeding the on board LDO or the battery.
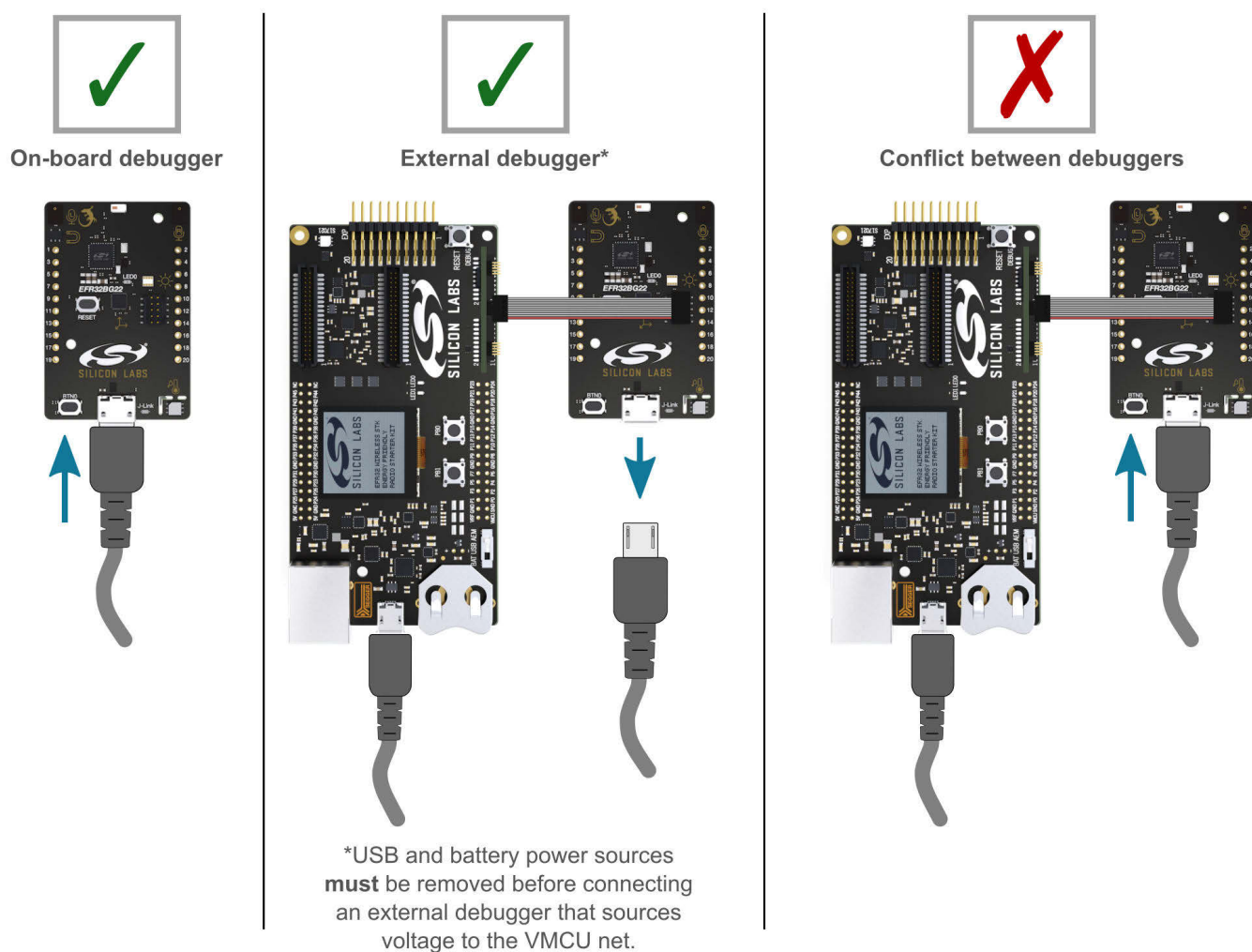
The figure below shows the possible debug options.

On-board debugger

External debugger*

Conflict between debuggers

*USB and battery power sources **must** be removed before connecting an external debugger that sources voltage to the VMCU net.

