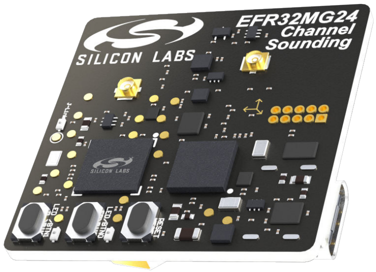
UG615: EFR32xG24 Channel Sounding Dev Kit User's Guide

The EFR32xG24 Channel Sounding 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 EFR32xG24 Channel Sounding Dev Kit is an ideal platform for developing energy-friendly connected IoT devices.

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



TARGET DEVICE

- EFR32 Wireless Gecko System-on-Chip (EFR32MG24B210F1536IM48-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

- Dual printed 2.4 GHz antenna
- UFL connectors for conducted measurements
- Power control of on-board peripherals for ultra-low power operation
- 6-axis inertial sensor
- 8 Mbit flash for OTA programming and data logging
- Two LEDs and two push buttons
- 10-pin 1.27 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 (not mounted by default)
- USB or coin cell battery powered

SOFTWARE SUPPORT

- Simplicity Studio™

Table of Contents

1. Introduction

The EFR32xG24 Channel Sounding Dev Kit (OPN: xG24-DK2606A) is 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 dual printed antenna and an inertial sensor, which is accessible to the EFR32MG24 wireless MCU.

Programming the EFR32xG24 Channel Sounding Dev Kit is easily done using a USB Type-C cable and the on-board J-Link debugger. A USB virtual COM port provides a serial connection to the target application, and PTI offers invaluable debug information about transmitted and received packets in wireless links. The board includes a 8 MBit serial flash that can be used for Over-The-Air (OTA) firmware upgrade, or as a general purpose non-volatile memory. The EFR32xG24 Channel Sounding 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 Mini Simplicity+ connector (not mounted by default) using an external Silicon Labs debugger.

Connecting external hardware to the EFR32xG24 Channel Sounding Dev Kit can be done using the 10 breakout pads which present peripherals from the EFR32MG24 Wireless Gecko such as I^2C, SPI, UART, and GPIOs. The board also features a Qwiic connector which can be used to connect hardware from the Qwiic Connect System through I^2C.

1.1 Kit Contents

The following items are included in the box:

- 1x EFR32xG24 Channel Sounding Dev Kit board (BRD2606A)

1.2 Getting Started

Detailed instructions for how to get started with your new EFR32xG24 Channel Sounding Dev Kit can be found at Silicon Labs web page.

1.3 Hardware Content

The following key hardware elements are included on the EFR32xG24 Channel Sounding Dev Kit board:

- EFR32MG24 Wireless Gecko SoC with 78.0 MHz operating frequency, 1536 kB Flash, and 256 kB RAM
- Two printed 2.4 GHz antennas for wireless transmission
- Two UFL connectors supporting conducted measurements
- TDK InvenSense ICM-40627 6-axis inertial sensor
- Macronix ultra low power 8 Mbit SPI flash (MX25R8035F)
- Two LEDs and two push buttons
- 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 PTI
- Mini Simplicity+ connector for access to energy profiling and advanced wireless network debugging (not mounted by default)
- 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

1.4 Kit Hardware Layout

Following is the layout of EFR32xG24 Channel Sounding Dev Kit.

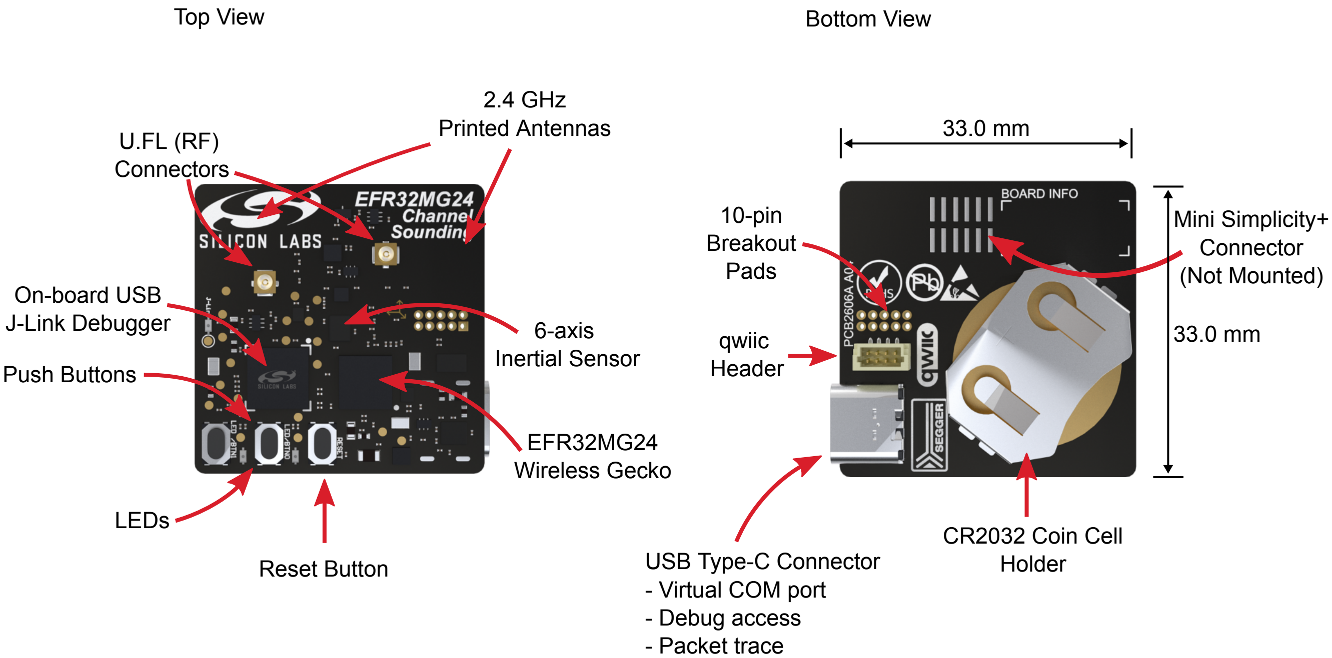


Figure 1.1. EFR32xG24 Channel Sounding Dev Kit Hardware Layout

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[1,2]	V_{VBAT}	1.9	3.0	3.6	V
Operating Temperature	T_{OP}	—	25	—	˚C

Note:

1. Brightness of the LEDs 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. Further details are present in EFR32MG24's data sheet.

