# UG524: xG24 Dev Kit User's Guide

The xG24 Dev Kit is a low-cost, small form factor development and evaluation platform for the EFR32MG24 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 xG24 Dev Kit is an ideal platform for developing energy-friendly connected IoT devices.

The xG24 Dev Kit ships with a Bluetooth demo that works with a cloud-connected smartphone app, showcasing easy collection of environmental and motion sensor data.

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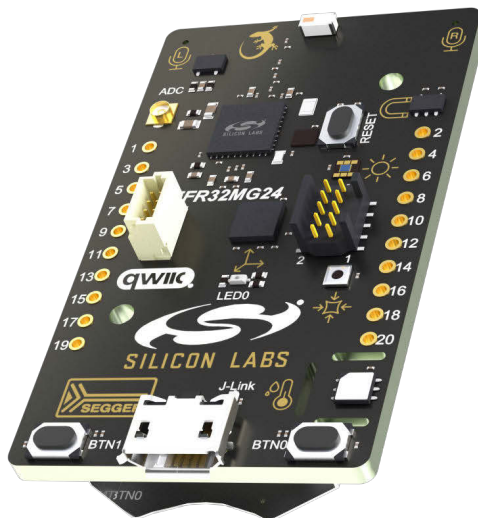


**TARGET DEVICE**

- EFR32 Wireless Gecko System-on-Chip (EFR32MG24B310F1536IM48-B)
- High-performance 2.4 GHz radio
- 32-bit ARM® Cortex®-M33 with 78.0 MHz maximum operating frequency
- 1536 flash and 256 kB RAM

**KIT FEATURES**

- 2.4 GHz ceramic chip antenna
- Power control of on-board peripherals for ultra-low power operation
- Relative humidity and temperature sensor
- Ambient light sensor
- Hall effect sensor
- 6-axis inertial sensor
- MEMS stereo microphones
- Pressure sensor
- 32 Mbit flash for OTA programming and data logging
- RGB LED and two push buttons
- Precise voltage reference and dedicated U.FL connector for ADC measurements
- 20-pin 2.54 mm breakout pads
- Qwiic® connector
- 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
- External battery connector

**SOFTWARE SUPPORT**

- Simplicity Studio™

# Table of Contents

# 1. Introduction

The xG24 Dev Kit (OPN: xG24-DK2601B) has been designed to inspire customers to make battery-operated IoT devices with the Silicon Labs EFR32MG24 Wireless Gecko System-on-Chip. The highlights of the board include five different environmental sensors, stereo I2S microphones, and a dedicated ADC U.FL connector and precise voltage reference, all accessible to the EFR32MG24 wireless MCU. The peripherals have been grouped into power domains that can be turned on and off by the application code as needed.

Programming the xG24 Dev Kit 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 a 32 Mbit serial flash that can be used for Over-The-Air (OTA) firmware upgrade, or as a general purpose non-volatile memory. The xG24 Dev Kit 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 xG24 Dev Kit can be done using the 20 breakout pads which present peripherals from the EFR32MG24 Wireless Gecko such as I$^2$C, SPI, UART, and GPIOs. The breakout pads follow the same pinout as the expansion headers (EXP) on other Silicon Labs Starter Kits. The board also features a Qwiic connector which can be used to connect hardware from the Qwiic Connect System through I$^2$C.

## 1.1 Kit Contents

The following items are included in the box:
- 1x MG24 Dev Kit board (BRD2601B)
- 1x USB Type A to Micro-B cable

## 1.2 Getting Started

Detailed instructions for how to get started with your new xG24 Dev Kit can be found on the Silicon Labs web page:

silabs.com/development-tools

## 1.3 Hardware Content

The following key hardware elements are included on the xG24 Dev Kit:
- EFR32MG24 Wireless Gecko SoC with 78.0 MHz operating frequency, 1536 kB flash, and 256 kB RAM
- 2.4 GHz ceramic antenna for wireless transmission
- Silicon Labs Si7021 relative humidity and temperature sensor
- Silicon Labs Si7210 hall effect sensor
- TDK InvenSense ICM-20689 6-axis inertial sensor
- Two ICS-43434 MEMS microphones
- Bosch Sensortec BMP384 barometric pressure sensor
- Ambient light sensor (VEML6035)
- Macronix ultra low power 32 Mbit SPI flash (MX25R3235F)
- RGB LED and two push buttons
- U.FL connector and precise external voltage reference for ADC measurements
- 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
- Qwiic connector for connecting external hardware from the Qwiic Connect System
- Reset button
- Automatic switchover between USB and battery power
- CR2032 coin cell holder and external battery connector

## 1.4 Kit Hardware Layout

xG24 Dev Kit layout is shown below.
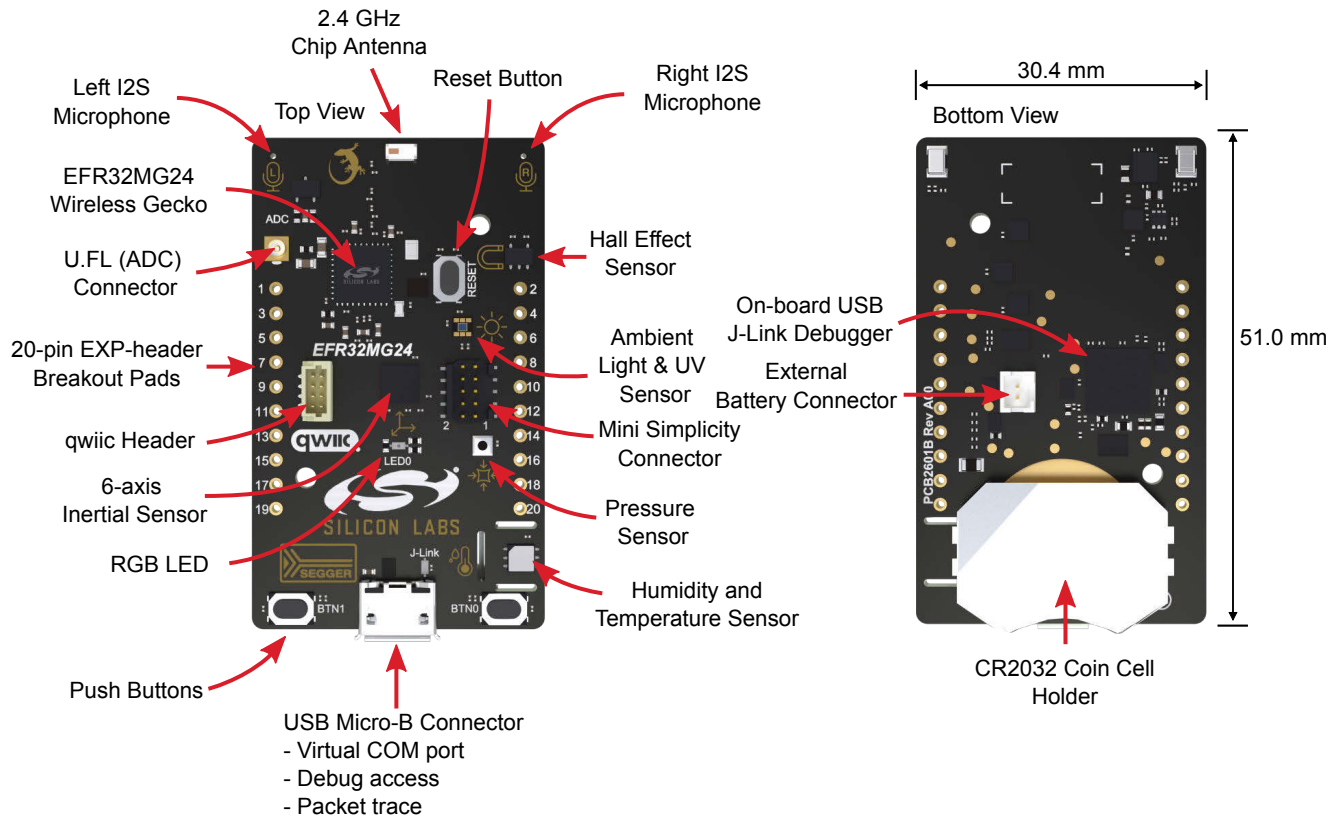


**Figure 1.1. xG24 Dev Kit Hardware Layout**

# 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 | $V_{VBAT}$ | 1.9 | 3.0 | 3.6 | V |
| Supply Input Voltage (VMCU supplied externally)[1,2,3] | $V_{VMCU}$ | 1.9 | 3.3 | 3.6 | V |
| Operating Temperature | $T_{OP}$ | — | 25 | — | ˚C |

**Note:**
1. Brightness of the RGB LED will vary with the supply voltage. Due to manufacturing tolerances, functionality is not guaranteed over the entire working range.
2. To optimize efficiency, EFR32MG24's internal DC-DC converter should be set in BYPASS mode when the input voltage approaches the output voltage, typically for supply voltages lower than 2.2 V. More details are found in EFR32MG24's data sheet.
3. Not recommended for use with rechargeable Lithium batteries. Most Li-Ion and Li-Po cells exceed 3.6 V when fully charged.

## 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. Note that the numbers are taken from the data sheets for the devices. For a full overview of the conditions that apply for a specific number from a data sheet, the reader is encouraged to read the specific data sheet.