Figure 4.1. Thunderboard EFR32BG22 Debugging Possibilities

4.1 On-board Debugger

The on-board debugger is a SEGGER J-Link debugger running on an EFM32 Giant Gecko. The debugger is directly connected to the debug and VCOM pins of the target EFR32BG22.

When the debug USB cable is inserted, the on-board debugger is automatically active, and takes control of the debug and VCOM interfaces. This means that debug and communication will *not* work with an external debugger connected at the same time. The on-board LDO is also activated which then powers the board. When the USB cable is removed, the on-board debugger goes into a very low power shutoff mode (EM4S), consuming around 80 nA typically (EFM32GG12 datasheet number). This means that an application running off batteries will not be affected too much by the on-board debugger power consumption. Since the I/O voltage rail of the debugger remains powered in the battery operated mode, the pins connected to the debug and VCOM interfaces maintain proper isolation and prevent leakage currents.

4.2 External Debugger

A Wireless Starter Kit (Wireless STK) mainboard with a debug adapter board from Silicon Labs can be connected to the Mini Simplicity Connector and used for debugging instead of the on-board debugger. For instruction on how this can be done see "AN958: Debugging and Programming Interfaces for Custom Designs". Debugging with an external Wireless STK mainboard gives access to the following debugging features:

* Debugging of the target device through SWD
* Communication using the VCOM port
* Packet Trace Interface
* Advanced Energy Monitor

Please note that the Mini Simplicity Connector *cannot* be used at the same time as the on-board debugger is active (USB cable is plugged in). For information on how to correctly connect to the kit, see Figure 4.1 Thunderboard EFR32BG22 Debugging Possibilities on page 19.

Powering the board when using the Mini Simplicity Connector with a Wireless STK mainboard and adapter board can be done using the AEM voltage supply of the Wireless STK mainboard. When doing this, remember to remove both the USB cable and the coin cell battery from the Thunderboard EFR32BG22 before connecting the Wireless STK mainboard to the Mini Simplicity Connector. The power switch on the Wireless STK mainboard should be set in "AEM". Power-cycling of the board, if necessary, can easily be done by flipping the power switch on the Wireless STK to "BAT" and back to "AEM" assuming a battery is not inserted in the Wireless STK mainboard.

It is possible to have the Thunderboard EFR32BG22 powered by a battery, and still use the Mini Simplicity Connector with a Wireless STK mainboard for debugging and communication. In this case the power switch on the Wireless STK mainboard must be set to the "BAT" position and the coin cell battery on the Wireless STK mainboard must be removed. In this case level shifters on the Wireless STK itself takes care of interfacing to different voltage levels on the Thunderboard EFR32BG22.

4.2.1 External Debugger Considerations

4.2.1.1 Pull-Up Resistor on Reset

A small current may be injected into the VDCDC rail when using an external debugger that has a pull up resistor to VMCU on the reset line. The debugger on the Wireless STK mainboard features a 100 kΩ pull-up resistor, and the following paragraph explains what happens when a Wireless STK mainboard with a debug adapter board is connected to the Thunderboard EFR32BG22.

The debugger on the Wireless STK mainboard features a pull-up resistor on the debug reset signal that connects to a buffered version of the power supply net VMCU when using the debug adapter board (BRD8010A). As the RESETn pin on the EFR32BG22 is connected to the DVDD pin through a pull-up resistor inside the chip, an electric path is created between the buffered VMCU rail on the Wireless STK mainboard and DVDD on the Thunderboard EFR32BG22. On Thunderboard EFR32BG22, DVDD is connected to the output of the EFR32BG22's DC/DC buck regulator (VDCDC) and current will flow from the buffered VMCU rail to the VDCDC net when VDCDC is regulated down to a voltage less than VMCU. The injected current will cause erroneous current consumption and current measurements, and raise the voltage on the VDCDC rail if the total current consumption of the VDCDC rail is less than the injected current. At the time of writing, the combination of the two pull-up resistors is 144 kΩ (typ) which would lead to ~10 µA injected current on VDCDC assuming VMCU is 3.3 V and VDCDC is 1.8 V.