2.2 Current Consumption

The operating current of the board greatly depends on the application. The following table 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 complete overview of the conditions that apply for a specific number from a data sheet, you are 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)	33.3	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)	19.1	mA
IMU Current Consumption[2]	I_{IMU}	Full-chip sleep mode at 1.8 V supply	7.5	µA
		6-Axis Gyroscope + Accelerometer, low-noise mode, at 1.8 V supply	0.65	mA
External Flash Current Consumption [3]	$I_{MX25R8035F}$	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
On-board Debugger Sleep Current Consumption [4]	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 ICM-40627 data sheet
3 From MX25R8035F data sheet
4 From EFM32GG12 data sheet

3. Hardware

The core of the EFR32xG24 Channel Sounding Dev Kit is the EFR32MG24 Wireless Gecko System-on-Chip. The board 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 EFR32xG24 Channel Sounding Dev Kit is illustrated in the figure below.

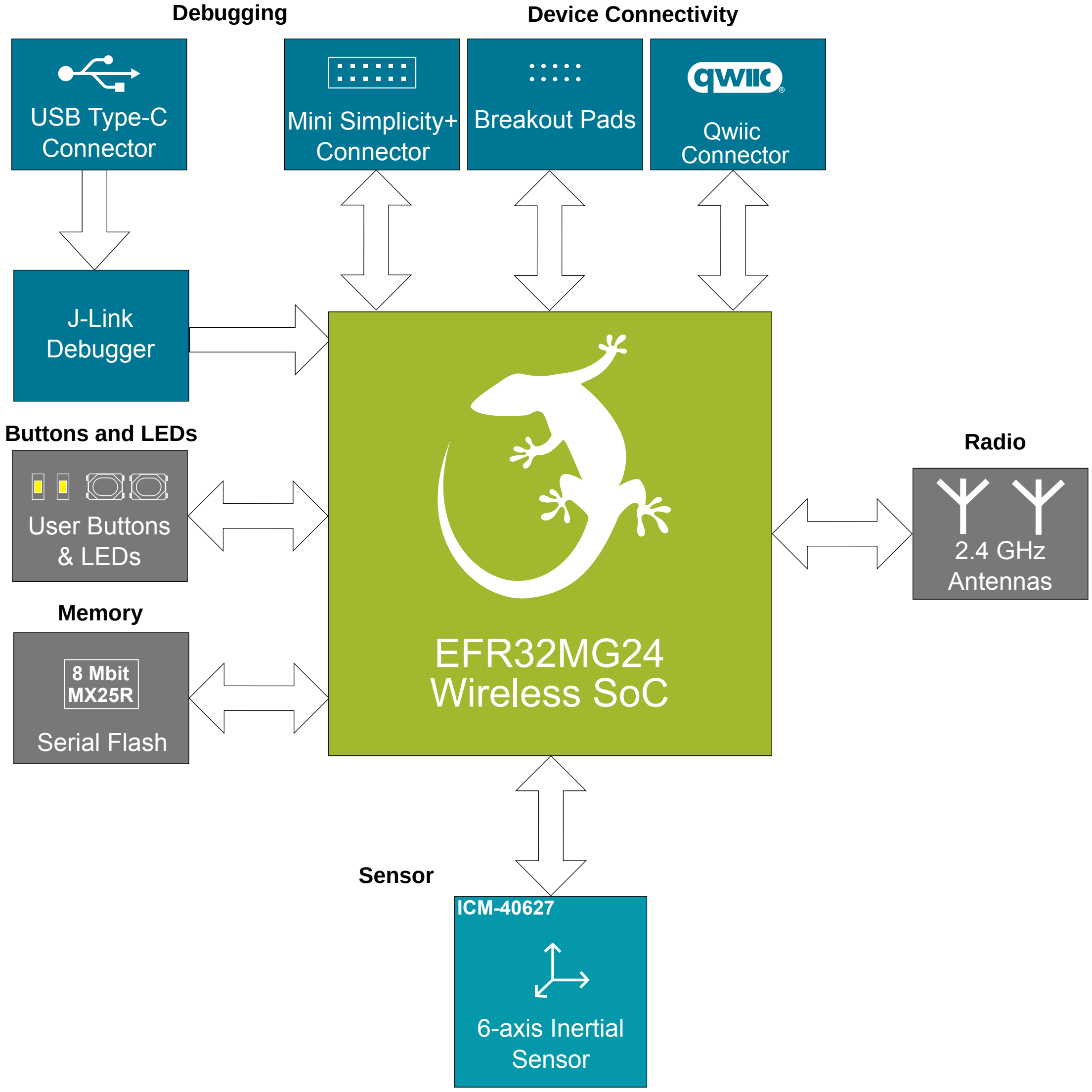


Figure 3.1. EFR32xG24 Channel Sounding Dev Kit Block Diagram

3.2 Power Supply

The kit can be powered by any of these interfaces:

- USB Type-C
- Battery
- Mini Simplicity+ connector (not mounted by default)

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

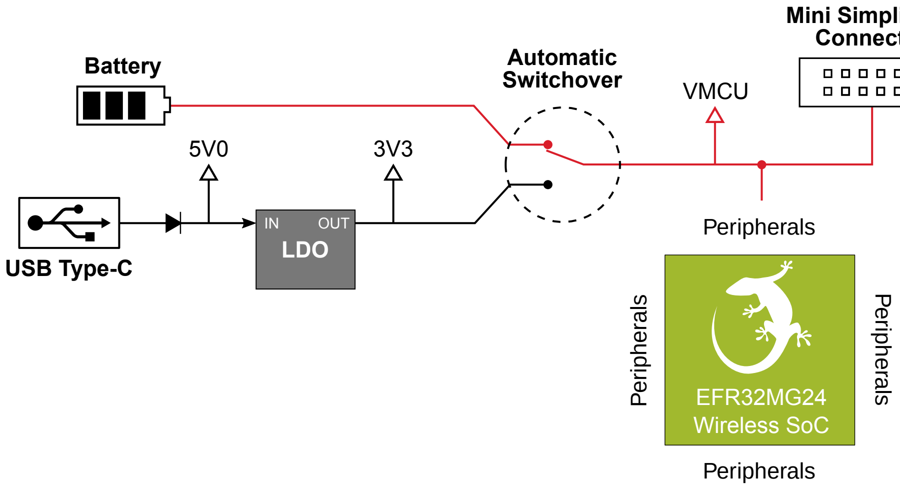


Figure 3.2. EFR32xG24 Channel Sounding Dev Kit Power Architecture

Power is normally applied either through the USB cable or 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. This requires that no other power sources are present on the kit, as power is injected directly to the VMCU net. It is important to follow this in order to avoid power conflicts and backfeeding the battery. Powering the EFR32xG24 Channel Sounding 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.