**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, 39 MHz crystal, CPU running Prime from flash at 25 ˚C) | 33.9 | µA/MHz |
| | | EM4, no BURTC, no LF oscillator | 0.25 | µA |
| | | 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 = 39 MHz, 1Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE1 at 25 ˚C) | 4.4 | mA |
| | | Radio system current consumption in transmit mode (DC-DC converter at 3.0 V input and 1.8 V output, MCU in EM1P and all MCU peripherals disabled, HCLK = 39 MHz, f = 2.4 GHz, CW, 10 dBm output power, VSCALE1 at 25 ˚C) | 20 | mA |
| RH/Temp Sensor Current Consumption [2] | $I_{Si7021}$ | 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 |
| Hall Effect Sensor Current Consumption [3] | $I_{Si7210}$ | Sleep mode at 3.3 V | 50 | µA |
| | | Average current for periodic activation at 3.3 V, sleep timer enabled, 200 msec sleep time | 0.4 | µA |
| | | Conversion in progress at 3.3 V | 5 | mA |
| Microphone Current Consumption[4,5] | $I_{MIC}$ | Sleep mode, $f_s$ less than 3.125 kHz | 12 | µA |
| | | Performance mode ($V_{DD}$ = 1.8 V) | 490 | µA |
| IMU Current Consumption [6] | $I_{IMU}$ | Full-chip sleep mode at 1.8 V supply | 6 | µA |
| | | Gyroscope + Accelerometer 6-Axis low power mode, 100 Hz update rate at 1.8 V supply | 1.9 | mA |
| External Flash Current Consumption [7] | $I_{MX25R3235F}$ | Deep Power-down at 1.8 V supply | 7 | nA |
| | | Standy at 1.8 V supply | 5 | µA |
| | | Program current (PP) at 1.8 V supply | 3.5 | mA |
| Ambient Light Sensor Current Consumption [8] | $I_{VEML6035}$ | Shutdown at 1.8 V supply | 0.5 | µA |
| | | Operation mode at 1.8 V supply (ALS only) | 170 | µA |
| Pressure Sensor Current Consumption [9] | $I_{BMP384}$ | Sleep current | 2 | µA |
| | | Peak current during pressure measurement | 700 | µA |
| Precise Voltage Reference | $I_{ADC\_VREF}$ | Enabled at 3.3 V supply | 127 | µA |

| Parameter | Symbol | Condition | Typ | Unit |
|---|---|---|---|---|
| On-board Debugger Sleep Current Consumption [10] | $I_{DBG}$ | On-board debugger current consumption when USB cable is not inserted (EFM32GG12 EM4S mode current consumption) | 80 | nA |

1    From EFR32MG24 Wireless Gecko SoC data sheet

2    From Si7021-A20 data sheet

3    From Si7210 data sheet

4    From ICS-43434 data sheet

5    Per microphone

6    From ICM-20689 data sheet

7    From MX25R3235F data sheet

8    From VEML6035 data sheet

9    From BMP384 data sheet

10   From EFM32GG12 data sheet

# 3. Hardware

The core of the xG24 Dev Kit is the EFR32MG24 Wireless Gecko System-on-Chip. The board also contains several peripherals connected to the EFR32MG24. Refer to section 1.4 Kit Hardware Layout for placement and layout of the hardware components.

## 3.1 Block Diagram

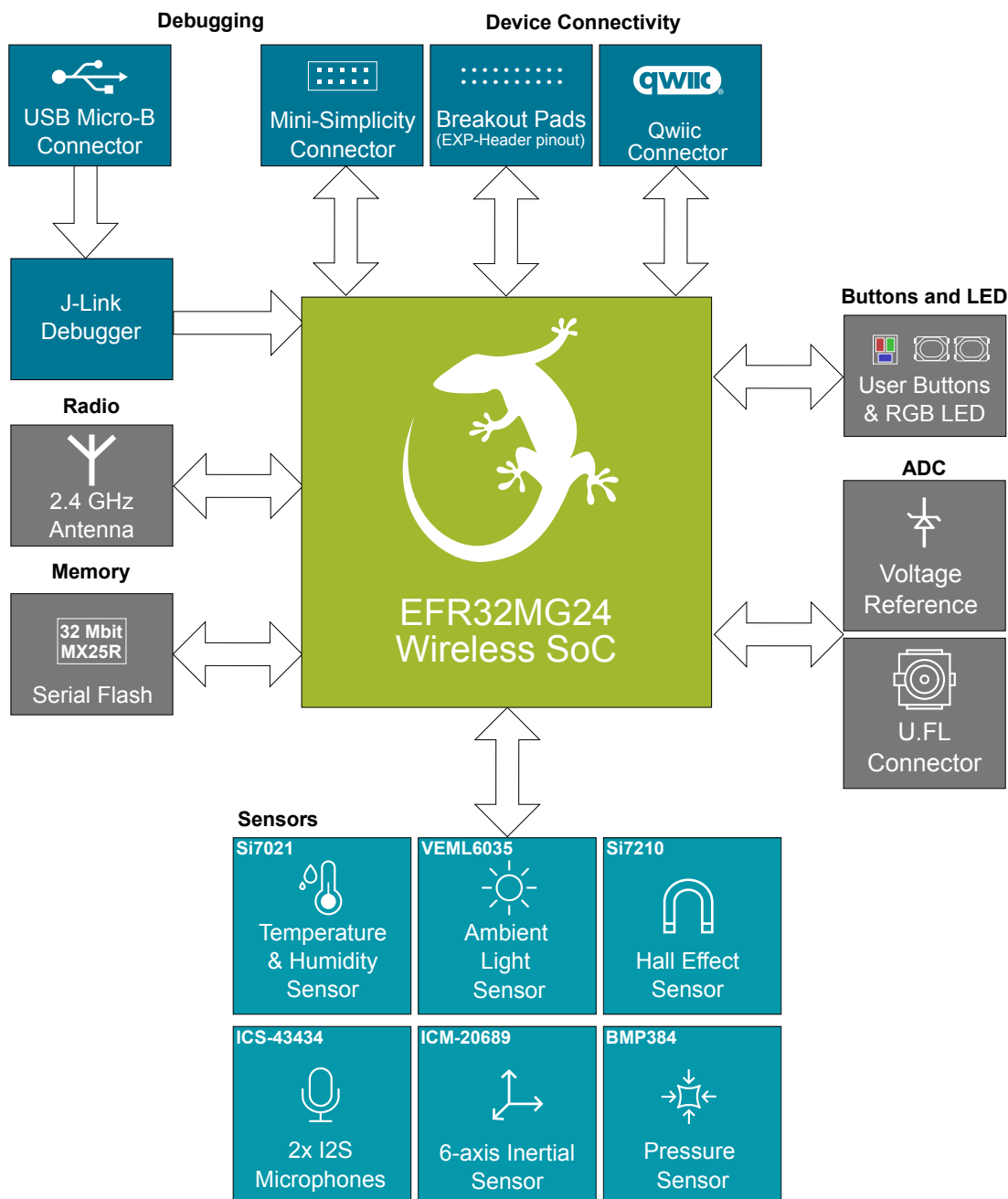An overview of the xG24 Dev Kit is illustrated in the figure below.



Figure 3.1.   Kit Block Diagram

### 3.2 Power Supply

The kit can be powered through one of these interfaces:

- USB Micro-B
- Battery (CR2032 battery or external battery connected through 2-pin battery header)
- Mini Simplicity connector

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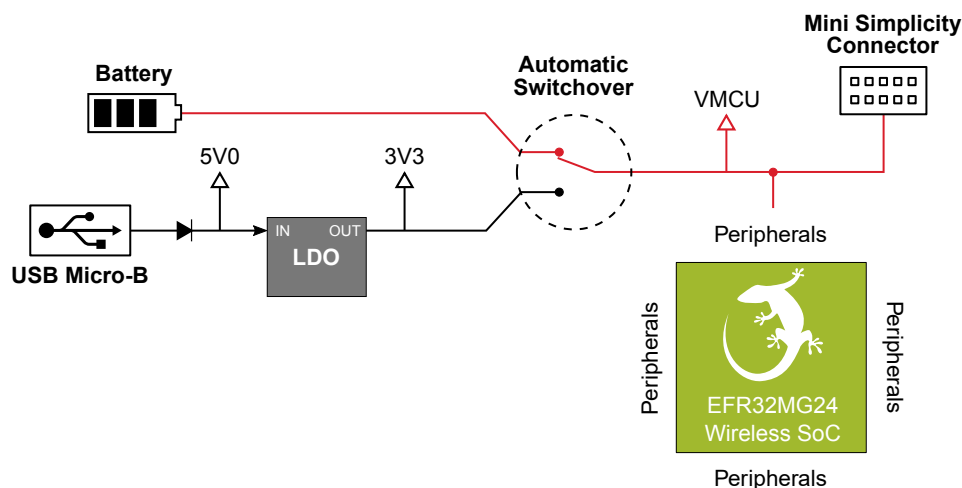


**Figure 3.2.  xG24 Dev Kit Power Architecture**

Power is normally applied either through the USB cable or a CR2032 battery. A 2-pin 1.25 mm pitch battery connector for external batteries is also available as an alternative to a CR2032 battery. When the USB cable is connected, VBUS is regulated down to 3.3 V. An automatic switchover circuit switches the main system power from battery power to USB power when the USB cable is inserted, and protects the battery from reverse current.

Power can also be applied through the Mini Simplicity connector. There must be no other power sources present on the kit as power is injected directly to the VMCU net. It is important to follow this recommendation to avoid power conflicts and backfeeding the battery. Powering the xG24 Dev Kit 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.  xG24 Dev Kit Power Options**

| Supply Mode | Typical Input Voltage | VMCU Source | 3V3 | 5V |
|---|---|---|---|---|
| USB power | 5.0 V | On-board regulator | On-board regulator | USB VBUS |
| Battery | 3.0 V | Battery voltage | Disconnected | No voltage present |
| Mini Simplicity | 3.3 V | Debugger dependent | Disconnected | No voltage present |

### 3.3 EFR32MG24 Reset

The EFR32MG24 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 xG24 Dev Kit contains a set of peripherals that can be accessed from the EFR32MG24. 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 EFR32MG24:

- Silicon Labs Si7021 relative humidity & temperature sensor
- Silicon Labs Si7210 hall effect sensor
- 2x TDK InvenSense ICS-43434 MEMS microphones with I2S output
- TDK InvenSense ICM-20689 6-axis inertial measurement sensor
- Vishay VEML6035 ambient light sensor
- Bosch BMP384 pressure sensor with internal temperature sensor
- Macronix MX25R3235F ultra-low power 32 Mbit SPI flash
- RGB LED and two push buttons
- External precise voltage reference for the EFR32 IADC
- U.FL connector for the EFR32 IADC