4.2.1.2 Input Voltage

When powering the Thunderboard EFR32BG22 with a Wireless STK mainboard and debug adapter board, the sourced voltage on VMCU will be 3.3 V typically. Powering the Thunderboard EFR32BG22 at 3.3 V may exceed the safe operating range of the EFR32BG22 unless the average load current of the DC/DC converter and temperature are restricted accordingly. For more information about this topic see the EFR32BG22 datasheet.

4.3 Virtual COM Port

The virtual COM port is a connection to a UART of the target EFR32BG22, and allows serial data to be sent and received from the device. The on-board debugger presents this as a virtual COM port on the host computer that shows up when the USB cable is inserted. Alternatively, the VCOM port can also be used through the Mini Simplicity Connector with an external Wireless STK.

Data is transferred between the host computer and the debugger through the USB connection, which emulates a serial port using the USB Communication Device Class (CDC). From the debugger, the data is passed on to the target device through a physical UART connection.

The serial format is 115200 bps, 8 bits, no parity, and 1 stop bit by default.

Using the VCOM port through the Mini Simplicity Connector with an external Wireless STK works in a similar way, but requires that the on-board debugger is unplugged. The board controller on the Wireless STK then makes the data available over USB (CDC) or an IP socket.

Note: Changing the baud rate for the COM port on the PC side does not influence the UART baud rate between the debugger and the target device.

5. Radio

5.1 RF Section

This section gives a short introduction to the RF section of the BRD4184A board.

The schematic of the RF section is shown in the figure below.
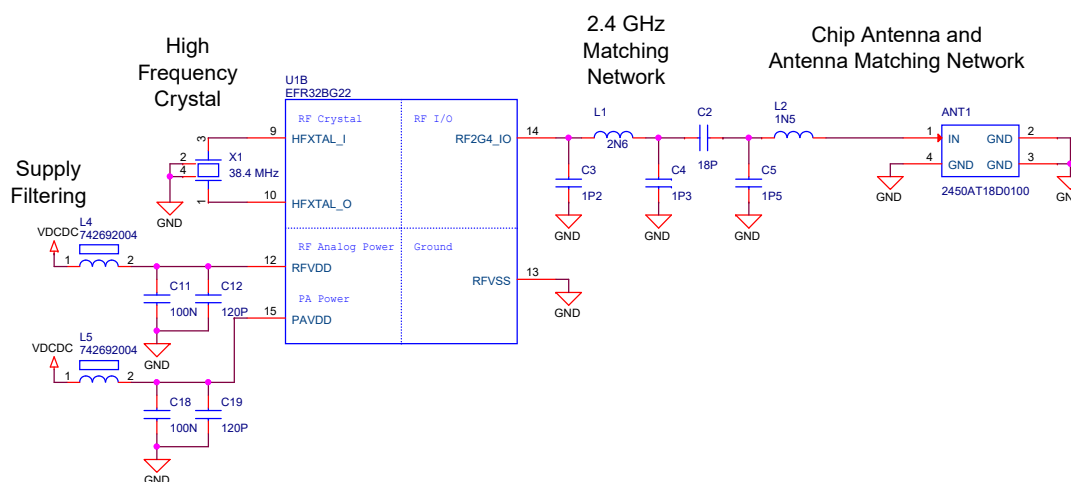
Figure 5.1. Schematic of the RF section

5.1.1 Description of the RF Matching

The impedance of the RF port of the EFR32BG22 is matched to 50 Ohm: the RF2G4_IO pin is connected to a three-element impedance matching and harmonic filter circuitry, and a DC blocking capacitor. The on-board ceramic antenna is also matched to 50 Ohm by its impedance matching components and connected to the EFR32BG22.

5.1.2 RF Section Power Supply

On the BRD4184A the supply for the radio (RFVDD) and the power amplifier (PAVDD) is connected to the on-chip DC-DC converter. By default, the DC-DC converter provides 1.8 V for the entire RF section (for details, see the schematic of the BRD4184A).

5.1.3 RF Matching Bill of Materials

The Bill of Materials of the BRD4184A RF matching network is shown in the following table.

Table 5.1. Bill of Materials of the BRD4184A RF Matching Network

Component name	Value	Manufacturer	Part Number
L1	2.6 nH	Murata	LQP03HQ2N6B02
C2	18 pF	Murata	GJM0335C1E180GB01D
C3	1.2 pF	Murata	GRM0335C1H1R2WA01D
C4	1.3 pF	Murata	GRM0335C1H1R3BA01D

5.1.4 Antenna

The BRD4184A has an on-board ceramic antenna.