Following is the summary table for power supply options.

Table 3.1. EFR32xG24 Channel Sounding Dev Kit Power Options

Supply Mode	Typical Input Voltage	VMCU Source	5V
USB power	5.0 V	On-board regulator	USB VBUS
CR2032 battery	3.0 V	Battery voltage	No voltage present
Mini Simplicity+ Connector	3.3 V	Debugger dependent	No voltage present

3.3 EFR32MG24 Reset

The EFR32MG24 can be reset by any of the following ways:

- The 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 EFR32xG24 Channel Sounding 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:

- TDK InvenSense ICM-40627 6-axis inertial measurement sensor
- Macronix MX25R8035F ultra-low power 8 Mbit SPI flash
- Two LEDs and two push buttons

The figure below gives an overview of the peripherals that are connected to the EFR32MG24.

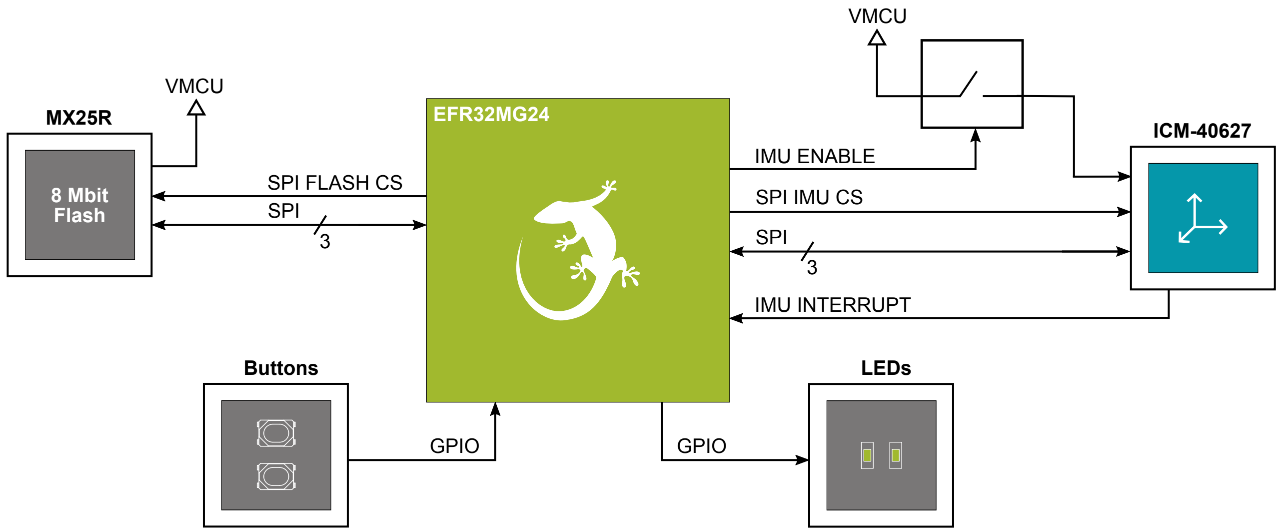


Figure 3.3. Peripherals

3.4.1 ICM-40627 6-Axis Inertial Sensor

The ICM-40627 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 the EFR32xG24 Channel Sounding Dev Kit, the voltage supply of the ICM-40627 is connected through a switching circuit. That must be enabled by setting PC09 high to enable the power to the ICM-40627. 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 figure below shows how the ICM-40627 is connected to the EFR32MG24.

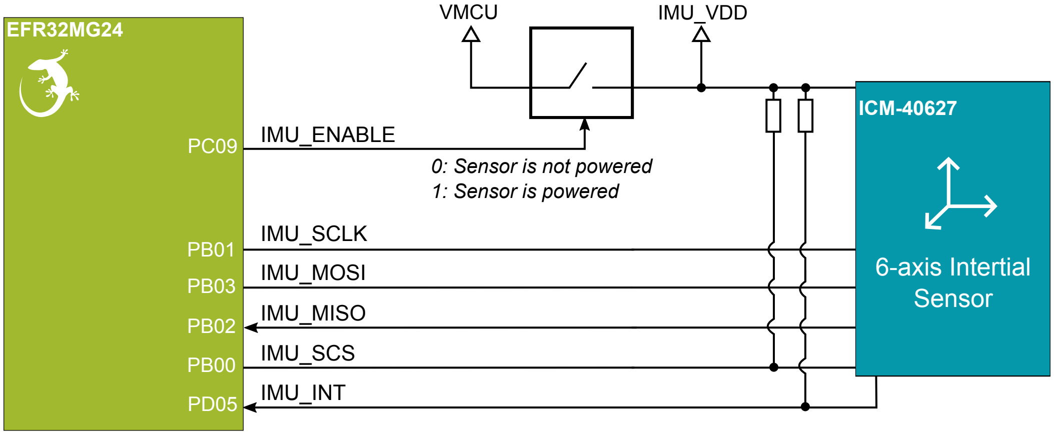


Figure 3.4. ICM-40627 6-Axis Inertial Sensor

The inertial sensor is located at 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.

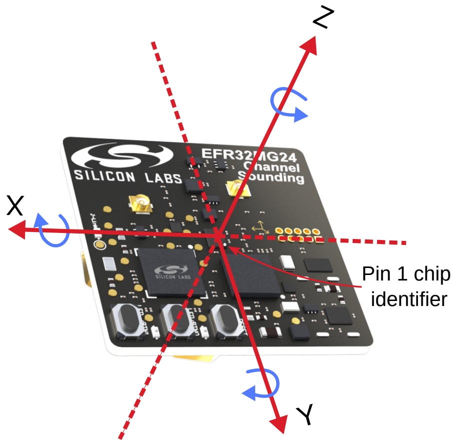


Figure 3.5. EFR32xG24 Channel Sounding Dev Kit Spatial Orientation

3.4.2 External Memory

The EFR32xG24 Channel Sounding Dev Kit includes an 8 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 100 nA to the current consumption. The figure below shows how the serial flash is connected to the EFR32MG24.