The figure below gives an overview of the peripherals that are connected to the EFR32MG24. Note that some of the peripherals share the same interface and enable signals. As the enable signals do 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.
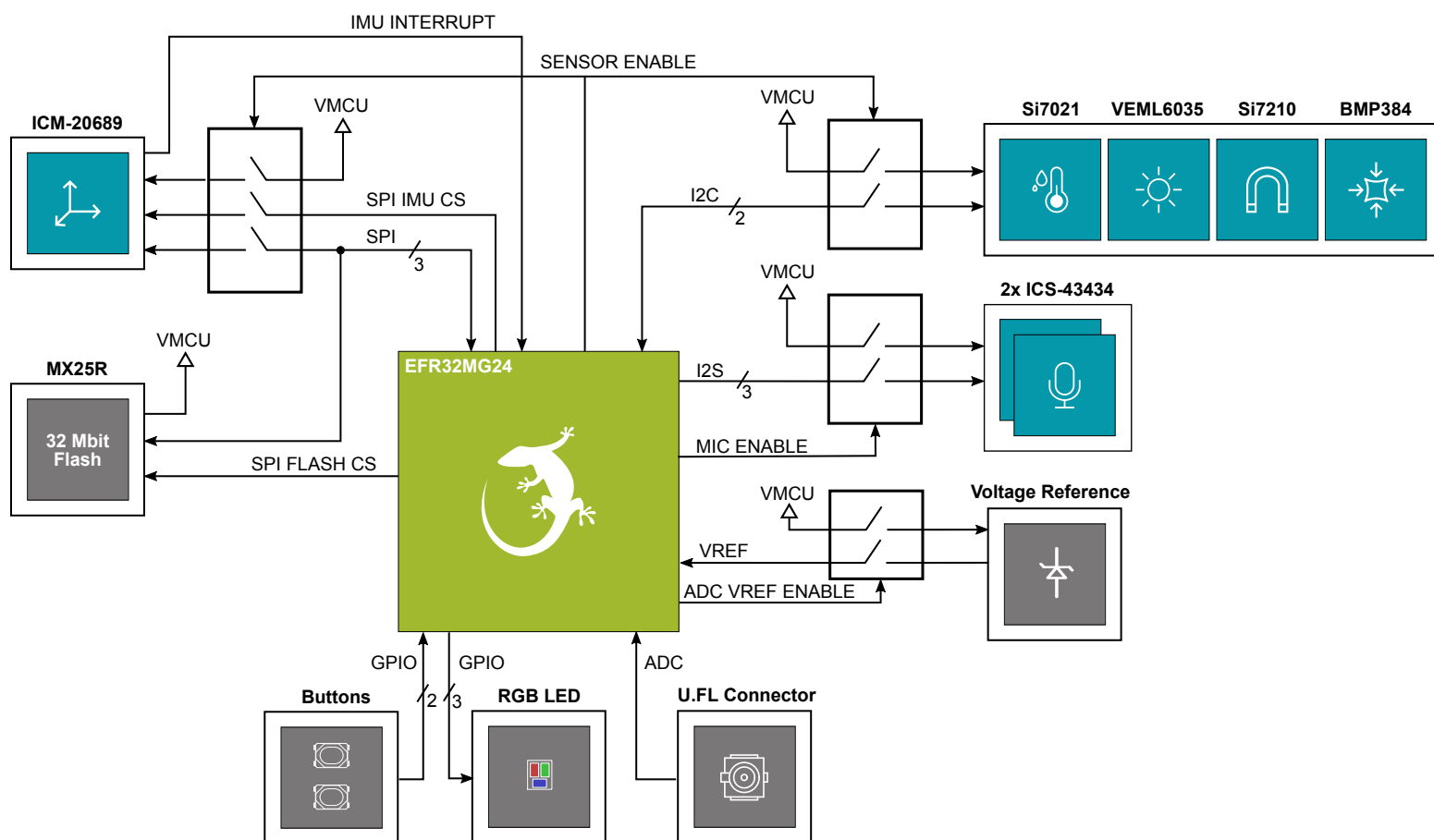


**Figure 3.3.  Peripherals**

### 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 xG24 Dev Kit, the Si7021 is connected through a switch. The switch must therefore be enabled by setting PC09 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 EFR32MG24 I$^2$C bus. The application code should always drive the PC09 signal either high or low to prevent it from floating. The figure below shows how the Si7021 is connected to the EFR32MG24.
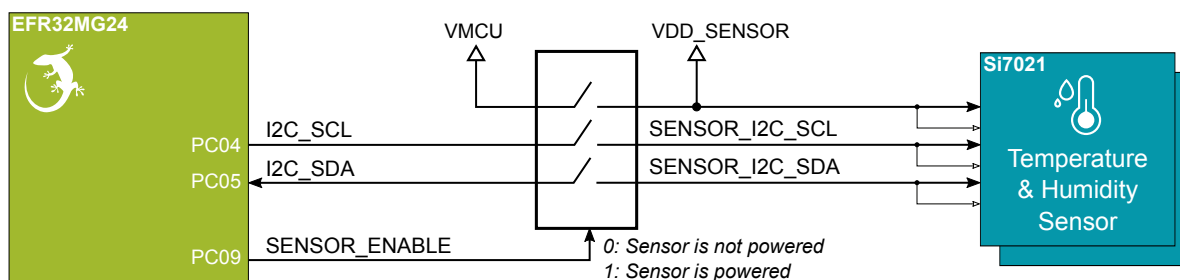


**Figure 3.4.  Si7021 Relative Humidity and Temperature Sensor**

Although measures have been taken to thermally isolate 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 xG24 Dev Kit, the Si7210 is connected through a switch. The switch must therefore be enabled by setting PC09 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 EFR32MG24 I$^2$C bus. The application code should always drive the PC09 signal either high or low to prevent it from floating. The figure below shows how the Si7210 is connected to the EFR32MG24.
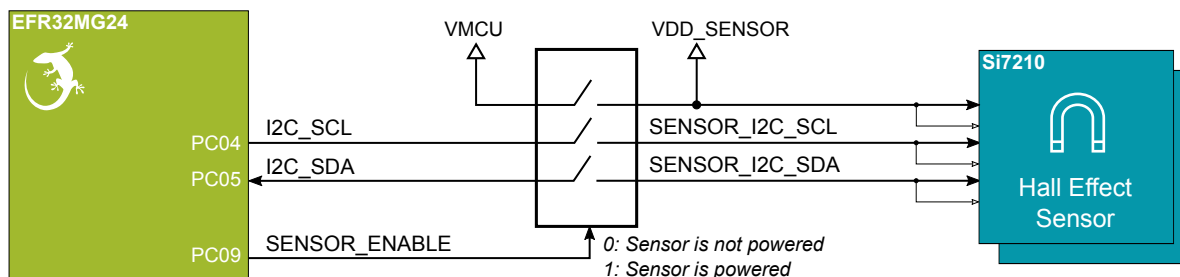


**Figure 3.5.  Hall Effect Sensor**

### 3.4.3 ICS-43434 MEMS Stereo Microphones

The ICS-43434 microphones are omnidirectional MEMS microphones with a wideband frequency response and a digital I$^2$S output. The microphones include a MEMS sensor, signal conditioning, ADC, filters, and different operating modes. The ICS-43434 is a bottom port microphone, and it is placed on the bottom side of xG24 Dev Kit with acoustic ventilation holes going through to the top side. These holes let sound waves into the microphone package.

On xG24 Dev Kit, the ICS-43434 microphones are connected through a switch. The switch must therefore be enabled by setting PC08 high before it can be used by the application. This enables power to the microphones and connects the I$^2$S lines used for the sensor to the EFR32MG24. The application code should always drive the PC08 signal either high or low to prevent it from floating. The figure below shows how the ICS-43434 microphones are connected to the EFR32MG24.
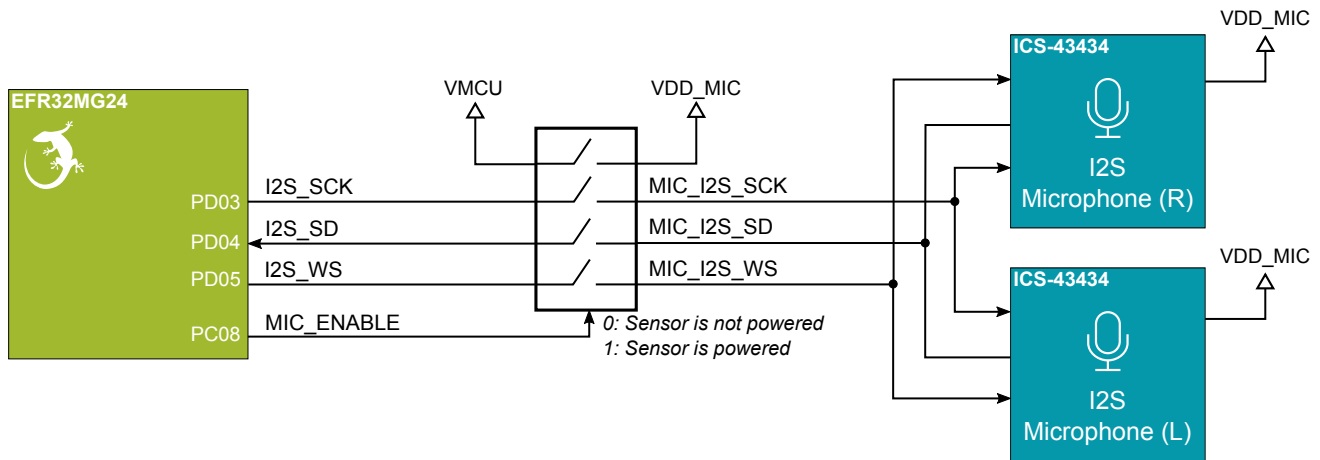


**Figure 3.6. ICS-43434 MEMS Microphones**

### 3.4.4 ICM-20689 6-Axis Inertial Sensor

The ICM-20689 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.