The land pattern for the antenna on the PCB layout was designed based on the recommendations of the antenna datasheet. Due to the fact that there is a significant difference between the layout (practically the board size) of the BRD4184A and the antenna evaluation board, the applied antenna matching network deviates from the recommendation.

The values of the antenna matching network components were fine tuned to match the antenna impedance close to 50 Ohm on the BRD4184A PCB. The resulting antenna impedance and reflection are shown in the figure below.
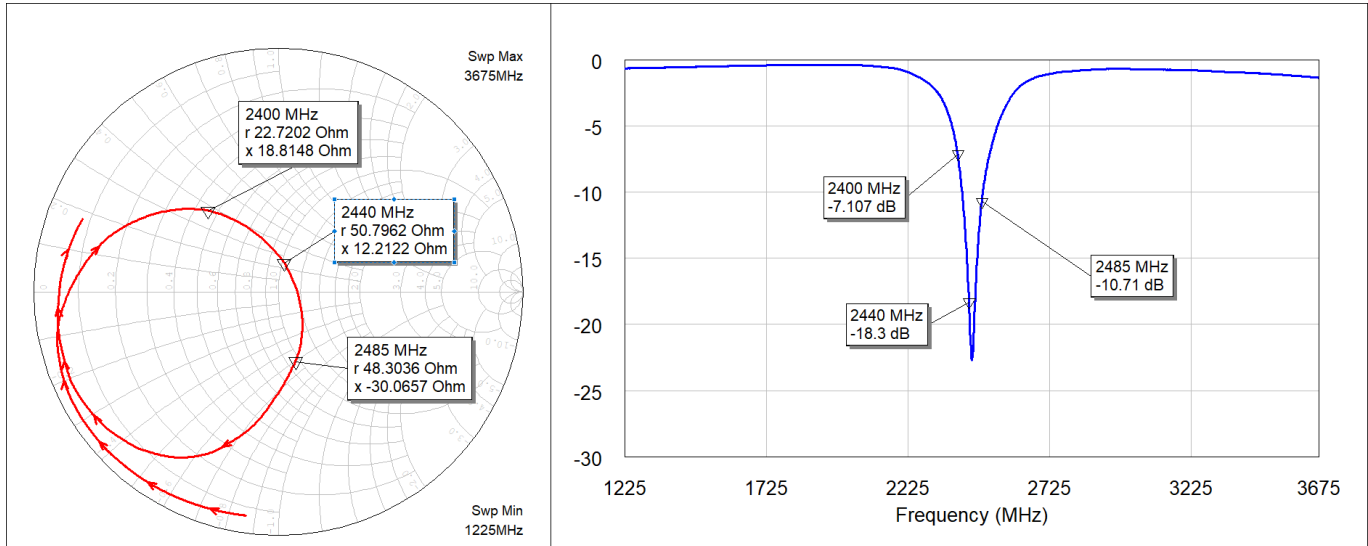
Figure 5.2. Fine Tuned Antenna Impedance (Red Curve) and Reflection (Blue Curve)

5.1.5 Antenna Matching Bill of Materials

The Bill of Materials of the BRD4184A antenna matching network is shown in the following table.

Table 5.2. Bill of Materials of the BRD4184A Antenna Matching Network

Component name	Value	Manufacturer	Part Number
ANT1	-	Johanson	2450AT18D0100
L2	1.5 nH	Murata	LQP03TN1N5B02D
C5	1.5 pF	Murata	GRM0335C1E1R5BA01D

5.2 EMC Regulations for 2.4 GHz

5.2.1 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.

5.2.2 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 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 (equals to -41.2 dBm in EIRP).

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 -41.2 dBm limit should be applied. For the 4th harmonic the -20 dBc limit should be applied.

5.2.3 Applied Emission Limits

The overall applied limits are shown in the table below. For the harmonics that fall into the FCC restricted bands, the FCC 15.209 limit is applied, and the ETSI EN 300-328 limit is applied for the rest.