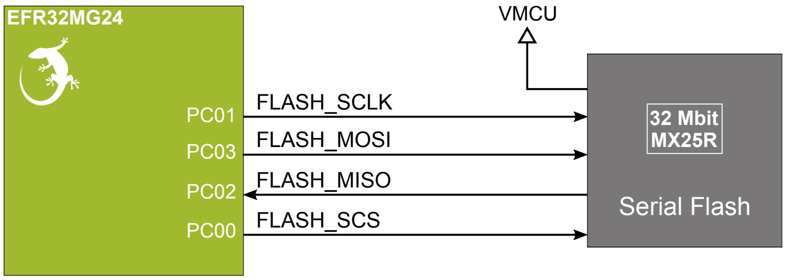


Figure 3.6. Serial Flash

3.4.3 Push Button and LED

The kit has two user push buttons, marked LED/BTN0 and LED/BTN1, that are connected to GPIOs on the EFR32MG24. The buttons are connected to pin PB04 and PB05, respectively, and they are debounced by an RC filter with a time constant of 1 ms. The logic state of a button is high while that button is not being pressed, and low when it is pressed.

The kit also features two orange LEDs, that are controlled by GPIO pins on the EFR32MG24. The LEDs are connected to pin PD04 and PC08, respectively, in an active-high configuration.

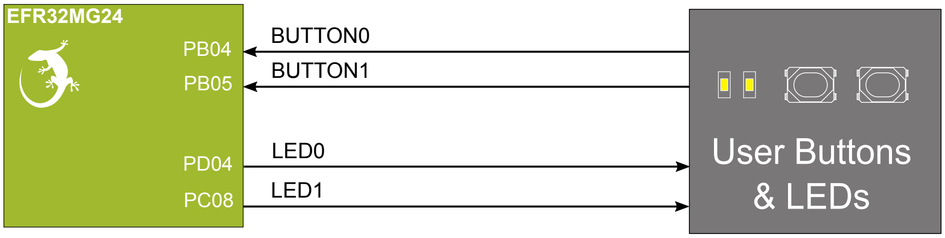


Figure 3.7. Buttons and LEDs

3.5 On-board Debugger

The EFR32xG24 Channel Sounding 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 Type-C 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. 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.

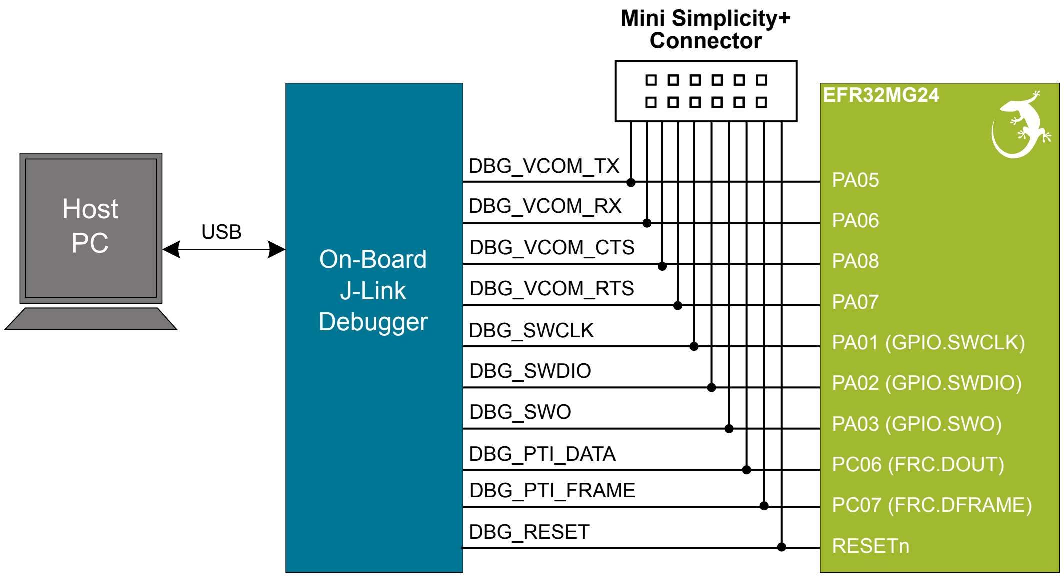


Figure 3.8. On-Board Debugger Connections

3.6 Connectors

The EFR32xG24 Channel Sounding Dev Kit features an option for a Mini Simplicity+ connector (not mounted by default), a USB Type-C connector, 10 breakout pads and a Qwiic connector. The connectors are placed on the bottom side of the board, and their placement and pinout are shown in the following figure. For additional information on the connectors, see the following sub-chapters.