On xG24 Dev Kit, the ICM-20689 is connected through a switch. The switch must be enabled by setting PC09 high before it can be used by the application. This enables power to the ICM-20689 and connects the SPI lines used for the sensor to the EFR32MG24 SPI bus. The application code should always drive the PC09 signal either high or low to prevent it from floating. 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 SPI CS line is also exported on the breakout pads, so simultaneous SPI operation on the breakout pads and IMU is not possible unless an alternative pin is used for SPI CS on the breakout pads. The figure below shows how the ICM-20689 is connected to the EFR32MG24.
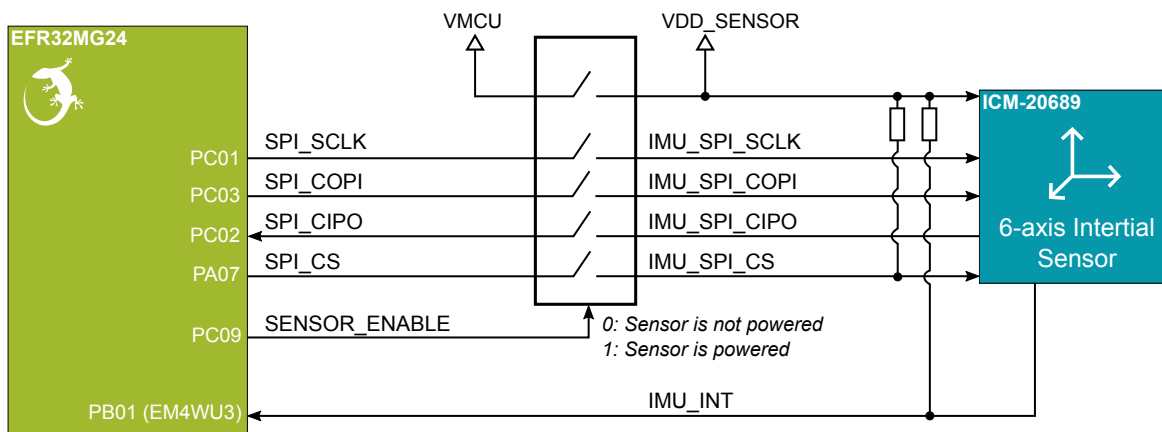


**Figure 3.7. ICM-20689 6-Axis Inertial Sensor**

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.
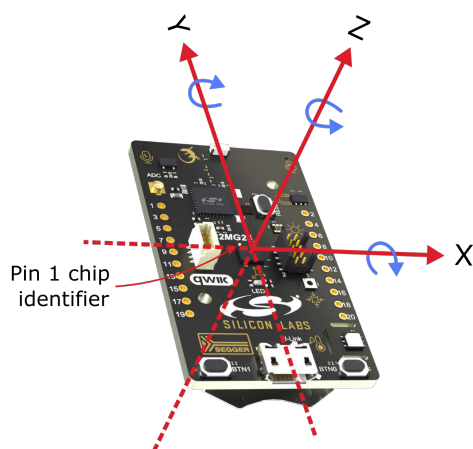


**Figure 3.8. xG24 Dev Kit Spatial Orientation**

### 3.4.5  VEML6035 Ambient Light Sensor

The VEML6035 is an ambient light sensor with $I^2C$ digital interface.

On xG24 Dev Kit, the VEML6035 is connected through a switch. The switch must therefore be enabled by setting PC09 high before it can be used by the application. This enables power to the VEML6035 and connects the $I^2C$ lines used for the sensor to the EFR32MG24 $I^2C$ bus. The $I^2C$ lines are shared with other on-board $I^2C$ peripherals. The application code should always drive the PC09 signal either high or low to prevent it from floating. The $I^2C$ bus is shared with the Qwiic Connector and is also exported on the breakout pads. The figure below shows how the VEML6035 is connected to the EFR32MG24.
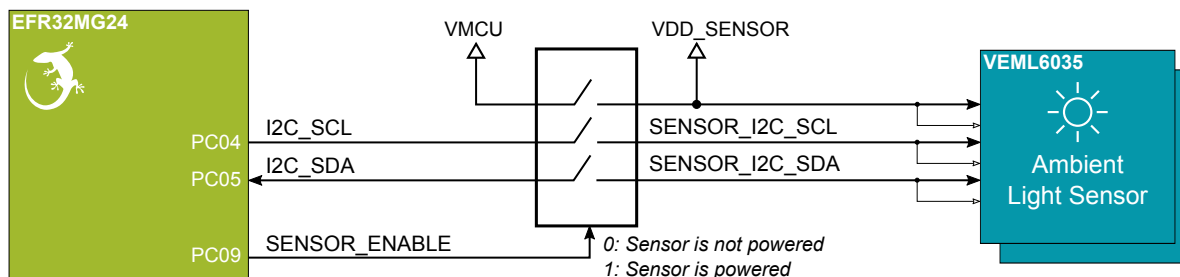
**Figure 3.9.  VEML6035 Ambient Light Sensor**

### 3.4.6  BMP384 Barometric Pressure Sensor

The BMP384 is a combined absolute barometric pressure sensor and temperature sensor with a digital interface supporting both SPI and $I^2C$. No external sensing elements are needed, and the device has an integrated ADC and ASIC with built-in configurable IIR filter to suppress noise. Selectable oversampling rates provide trade-off between low power and high resolution, and an option to skip either temperature or pressure measurement is available in case one or the other is unnecessary.

On xG24 Dev Kit, the BMP384 is connected through a switch. The switch must therefore be enabled by setting PC09 high before it can be used by the application. This enables power to the BMP384 and connects the $I^2C$ lines used for the sensor to the EFR32MG24 $I^2C$ bus. The $I^2C$ lines are shared with other on-board $I^2C$ peripherals. The application code should always drive the PC09 signal either high or low to prevent it from floating. The $I^2C$ bus is shared with the Qwiic Connector and is also exported on the breakout pads. The figure below shows how the BMP384 is connected to the EFR32MG24.
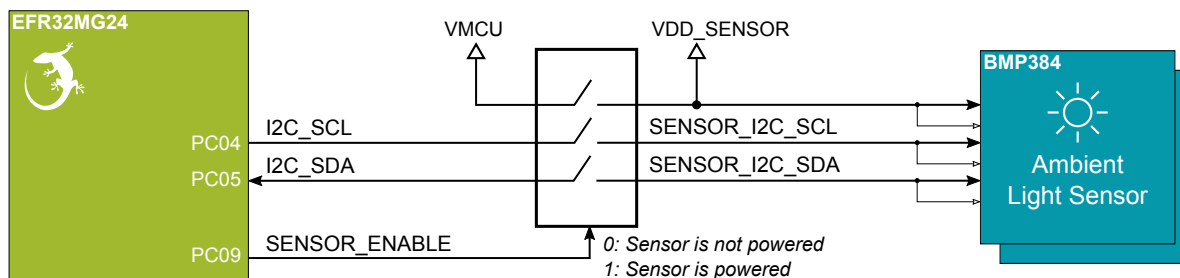
**Figure 3.10.  BMP384 Absolute Pressure Sensor**

### 3.4.7 External Memory

The xG24 Dev Kit includes a 32 Mbit Macronix SPI Flash that is connected directly to the EFR32MG24. 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 7 nA to the current consumption. The figure below shows how the serial flash is connected to the EFR32MG24.
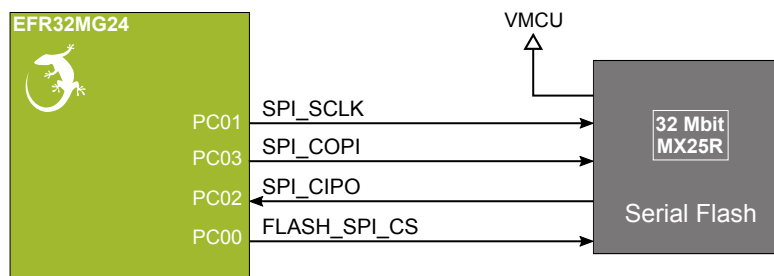
**Figure 3.11. Serial Flash**

### 3.4.8 Push Buttons and RGB LED

The kit has two user push buttons marked BTN0 and BTN1. They are connected directly to the EFR32MG24 and are debounced by RC filters with a time constant of 1 ms. The buttons are connected to pins PB02 and PB03.

The kit also features an RGB LED marked LED0, controlled by GPIO pins on the EFR32MG24. The LED is connected in an active-low configuration, and each color can be PWM controlled using the EFR32MG24's TIMER peripherals to generate a wide variety of colors.
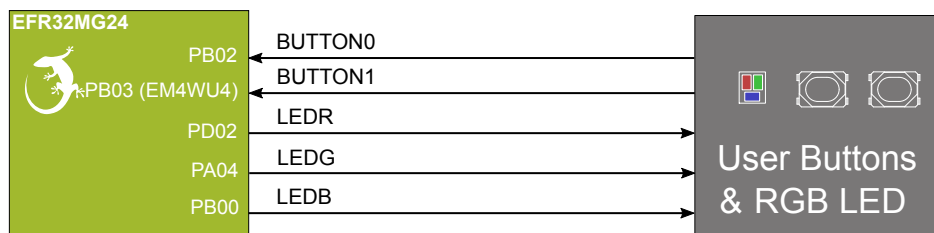
**Figure 3.12. Buttons and RGB LED**

### 3.4.9 Precise ADC Voltage Reference

The xG24 Dev Kit includes a high precision voltage reference based on the ADR1581, which features an initial accuracy of 0.12 % (1 mV) and low temperature drift. The voltage reference, when enabled, provides a low-noise 1.25 V external reference input to the EFR32MG24 IADC, enabling optimal measurement performance.

On the xG24 Dev Kit, the voltage reference is connected through a switch. The switch must therefore be enabled by setting PA00 high before it can be used by the IADC. The application code should always drive the PA00 signal either high or low to prevent it from floating. The figure below shows how the voltage reference is connected to the EFR32MG24.
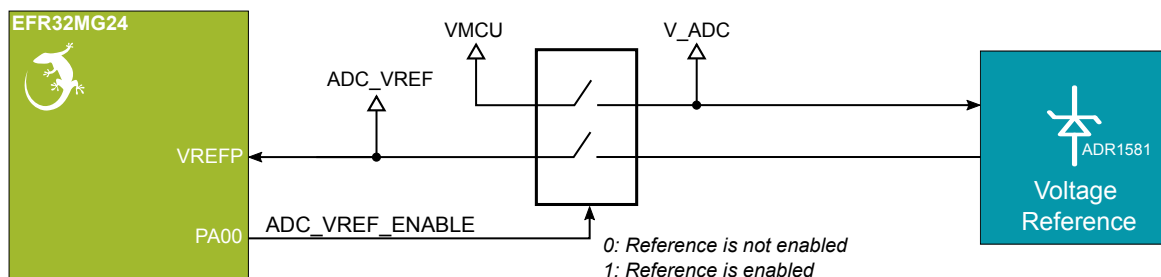
**Figure 3.13. Precise ADC Voltage Reference**

### 3.4.10  IADC U.FL Connector

The kit features a U.FL connector which is connected to the EFR32MG24 IADC through one of the dedicated ADC input pins (AIN0) in a single-ended configuration. The dedicated ADC inputs facilitate optimal connections between external signals and the IADC.