Table 5.3. Applied Limits for Spurious Emissions

Harmonic	Frequency	Limit
2nd	4800~4967 MHz	-41.2 dBm
3rd	7200~7450.5 MHz	-41.2 dBm
4th	9600~9934 MHz	-30 dBm
5th	12000~12417.5 MHz	-41.2 dBm

5.3 Relaxation with Modulated Carrier

Depending on the applied modulation scheme, and the Spectrum Analyzer settings specified by the relevant EMC regulations, the measured power levels are usually lower compared to the results with unmodulated carrier. These differences have been measured and used as relaxation factors on the results of the radiated measurement performed with unmodulated carrier. This way, the radiated compliance with modulated transmission can be evaluated.

In this case, both the ETSI EN 300-328 and the FCC 15.247 regulations define the following Spectrum Analyzer settings for measuring the unwanted emissions above 1 GHz:
* Detector: Average
* RBW: 1 MHz

The table below shows the relative levels of the measured modulated signals compared to the unmodulated levels with the above Spectrum Analyzer settings in case of the supported modulation schemes.

Table 5.4. Measured Relaxation Factors for the Supported Modulation Schemes

Applied Modulation (Packet Length: 255 bytes)	BLE Coded PHY: 125 Kb/s (PRBS9) [dB]	BLE Coded PHY: 500 Kb/s (PRBS9) [dB]	BLE 1M PHY: 1 Mb/s (PRBS9) [dB]	BLE 2M PHY: 2 Mb/s (PRBS9) [dB]
2nd harmonic	-2.7	-3.1	-3.3	-9.1
3rd harmonic	-4.8	-5.2	-5.2	-10.7
4th harmonic	-5.5	-6.5	-6.7	-11.9
5th harmonic	-6.3	-6.5	-6.7	-11.4

As it can be observed, the BLE 125 Kb/s coded modulation scheme has the lowest relaxation factors. These values will be used as the worst case relaxation factors for the radiated measurements.

5.4 Radiated Power Measurements

The output power of the EFR32BG22 was set to 6 dBm. The board was supplied through its USB connector by connecting to a PC through a USB cable.

During the measurements the board was rotated in three cuts, see the reference plane illustration in the figure below. The radiated powers of the fundamental and the harmonics were measured with horizontal and vertical reference antenna polarizations.
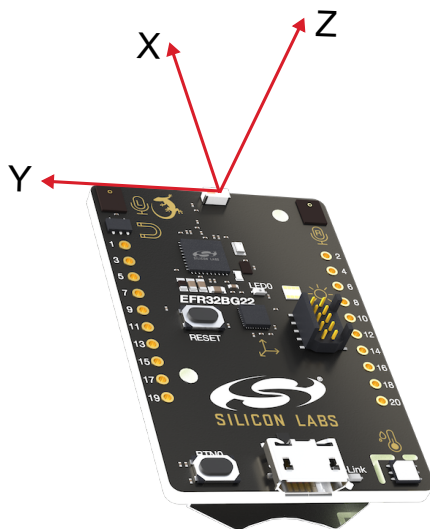
Figure 5.3. DUT Reference Planes

5.4.1 Maximum Radiated Power Measurement

The transceiver was operated in unmodulated carrier transmission mode, the output power of the radio was set to 6 dBm. The results are shown in the table below.

The correction factors are applied based on the BLE 125 Kb/s coded modulation, showed in section 5.3 Relaxation with Modulated Carrier. For the rest of the supported modulation schemes the correction factors are larger, thus the related calculated margins would be higher compared to the ones shown in the table below. Thus the below margins can be considered as worst case margins.

Table 5.5. Maximums of the Measured Radiated Powers of BRD4184A

Frequency (2440 MHz)	Measured Un-modulated EIRP [dBm]	Orientation	BLE 125 Kb/s Coded Modulation			Limit in EIRP [dBm]
			Correction Factor [dB]	Calculated Modulated EIRP [dBm]	Modulated Margin [dB]	
Fund	7.6	XY/H	NA (0 is used)	7.6	22.4	30
2nd	-51.4	XY/H	-2.7	-54.1	12.9	-41.2
3rd	-45.8	YZ/H	-4.8	-50.6	9.4	-41.2
4th	<-50*	-/-	-5.5	-	>20	-30
5th	-41.3	XZ/H	-6.3	-47.6	6.4	-41.2
* Signal level is below the Spectrum Analyzer noise floor.						