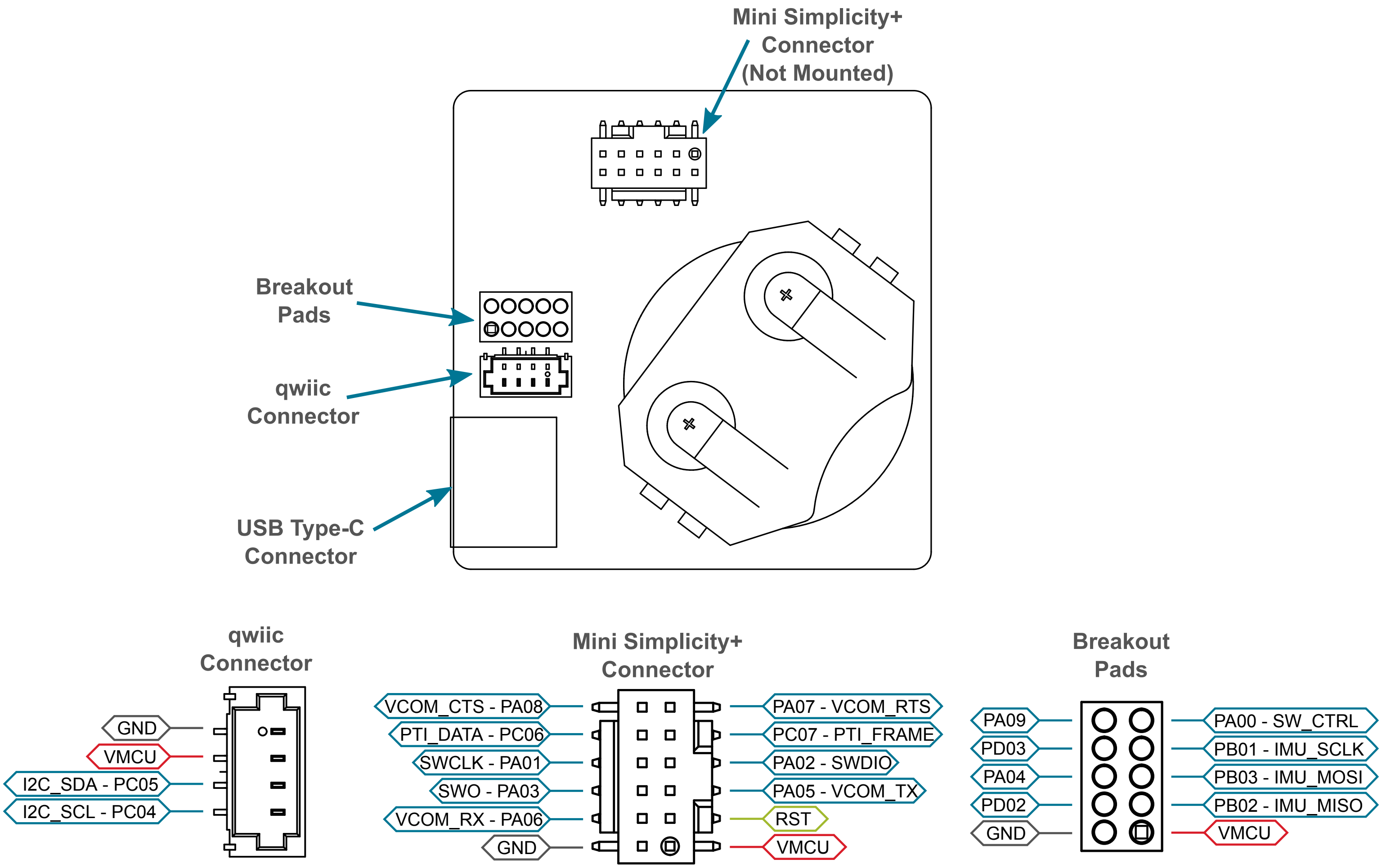


Figure 3.9. EFR32xG24 Channel Sounding Dev Kit Connectors (Bottom View)

3.6.1 Breakout Pads

Ten breakout pads, are provided and allow connection of peripherals or add-on boards. The breakout pads expose I/O pins that can be used with most of the EFR32MG24's features. Four of them are freely configurable, three enable access to the inertial sensor SPI interface, and one enables access to the RF switch control signal. Additionally, the VMCU (main power rail) and the GND are also exposed.

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 EFR32xG24 Channel Sounding Dev Kit. The table below includes an overview of the breakout header and functionality that is shared with the kit.

Table 3.2. Breakout Header Pinout

Pin	Connection	Breakout Header Function	Shared Feature
2	GND	Ground	—
4	PD02	GPIO	—
6	PA04	GPIO	—
8	PD03	GPIO	—
10	PA09	GPIO	—
1	VMCU	EFR32MG24 voltage domain, included in AEM measurements.	—
3	PB02	GPIO	IMU_MISO
5	PB03	GPIO	IMU_MOSI
7	PB01	GPIO	IMU_SCLK
9	PA00	GPIO	RF Switch Control

3.6.2 Qwiic Connector

The EFR32xG24 Channel Sounding 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 EFR32xG24 Channel Sounding 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.

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	—
SCL	PC04	—

3.6.3 Mini Simplicity+ Connector

The Mini Simplicity+ connector is a 12-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 mainboard. 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
11	VCOM_CTS	PA08	Virtual COM CTS
12	VCOM_RTS	PA07	Virtual COM RTS

3.6.4 Debug USB Type-C 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 EFR32xG24 Channel Sounding 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. 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 Type-C connector.

An external debugger can be used instead of the on-board debugger by connecting it to the Mini Simplicity+ connector (not mounted by default). 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 EFR32xG24 Channel Sounding 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 EFR32xG24 Channel Sounding Dev Kit. Failure to do so will create power conflicts.

The figure below shows the possible debug options.