A charge bucket filter has been placed at the ADC input, which helps improve sampling performance and measurement accuracy at high sampling speeds, and provides some anti-aliasing for high-frequent signals. For information about the IADC performance and configuration, refer to the EFR32MG24 data sheet.



**Figure 3.14.  U.FL Connector**

### 3.5  On-board Debugger

The xG24 Dev Kit contains a microcontroller separate from the EFR32MG24 Wireless Gecko that provides the user with an 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).

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.

The figure below shows the connections between the target EFR32MG24 device and the on-board debugger. The figure also shows the Mini Simplicity Connector, and how this is connected to the same I/O pins.

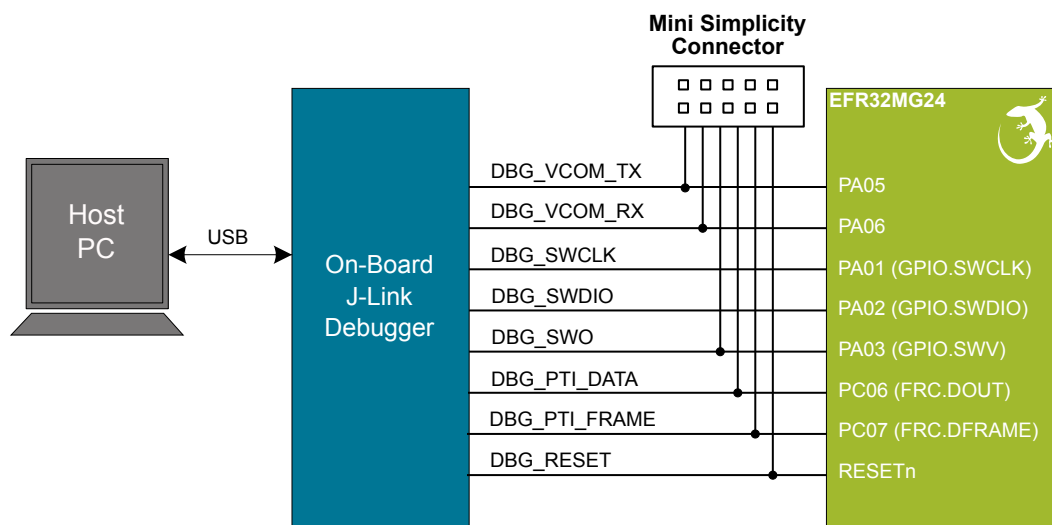Refer to section 4. Debugging for more details on debugging.



**Figure 3.15.  On-Board Debugger Connections**

## 3.6 Connectors

The xG24 Dev Kit features a Mini Simplicity Connector, a USB Micro-B connector, and 20 breakout pads that follow the EXP header pinout. The connectors are placed on the top side of the board, and their placement and pinout can be seen in the figure below. For additional information on the connectors, see the following sub-sections.
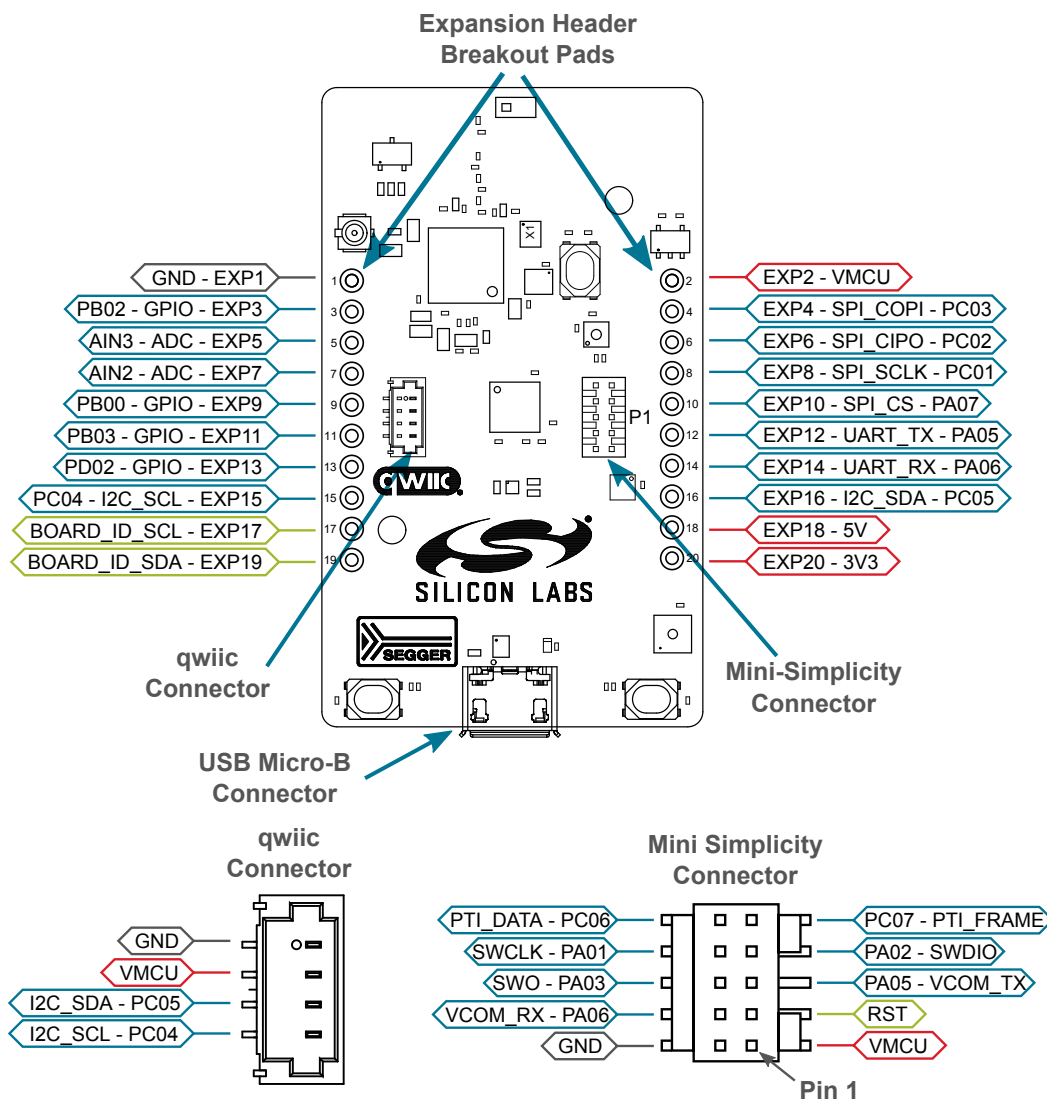


**Figure 3.16. xG24 Dev Kit Connectors**

### 3.6.1 Breakout Pads

Twenty breakout pads, which follow the EXP 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 and ten are located on the right side. The breakout pads expose I/O pins that can be used with most of the EFR32MG24's features. Additionally, the VMCU (main power rail), 3V3 (LDO regulator output), and 5V power rails are also exposed.

The breakout pads are pinned out similar to the EXP 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 EXP boards that can plug into a number of different Silicon Labs starter kits.

The pin-routing on 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 xG24 Dev Kit. The table below includes an overview of the EXP header and functionality that is shared with the kit.

**Table 3.2. Expansion Header Pinout**

| Pin | Connection | EXP Header Function | Shared Feature |
|:---:|:---:|:---:|:---:|
| **Right Side Breakout Pins** | | | |
| 2 | VMCU | EFR32MG24 voltage domain, included in AEM measurements. | |
| 4 | PC03 | SPI_COPI | IMU & Flash |
| 6 | PC02 | SPI_CIPO | IMU & Flash |
| 8 | PC01 | SPI_SCLK | IMU & Flash |
| 10 | PA07 | SPI_CS | IMU_SPI_CS (when SENSOR_ENABLE = 1) |
| 12 | PA05 | UART_TX | VCOM & Mini Simplicity |
| 14 | PA06 | UART_RX | VCOM & Mini Simplicity |
| 16 | PC05 | I2C_SDA | Qwiic $I^2C$ bus |
| 18 | 5V | Board USB voltage | |
| 20 | 3V3 | Board controller supply | |
| **Left Side Breakout Pins** | | | |
| 1 | GND | Ground | |
| 3 | PB02 | GPIO | BTN0 |
| 5 | AIN3 | ADC Negative Input | |
| 7 | AIN2 | ADC Positive Input | |
| 9 | PB00 | GPIO | LEDB |
| 11 | PB03 | GPIO | BTN1 |
| 13 | PD02 | GPIO | LEDR |
| 15 | PC04 | I2C_SCL | Qwiic $I^2C$ bus |
| 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 Qwiic Connector

The xG24 Dev Kit features a Qwiic connector compatible with Qwiic Connect System hardware. The Qwiic connector provides an easy way to expand the functionality of the xG24 Dev Kit with sensors, LCDs, and other peripherals over the $I^2C$ interface. The Qwiic connector is a 4-pin polarized JST connector, which ensures the cable is inserted the right way.

Qwiic Connect System hardware is daisy chain-able as long as each $I^2C$ device in the chain has a unique $I^2C$ address.

**Note:** The Qwiic $I^2C$ lines are shared with the on-board $I^2C$ sensors, and are also exposed on the breakout pads.

The table below gives an overview of the Qwiic connections to the EFR32MG24.

**Table 3.3.  Qwiic Connector Pinout**

| Qwiic Pin | Connection | Shared Feature |
|---|---|---|
| Ground | GND | |
| 3.3V | VMCU | |
| SDA | PC05 | Breakout pads, $I^2C$ sensors |
| SCL | PC04 | Breakout pads, $I^2C$ sensors |

### 3.6.3 Mini Simplicity Connector

The Mini Simplicity connector is a 10-pin 1.27 mm pitch connector that allows the use of an external debugger such as the one found on one of the Silicon Labs Wireless mainboards. See section 4.2 External Debugger for more details. The pinout of the connector on the board is described in the table below with the names being referenced from the EFR32MG24.