As it can be observed the radiated power levels with modulation are far below the applied limits.

5.4.2 Antenna Pattern Measurement

The measured typical antenna patterns are shown in the figures below.

Figure 5.4. Antenna Pattern - XY

Normalized Radiation Pattern [dB], XZ cut
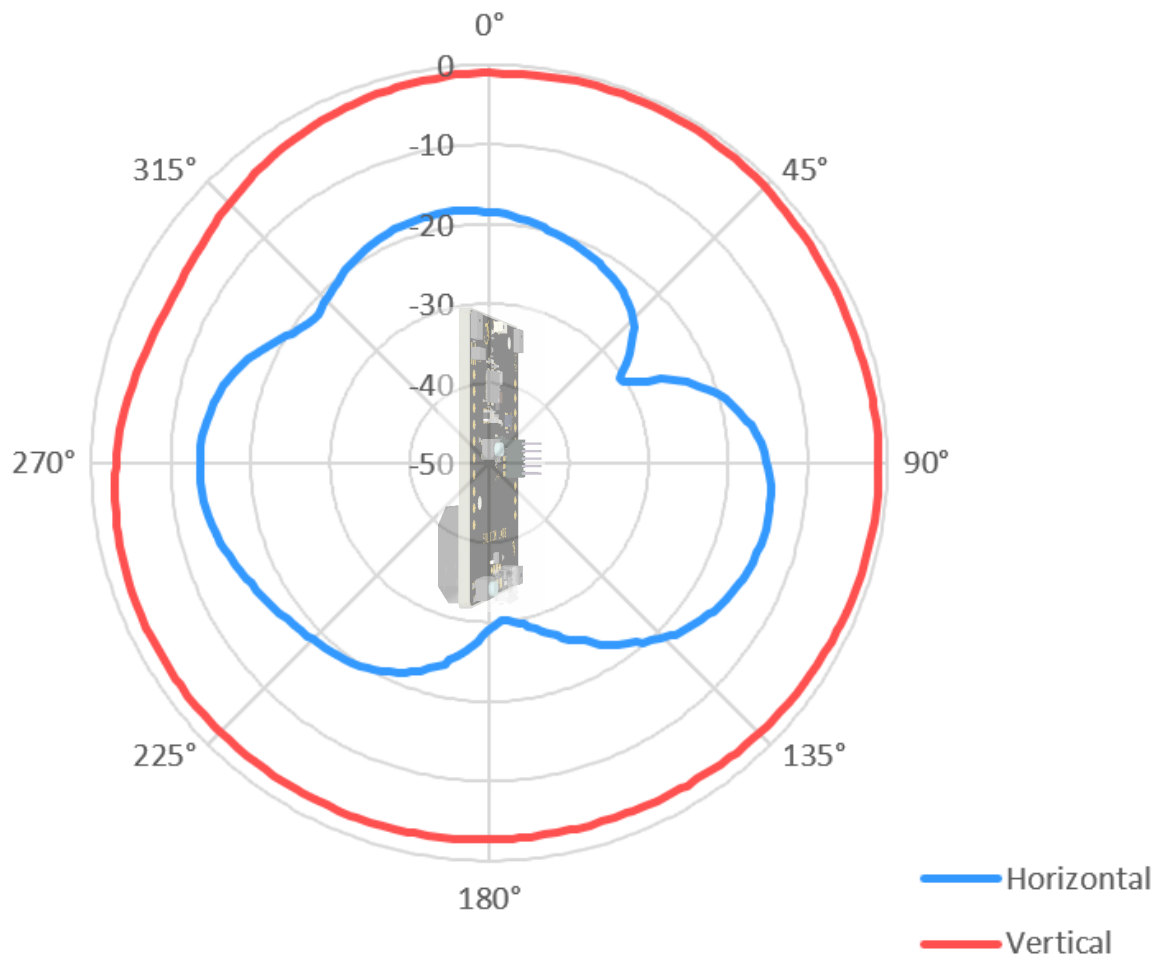
Figure 5.5. Antenna Pattern - XZ
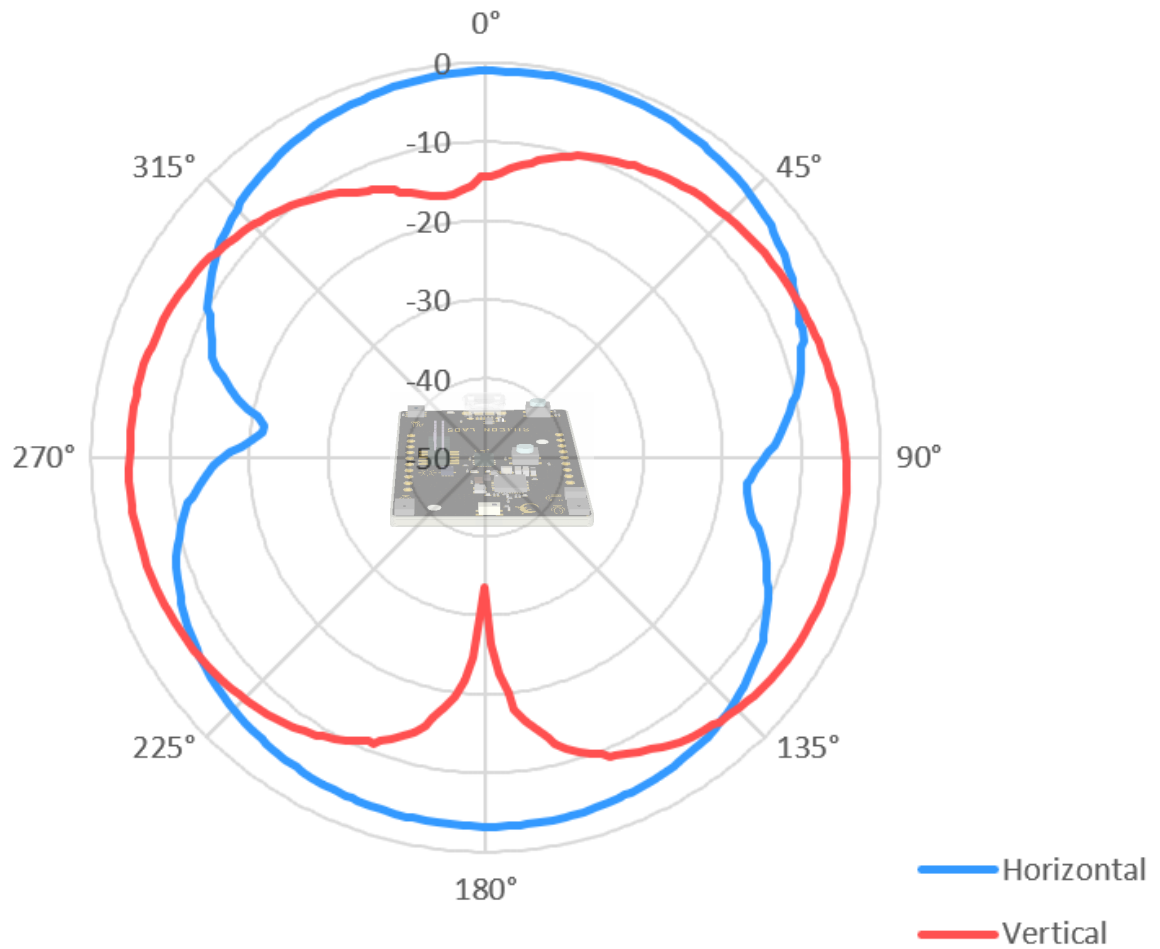
Figure 5.6.   Antenna Pattern - YZ