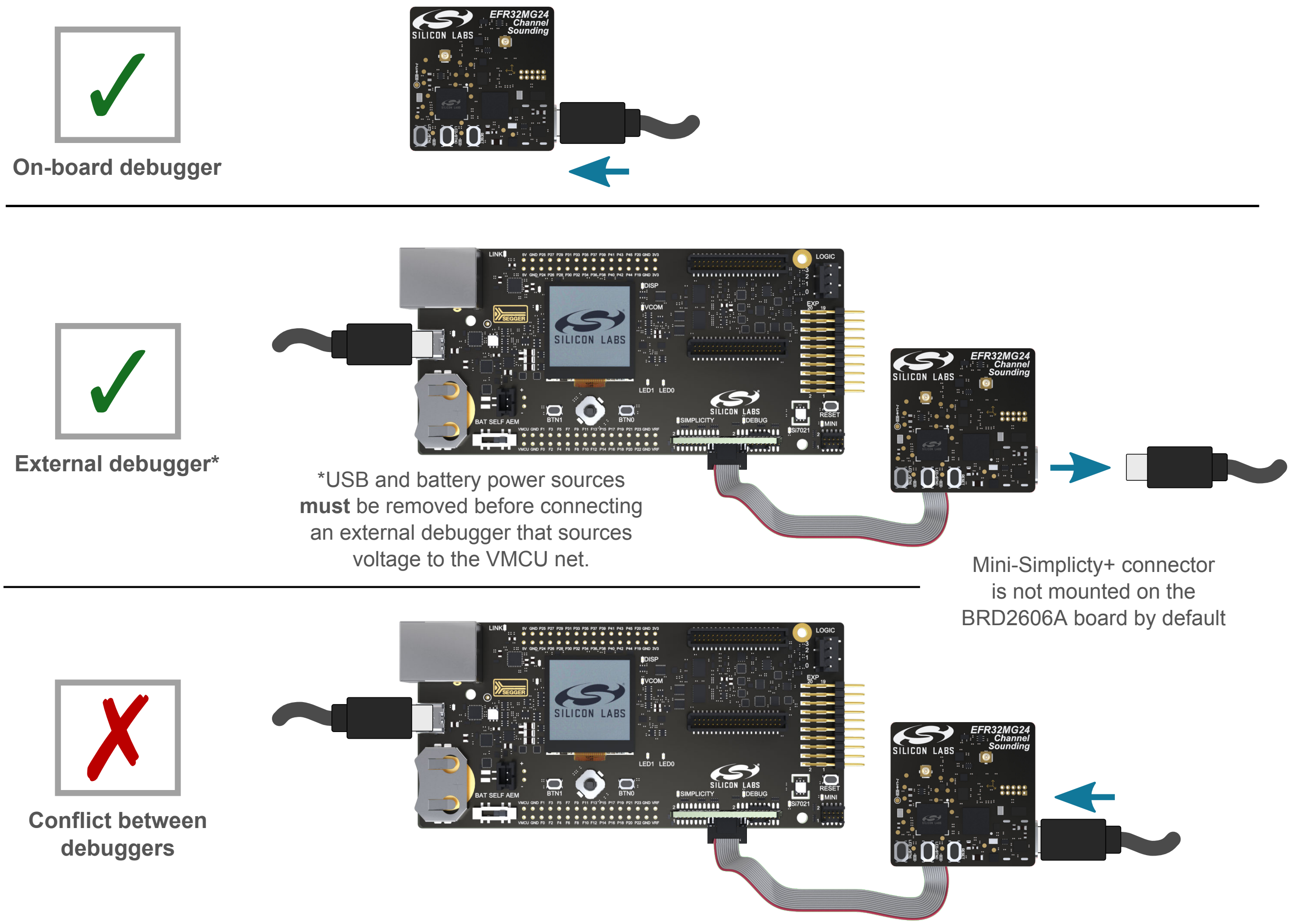


Figure 4.1. EFR32xG24 Channel Sounding Dev Kit Debugging Possibilities

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 life-time 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 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. Note that both the Wireless STK Mainboard (BRD4001A) and the Wireless Pro Kit Mainboard (BRD4002A) requires a BRD8010B STK/WSTK Debug Adapter to get access to the Mini Simplicity+ connector. 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 with flow control
- 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 section Figure 4.1 EFR32xG24 Channel Sounding Dev Kit Debugging Possibilities on page 17.

Powering the board when using the Mini Simplicity+ connector with a Wireless mainboard 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 EFR32xG24 Channel Sounding 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, is easily 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 EFR32xG24 Channel Sounding 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 EFR32xG24 Channel Sounding 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 EFR32xG24 Channel Sounding 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 EFR32xG24 Channel Sounding 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 (BRD8010B). 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 EFR32xG24 Channel Sounding Dev Kit. On EFR32xG24 Channel Sounding 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 connection 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 it 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 BRD2606A board.

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

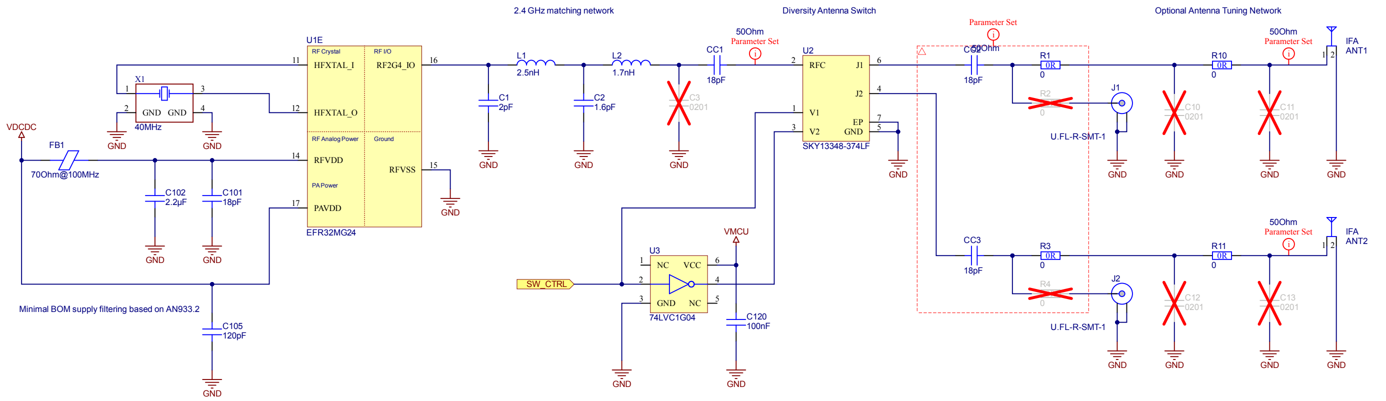


Figure 5.1. Schematic of the RF section

5.1.1 Description of the RF Section

The EFR32MG24 RF port impedance is matched to 50 Ohm: the RF2G4_IO pin is connected to a four-element impedance matching and harmonic filter circuitry and a dc blocking capacitor. A single pole double throw RF switch (U2) is used for switching between the two antennas during the Channel Sounding operation. The switch is controlled by one GPIO of the EFR32MG24 through an inverter (U3). To support conducted measurements, UFL connectors (J1, J2) are added to both of the output paths. To enable conducted measurements, the 0 Ohm resistors should be moved to connect the UFL connectors instead of the on-board antennas (R1-->R2, R3-->R4). The on-board printed antennas are matched to 50 Ohm by their geometry, so there is no need for mounting additional antenna matching components.

5.1.2 RF Section Power Supply

On the BRD2606A, 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 BRD2606A).

5.1.3 RF Section Bill of Materials

The Bill of Materials of the BRD2606A RF matching network and antenna switch is shown in the following table.