**Table 3.4.  Mini Simplicity Connector Pin Descriptions**

| Pin number | Function | Connection | Description |
|---|---|---|---|
| 1 | AEM | VMCU | Target voltage on the debugged application. May be supplied and monitored by the AEM on an external debugger. |
| 2 | GND | GND | Ground. |
| 3 | RST | RESET | EFR32MG24 reset. |
| 4 | VCOM_RX | PA06 | Virtual COM Rx |
| 5 | VCOM_TX | PA05 | Virtual COM Tx |
| 6 | SWO | PA03 | Serial Wire Output |
| 7 | SWDIO | PA02 | Serial Wire Data |
| 8 | SWCLK | PA01 | Serial Wire Clock |
| 9 | PTI_FRAME | PC07 | Packet Trace Frame |
| 10 | PTI_DATA | PC06 | Packet Trace Data |

### 3.6.4 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 xG24 Dev Kit contains an on-board SEGGER J-Link Debugger that interfaces to the target EFR32MG24 using the Serial Wire Debug (SWD) interface. The debugger allows the user to download code and debug applications running in the target EFR32MG24. Additionally, it also provides a VCOM port 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 xG24 Dev Kit, as the external debugger might source a voltage on the target power domain (VMCU).

**Important:** When connecting an external debugger that sources voltage to the VMCU net, the USB cable and battery must be removed from the xG24 Dev Kit. Failure to do so will create power conflicts.

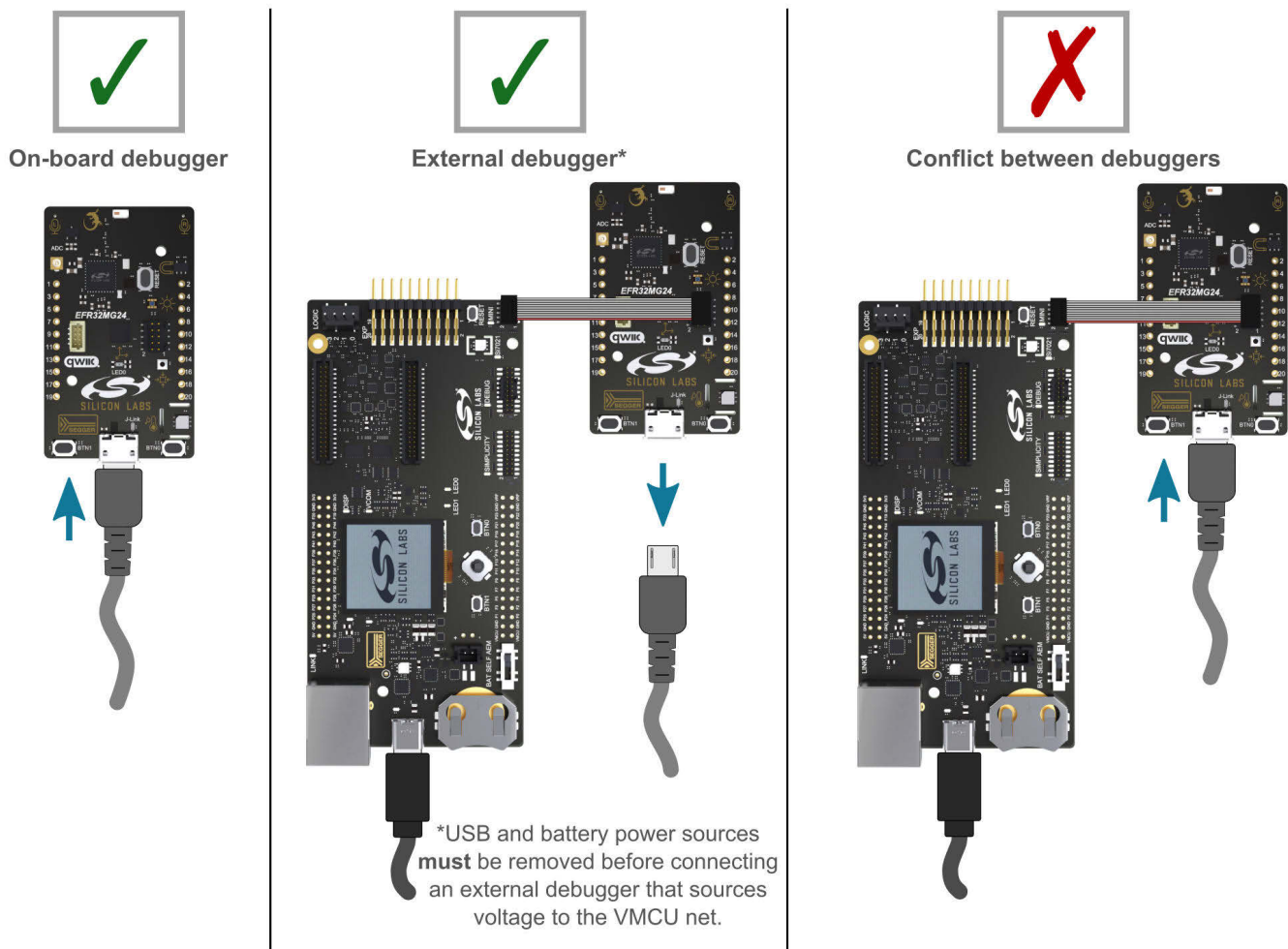The figure below shows the possible debug options.



**Figure 4.1. xG24 Dev Kit 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 EFR32MG24.

When the debug USB cable is inserted, the on-board debugger is automatically activated, 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, providing power to the board.

When the USB cable is removed, the board might still be running on battery power, as described in section 3.2 Power Supply. In this case, the on-board debugger goes into a very low power shutoff mode (EM4S), consuming about 80 nA. This means that battery lifetime 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 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 using the mainboard for debugging, see "AN958: Debugging and Programming Interfaces for Custom Designs". Debugging with an external Wireless mainboard gives access to the following debugging features:

*   Debugging of the target device through SWD
*   Communication using the VCOM port
*   Packet Trace Interface (for wireless devices only)
*   Advanced Energy Monitor

Note that the Mini Simplicity Connector *cannot* be used at the same time that 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 xG24 Dev Kit Debugging Possibilities on page 21.

Powering the board when using the Mini Simplicity Connector with a Wireless mainboard and adapter board can be done using the AEM voltage supply of the Wireless mainboard. When doing this, remove both the USB cable and the coin cell battery from the xG24 Dev Kit before connecting the Wireless mainboard to the Mini Simplicity Connector. The power switch on the Wireless 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 to "BAT" and back to "AEM" assuming a battery is not inserted in the Wireless mainboard.

It is possible to have the xG24 Dev Kit powered by a battery, and still use the Mini Simplicity Connector with a Wireless mainboard for debugging and communication. In this case, the power switch on the Wireless mainboard must be set to the "BAT" position and the coin cell battery on the Wireless mainboard must be removed. In this case, level shifters on the Wireless mainboard itself take care of interfacing to different voltage levels on the xG24 Dev Kit. Connecting the board to an external debugger in other ways than those described above might create power conflicts, compromise the ability to monitor power consumption, and hazardously feed power back to the on-board battery.

**Important:** Always remove the battery if you are not sure whether the external debugger is sourcing voltage to xG24 Dev Kit.

### 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 mainboards features a 100 kΩ pull-up resistor, and the following paragraph explains what happens when a Wireless mainboard with a debug adapter board is connected to the xG24 Dev Kit.

The debugger on a Wireless 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 EFR32MG24 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 mainboard and DVDD on the xG24 Dev Kit. On xG24 Dev Kit, DVDD is connected to the output of the EFR32MG24'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.

**4.3 Virtual COM Port**

The virtual COM port (VCOM) is a connection to a UART on the EFR32MG24, 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.

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.

**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. However, it is possible to change the VCOM baud rate through the kits Admin Console available through Simplicity Studio.

Alternatively, the VCOM port can also be used through the Mini Simplicity Connector with an external Wireless mainboard. Using the VCOM port through the Mini Simplicity Connector with an external Wireless mainboard works in a similar way, but requires that the USB cable to the on-board debugger is unplugged. The board controller on the Wireless mainboard then makes the data available over USB (CDC) or an IP socket. Flow control is not available over the Mini Simplicity Connector.

# 5. Radio

## 5.1 RF Section

This section gives a short introduction to the RF section of the BRD2601B board.

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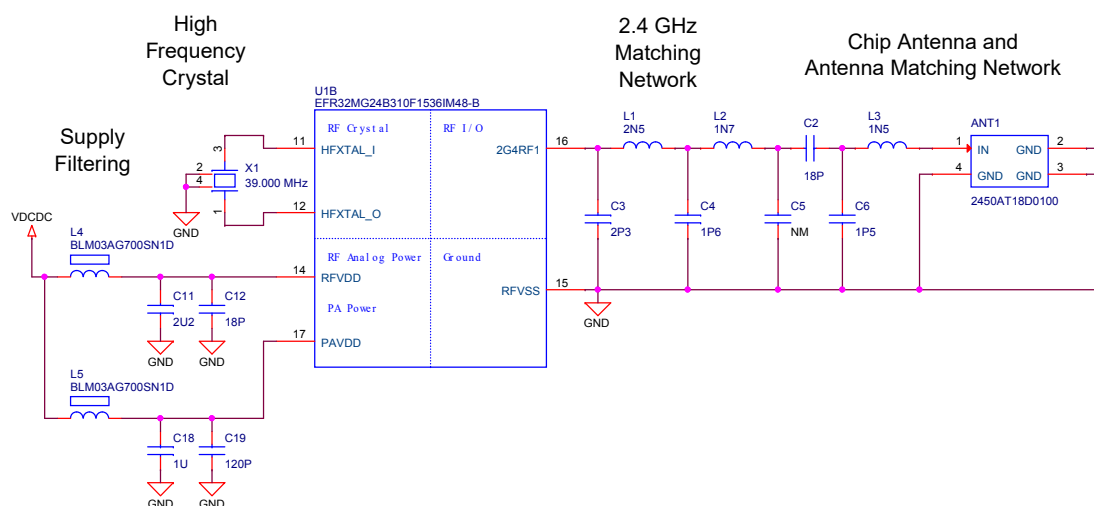


**Figure 5.1.  Schematic of the RF section**

### 5.1.1 RF Matching Description

The EFR32MG24 RF port impedance is matched to 50 Ohm: the 2G4RF1 pin is connected to a four-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 EFR32MG24.