5.5 EMC Compliance Recommendations

5.5.1 Recommendations for 2.4 GHz ETSI EN 300-328 Compliance

As it was shown in the previous chapter, with the EFR32BG22 output power set to 6 dBm, the radiated power of the fundamental of the BRD4184A complies with the 20 dBm limit of the ETSI EN 300-328. The harmonic emissions are under the applied limits with margin.

5.5.2 Recommendations for 2.4 GHz FCC 15.247 Compliance

As it was shown in the previous chapter, with the EFR32BG22 output power set to 6 dBm, the radiated power of the fundamental of the BRD4184A complies with the 30 dBm limit of the FCC 15.247. The harmonic emissions are under the applied limits with margin.

6. Schematics, Assembly Drawings, and BOM

Schematics, assembly drawings, and bill of materials (BOM) are available through Simplicity Studio when the kit documentation package has been installed.

7. Kit Revision History and Errata

7.1 Revision History

The kit revision can be found printed on the box label of the kit, as outlined in the figure below. The kit revision history is summarised in .

Figure 7.1. Revision Info

Table 7.1. Kit Revision History

Kit Revision	Released	Description
A01	2020-01-22	Updated revision to include BRD4184A Rev. A02.
A00	2019-11-25	Initial kit revision with BRD4184A Rev. A01.

7.2 Errata

Table 7.2. Kit Errata

Kit Revision	Problem	Description
A01-A00	Contains board with known erratas	The kit contains a board revision with known erratas.

8. Board Revision History and Errata

8.1 Revision History

The board revision can be found laser printed on the board, and the board revision history is summarised in Table 8.1 Board Revision History on page 31.

Table 8.1. Board Revision History

Revision	Released	Description
A02	2020-22-01	Changed C5 and X900.
A01	2019-11-04	Changed U1 part number, updated RF matching network, removed NM components and updated PCB revision.
A00	2019-09-13	Initial version.

8.2 Errata

Table 8.2. Board Errata

Board Revision	Problem	Description
A02-A00	External debuggers may inject current on VDCDC.	A small current may be injected into the VDCDC rail when using an external debugger that has a pull up resistor to VMCU on the reset line as described in section 4.2.1.1 Pull-Up Resistor on Reset.
	Chosen PDM microphone interface pinout and routing affects radio performance.	Using the microphones and the radio at the same time leads to severe degradation of radio performance and unstable Bluetooth link. This is because the PDM microphone interface pin selection and routing is too close to the HFXTAL pins and the HFXO, causing signal coupling to the HFXO and further into the radio. As a consequence of this issue the PDM microphones are not supported by the sample application that is pre-programmed into the board, and the sound level will not be displayed in the Thunderboard mobile app. This issue will be addressed on a new board revision, in which a new pinout of the PDM interface will be chosen.

9. Document Revision History

Revision 1.0

March, 2020

- Initial document release.

Simplicity Studio

One-click access to MCU and wireless tools, documentation, software, source code libraries & more. Available for Windows, Mac and Linux!

IoT Portfolio *www.silabs.com/IoT*	**SW/HW** *www.silabs.com/simplicity*	**Quality** *www.silabs.com/quality*	**Support and Community** *community.silabs.com*

Silicon Laboratories Inc.
400 West Cesar Chavez
Austin, TX 78701
USA

http://www.silabs.com

X-ON Electronics

Largest Supplier of Electrical and Electronic Components

Click to view similar products for Bluetooth Development Tools - 802.15.1 *category:*

Click to view products by Silicon Labs *manufacturer:*

Other Similar products are found below :

DA14580PRODTLKT 1628 SP14808ST MBH7BLZ02-EF-KIT CYBLE-014008-PROG FWM7BLZ20-EB-KIT SP14801-DUT ATSAMB11ZR-XPRO SKY66111-21EK1 SECO-RSL10-TAG-GEVB ENW89857AXKF 3026 MIKROE-2471 MOD-NRF8001 BLE-IOT-GEVB 450-0184 EKSHCNZXZ EVAL_PAN1026 EVAL_PAN1720 EVAL_PAN1740 2267 2479 2487 2633 STEVAL-IDB005V1D STEVAL-IDB001V1 MIKROE-2545 SIPKITSLF001 2995 STEVAL-IDB007V1M 2829 DFR0267 DFR0296 DFR0492 TEL0073 BM-70-CDB WSM-BL241-ADA-008DK STEVAL-BTDP1 ACD52832 TEL0095 ISP1507-AX-TB RN-4871-PICTAIL DA14695-00HQDEVKT-P DA14695-00HQDEVKT-U EVK-NINA-B112 EBSHJNZXZ EKSGJNZWY EKSHJNZXZ BMD-200-EVAL-S ACN BREAKOUT BOARD