Table 5.1. Bill of Materials of the BRD2606A RF Matching Network and Antenna Switching

Component name	Value	Manufacturer	Part Number
L1	2.5 nH	Murata	LQP03HQ2N5W02D
L2	1.7 nH	Murata	LQP03HQ1N7W02D
C1	2.0 pF	Murata	GRM0335C1H2R0BA01D
C2	1.6 pF	Murata	GRM0335C1H1R6WA01D
CC1, CC2, CC3	18 pF	Murata	GRM0335C1H180JA01D
U2	—	Skyworks	SKY13348-374LF
U3	—	Texas Instruments	74LVC1G04

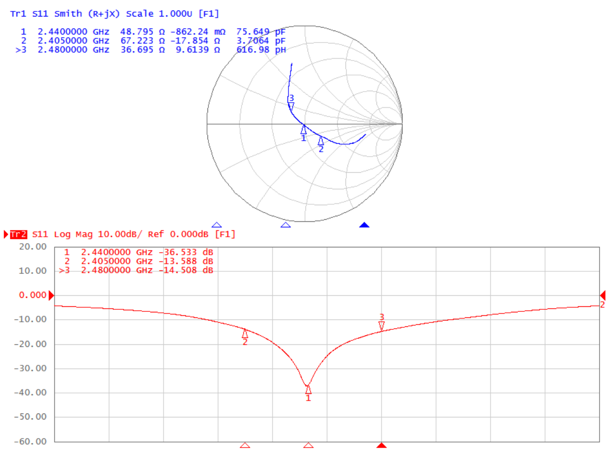
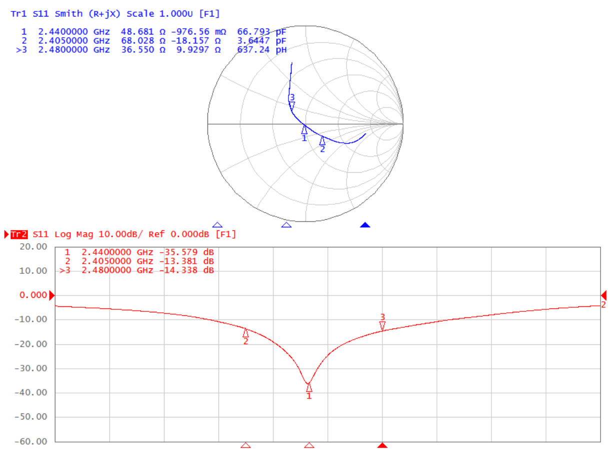
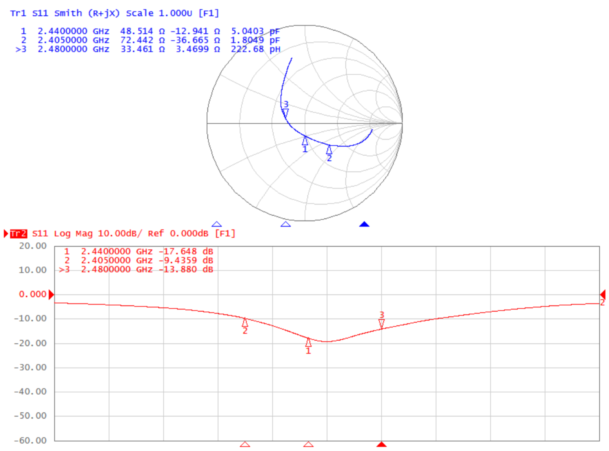
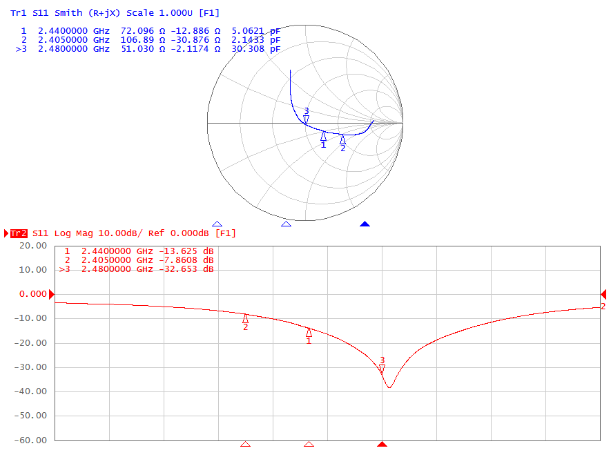
5.1.4 Antenna

The BRD2606A has two on-board printed Inverted-F antennas in orthogonal orientation.

The land pattern for the antennas on the PCB layout were designed and fine-tuned to match the antenna impedances close to 50 Ohm on the BRD2606A PCB when the coin cell battery is inserted. The resulting antenna impedances and reflections are shown in the following figures.

For more details on the antenna design, see AN1493: Antenna Design Guidelines for BLE Channel Sounding.

Table 5.2. Fine-tuned Antenna Impedances (Blue Curves) and Reflections (Red Curve)

	With CR2032 battery	With USB cable plugged in
ANT1		
ANT2		

Note: ANT2 is more sensitive to the presence of the USB cable, so some detuning can be observed in the antenna impedance when the USB cable is plugged in.

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).

If 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 following table. 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 an unmodulated carrier. These differences have been measured and used as relaxation factors on the results of the radiated measurement performed with an unmodulated carrier. With this method, 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 following table lists 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 in case of both on-board printed antennas.

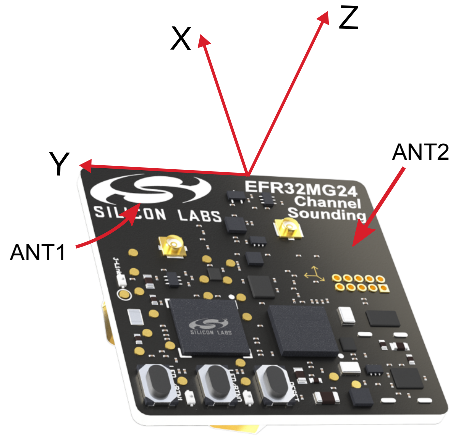


Figure 5.2. DUT Reference Planes and Printed Antenna Locations

5.4.1 Maximum Radiated Power Measurement

The transceiver was operated in unmodulated carrier transmission mode, and the output power of the radio was set to 10 dBm. The results are shown in the following table.

The correction factors are applied based on the BLE 125 Kb/s coded modulation, showed in section 5.3 Relaxation with Modulated Carrier. The correction factors are larger for the rest of the supported modulation schemes; thus, the related calculated margins would be higher than those 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 BRD2606A with ANT1

Frequency (2440 MHz)	Measured Un-modulated EIRP [dBm]	Orientation	BLE 125 Kb/s Coded Modulation			Limit in EIRP [dBm]
			Correction Fac-tor [dB]	Calculated Modulated EIRP [dBm]	Modulated Mar-gin [dB]	
Fund	9.5	XY/H	NA (0 is used)	9.5	20.5	30
2nd	-52.7	YZ/H	-2.7	-55.4	14.2	-41.2
3rd	-43.8	XZ/H	-4.8	-48.6	7.4	-41.2
4th	<-50*	—	-5.5	—	>20.0	-30
5th	<-50*	—	-6.3	—	>15.0	-41.2
* Signal level is below the Spectrum Analyzer noise floor.						