### 5.1.2 RF Section Power Supply

On the BRD2601B, 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 BRD2601B).

### 5.1.3 RF Matching Bill of Materials

The bill of materials for the BRD2601B RF matching network is shown in the following table.

**Table 5.1.  Bill of Materials of the BRD2601B RF Matching Network**

| Component name | Value | Manufacturer | Part Number |
|---|---|---|---|
| L1 | 2.5 nH | Murata | LQP03HQ2N5B02 |
| L2 | 1.7 nH | Murata | LQP03HQ1N7B02 |
| C2 | 18 pF | Murata | GJM0335C1E180GB01D |
| C3 | 2.3 pF | Murata | GRM0335C1H2R3WA01D |
| C4 | 1.6 pF | Murata | GRM0335C1H1R6WA01D |

**5.1.4 Antenna**

The BRD2601B 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 BRD2601B 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 BRD2601B PCB. The resulting antenna impedance and reflection are shown in the figure below.
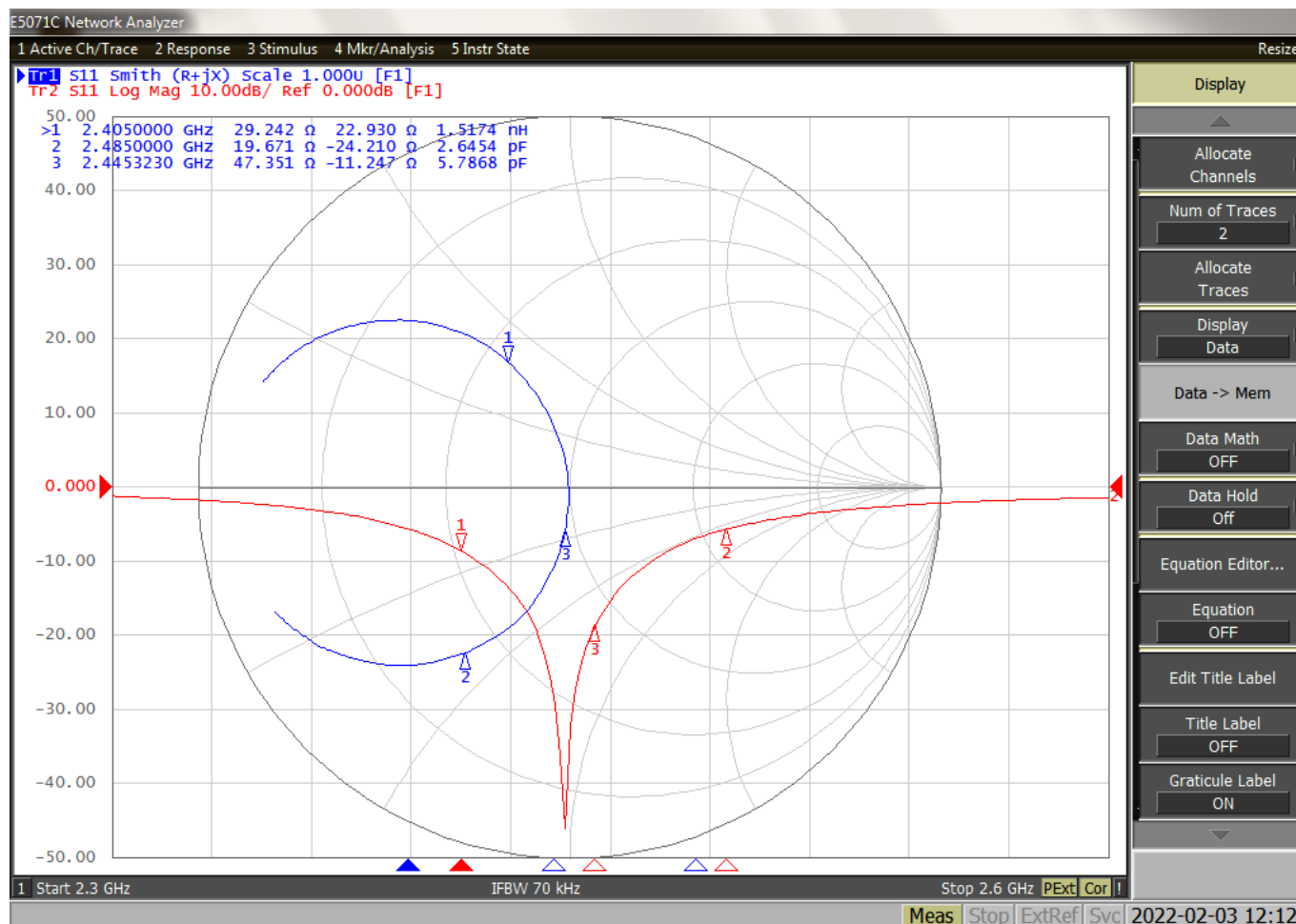


**Figure 5.2. Fine Tuned Antenna Impedance (Blue Curve) and Reflection (Red Curve)**

**5.1.5 Antenna Matching Bill of Materials**

The bill of materials for the BRD2601B antenna matching network is shown in the following table.

**Table 5.2. Bill of Materials of the BRD2601B Antenna Matching Network**

| Component name | Value | Manufacturer | Part Number |
|---|---|---|---|
| ANT1 | — | Johanson | 2450AT18D0100 |
| L3 | 1.5 nH | Murata | LQP03TN1N5B02D |
| C6 | 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 EFR32MG24 was set to 10 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.
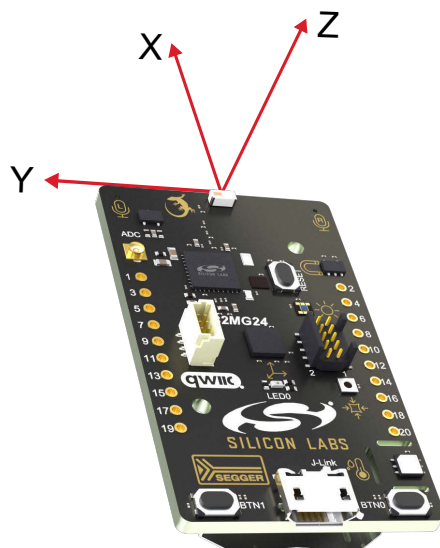


**Figure 5.3. DUT Reference Planes**

## 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 10 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 BRD2601B**

| Frequency (2445 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 | 10.6 | XY/H | NA (0 is used) | 10.6 | 19.4 | 30 |
| 2nd | -55.9 | YZ/H | -2.7 | -58.9 | 17.7 | -41.2 |
| 3rd | -41.8 | YZ/H | -4.8 | -46.6 | 5.2 | -41.2 |
| 4th | <-50* | -/- | -5.5 | - | >20 | -30 |
| 5th | -44.2 | YZ/H | -6.3 | -50.5 | 9.3 | -41.2 |
| * Signal level is below the Spectrum Analyzer noise floor. | | | | | | |

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

### 5.4.2 Antenna Pattern Measurement

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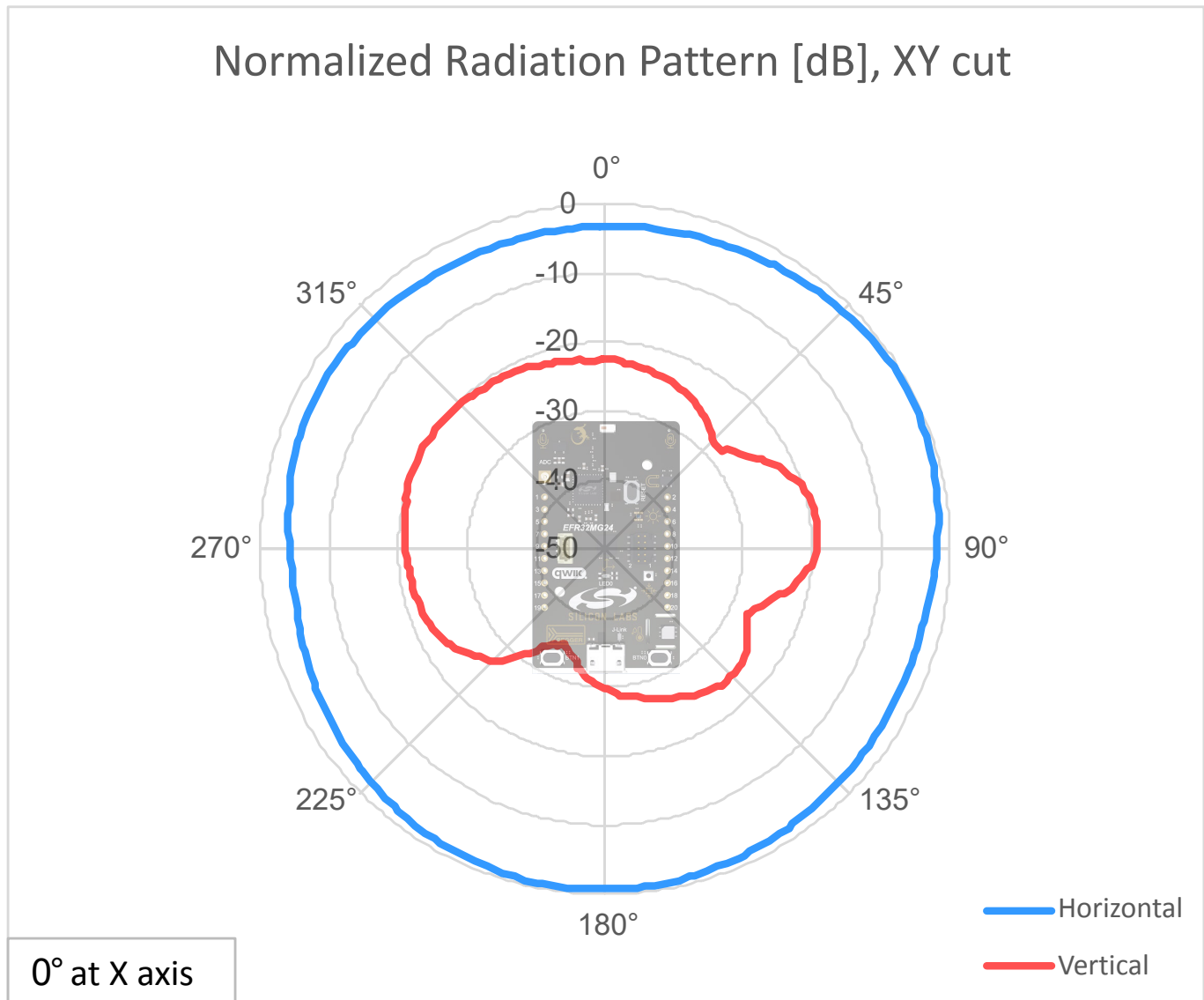