Table 5.6. Maximums of the Measured Radiated Powers of BRD2606A with ANT2

Frequency (2440 MHz)	Measured Un-modulated EIRP [dBm]	Orientation	BLE 125 Kb/s Coded Modulation			Limit in EIRP [dBm]
			Correction Fac-tor [dB]	Calculated Modulated EIRP [dBm]	Modulated Mar-gin [dB]	
Fund	10.4	XY/H	NA (0 is used)	10.4	19.6	30
2nd	-52.3	XZ/H	-2.7	-55.0	13.8	-41.2
3rd	-44.1	XZ/H	-4.8	-48.9	7.7	-41.2
4th	<-50*	—	-5.5	—	>20.0	-30
5th	<-50*	—	-6.3	—	>15.0	-41.2
* Signal level is below the Spectrum Analyzer noise floor.						

As shown in the above table, the radiated power levels with modulation are far below the applied limits.

5.4.2 Antenna Pattern Measurement

The following figures show the typical antenna patterns.

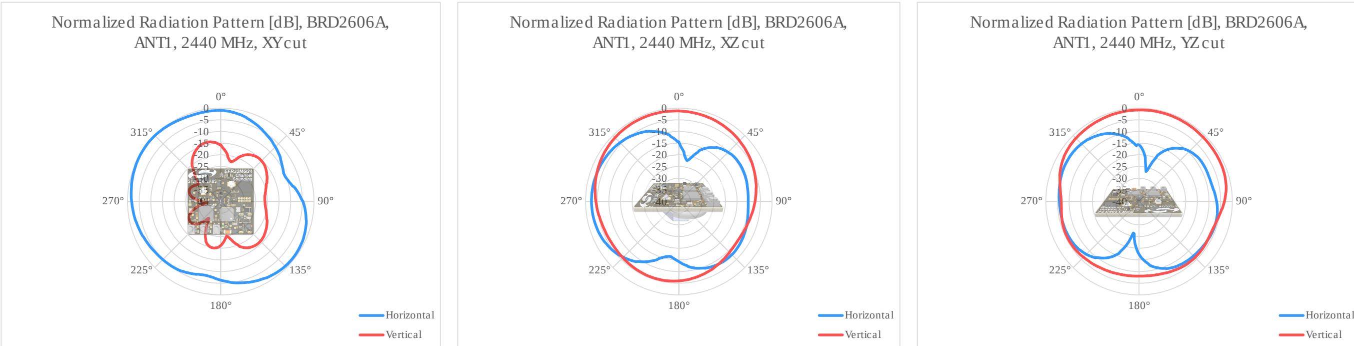


Figure 5.3. Antenna Pattern - ANT1

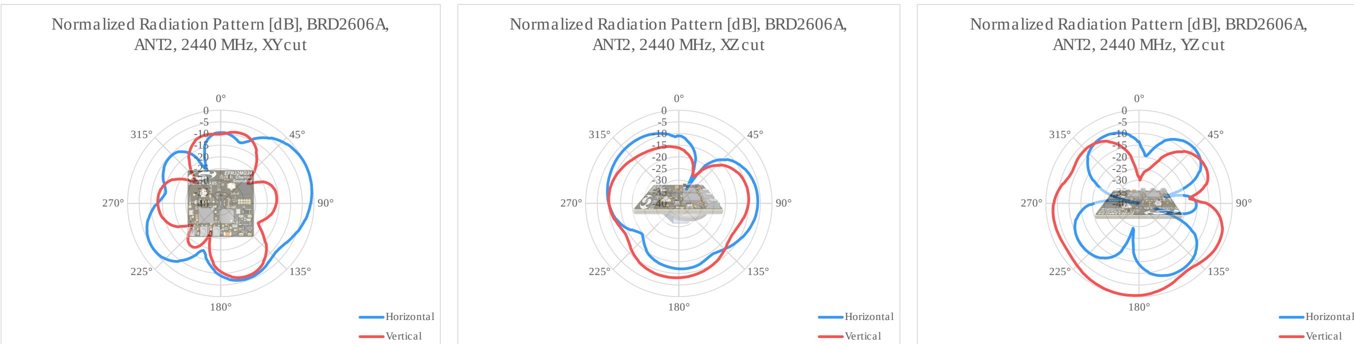


Figure 5.4. Antenna Pattern - ANT2

5.5 EMC Compliance Recommendations

5.5.1 Recommendations for 2.4 GHz ETSI EN 300-328 Compliance

As shown in section 5.4.1 Maximum Radiated Power Measurement, with the EFR32MG24 output power set to 10 dBm, the radiated power of the BRD2606A fundamental 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 shown in section 5.4.1 Maximum Radiated Power Measurement, with the EFR32MG24 output power set to 10 dBm, the radiated power of the BRD2606A fundamental complies with the 30 dBm limit of the FCC 15.247. The harmonic emissions are under the applied limits with margin.

6. Channel Sounding

For more details on Channel Sounding, see Bluetooth LE Channel Sounding Fundamentals.

7. 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.

8. Kit Revision History and Errata

8.1 Revision History

The kit revision can be found printed on the box label of the kit, as outlined in the following figure. The kit revision history is summarized in Table 8.1 Kit Revision History on page 28. The revision history given in this section may not list every kit revision. Revisions with minor changes may be omitted.

Figure 8.1. Revision Info

Table 8.1. Kit Revision History

Kit Revision	Released	Description
A01	28 August 2024	Kit revised due to BRD2606A upped to A04.
A00	26 June 2024	Initial kit revision with BRD2606A Rev. A03.

8.2 Errata

There are no known errata at present.

9. Board Revision History and Errata

9.1 Revision History

The board revision can be found laser printed on the board, and the board revision history is summarized in Table 9.1 Board Revision History on page 29. The revision history given in this section may not list every board revision. Revisions with minor changes may be omitted.

Table 9.1. Board Revision History

Revision	Released	Description
A04	31 July 2024	Added 'Channel Sounding' to silkscreen.
A03	30 May 2024	Tuned antennas for new stackup.
A02	16 May 2024	Increased via sizes for PCB manufacturability.
A01	21 February 2024	Initial board revision.

9.2 Errata

There are no known errata at present.

10. Document Revision History

Revision 1.0

March, 2025

- Initial document release.

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