**Figure 5.4.  Antenna Pattern - XY**
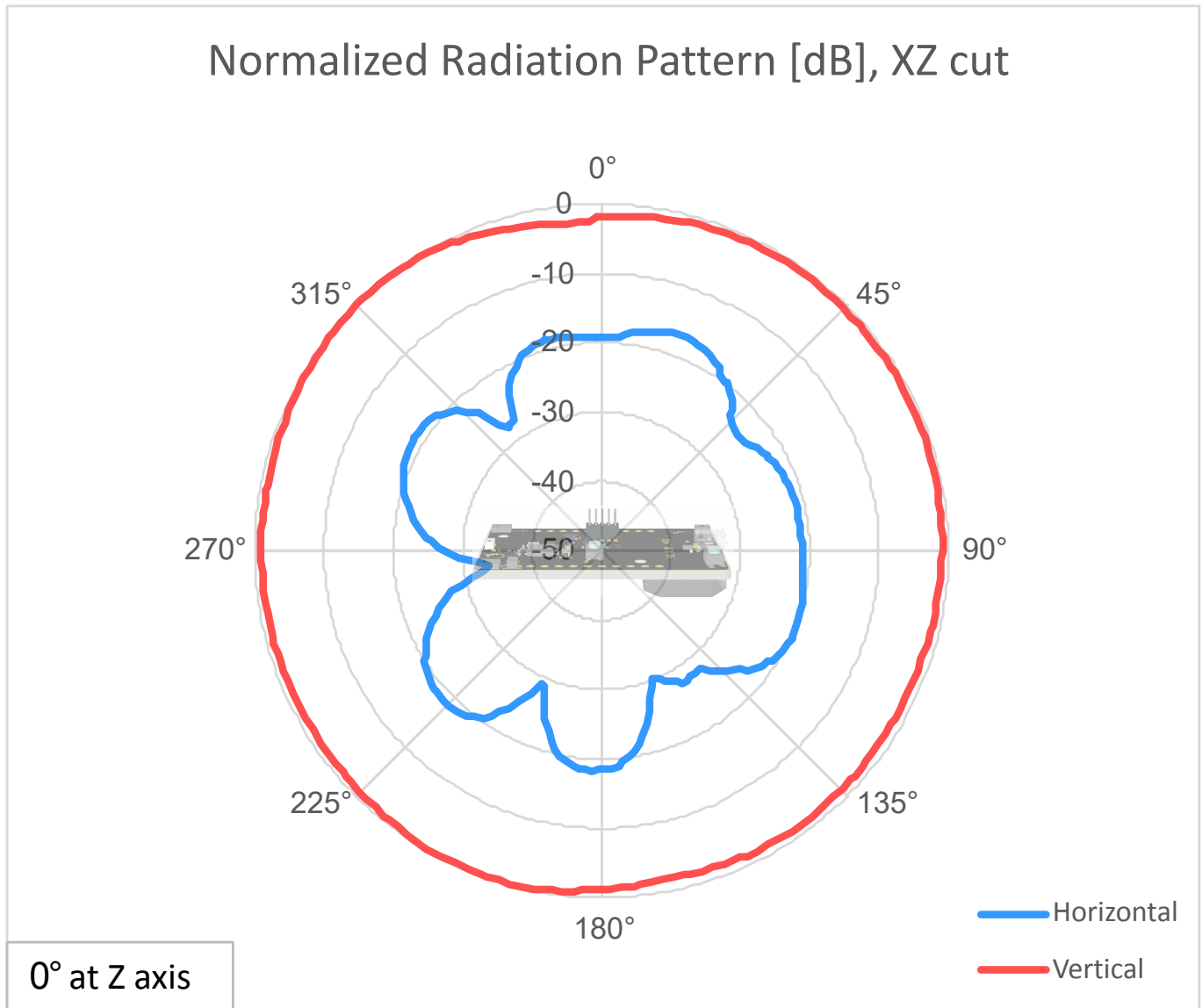
Figure 5.5.  Antenna Pattern - XZ
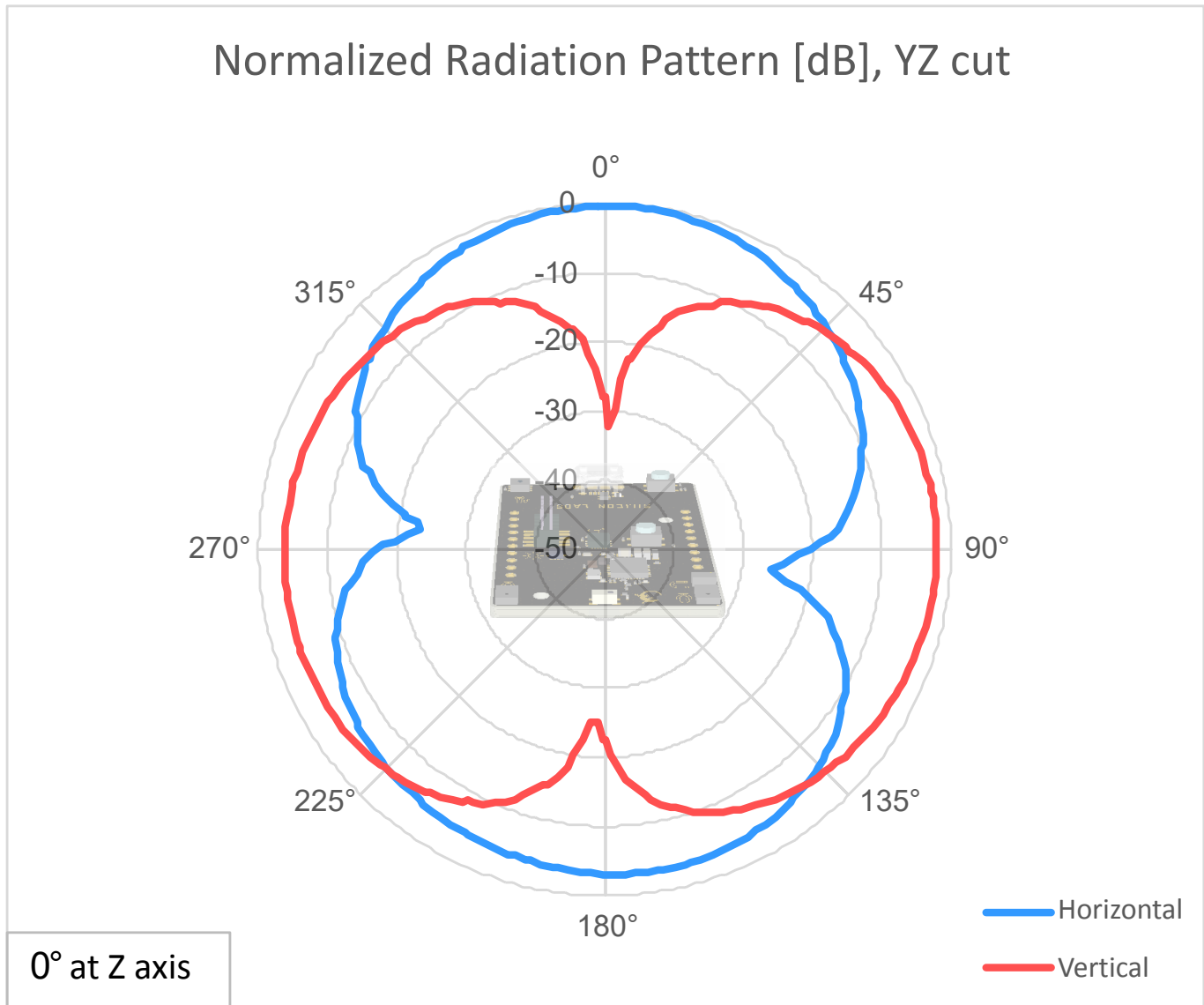
Figure 5.6.  Antenna Pattern - YZ

## 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 EFR32MG24 output power set to 10 dBm, the radiated power of the fundamental of the BRD2601B 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 EFR32MG24 output power set to 10 dBm, the radiated power of the fundamental of the BRD2601B 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. They are also available from the kit page on the Silicon Labs website: silabs.com.

## 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 summarized in Table 7.1 Kit Revision History on page 32. The revision history given in this section may not list every kit revision. Revisions with minor changes may be omitted.



**xG24 Dev Kit**
(1P) Part: xG24-DK2601B       (D) Date: 02-22-22

S.nr: 1632000960       (Q) Qty: 1

Rev.A02

**Figure 7.1. Revision Info**

**Table 7.1. Kit Revision History**

| Kit Revision | Released | Description |
|---|---|---|
| A02 | 2022-02-01 | Initial kit revision with BRD2601B Rev. A01. |

### 7.2 Errata

There are no known errata at present.

## 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 summarized in Table 8.1 Board Revision History on page 33. The revision history given in this section may not list every board revision. Revisions with minor changes may be omitted.

**Table 8.1. Board Revision History**

| Revision | Released | Description |
|---|---|---|
| A01 | 2022-02-01 | Initial board revision. |

### 8.2 Errata

There are no known errata at present.

# 9. Document Revision History

**Revision 0.1**

April, 2022

- Initial document release.

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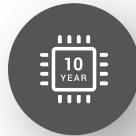
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