

EFR32BG22 Wireless Gecko SoC Family

Data Sheet



The EFR32BG22 Wireless Gecko family of SoCs is part of the Wireless Gecko portfolio. EFR32BG22 Wireless Gecko SoCs are ideal for enabling energy-friendly Bluetooth 5.2 networking for IoT devices.

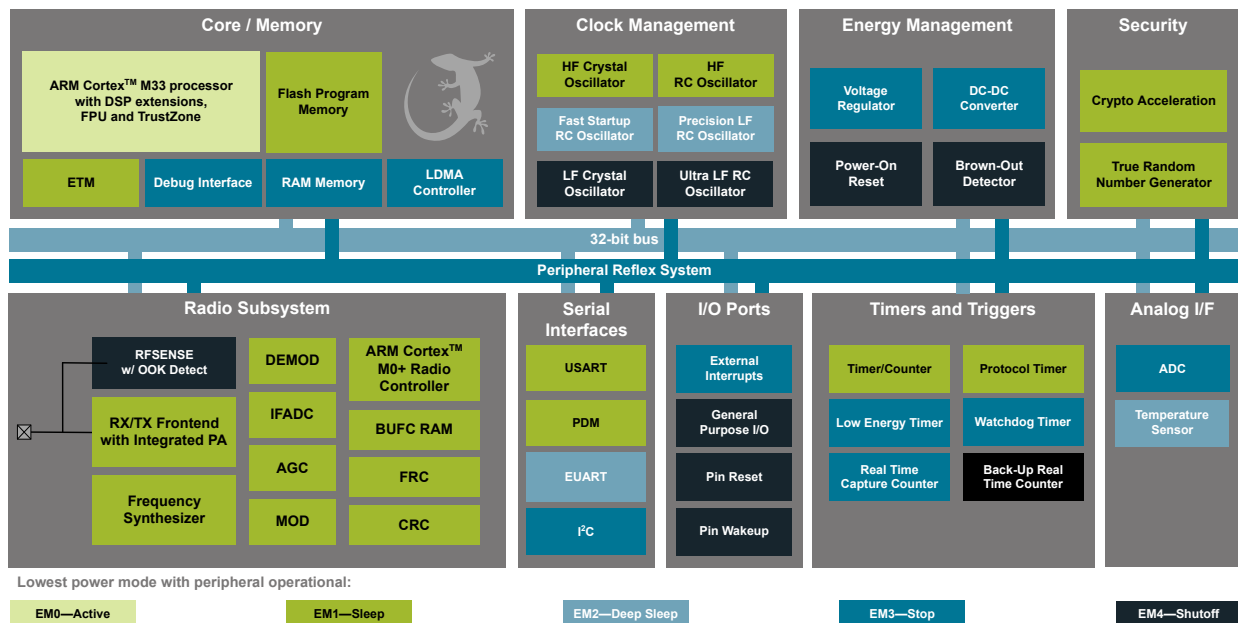
The single-die solution combines a 76.8 MHz Cortex-M33 with a high performance 2.4 GHz radio to provide an industry-leading, energy efficient wireless, SoC for IoT connected applications.

Wireless Gecko applications include:

- Asset Tags and Beacons
- Consumer Electronics Remote Controls
- Portable Medical
- Bluetooth Mesh Low Power Nodes
- Sports, Fitness, and Wellness devices
- Connected Home
- Building Automation and Security

KEY FEATURES

- 32-bit ARM® Cortex®-M33 core with 76.8 MHz maximum operating frequency
- Up to 512 kB of flash and 32 kB of 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)



1. Feature List

The EFR32BG22 highlighted features are listed below.

- **Low Power Wireless System-on-Chip**
 - High Performance 32-bit 76.8 MHz ARM Cortex®-M33 with DSP instruction and floating-point unit for efficient signal processing
 - Up to 512 kB flash program memory
 - Up to 32 kB RAM data memory
 - 2.4 GHz radio operation
- **Radio Performance**
 - -106.7 dBm sensitivity @ 125 kbps GFSK
 - -98.9 dBm sensitivity @ 1 Mbit/s GFSK
 - -96.2 dBm sensitivity @ 2 Mbit/s GFSK
 - TX power up to 6 dBm
 - 2.5 mA radio receive current
 - 3.4 mA radio transmit current @ 0 dBm output power
 - 7.5 mA radio transmit current @ 6 dBm output power
- **Low System Energy Consumption**
 - 3.6 mA RX current (1 Mbps GFSK)
 - 4.1 mA TX current @ 0 dBm output power
 - 8.2 mA TX current @ 6 dBm output power
 - 27 μ A/MHz in Active Mode (EM0) at 76.8 MHz
 - 1.40 μ A EM2 DeepSleep current (32 kB RAM retention and RTC running from LFXO)
 - 1.75 μ A EM2 DeepSleep current (32 kB RAM retention and RTC running from Precision LFRCO)
 - 0.17 μ A EM4 current
- **Supported Modulation Format**
 - 2 (G)FSK with fully configurable shaping
 - OQPSK DSSS
 - (G)MSK
- **Protocol Support**
 - Bluetooth Low Energy (Bluetooth 5.2)
 - Direction finding using Angle-of-Arrival (AoA) and Angle-of-Departure (AoD)
 - Proprietary
- **Wide selection of MCU peripherals**
 - 12-bit 1 Msps SAR Analog to Digital Converter (ADC)
 - Up to 26 General Purpose I/O pins with output state retention and asynchronous interrupts
 - 8 Channel DMA Controller
 - 12 Channel Peripheral Reflex System (PRS)
 - 4 \times 16-bit Timer/Counter with 3 Compare/Capture/PWM channels
 - 1 \times 32-bit Timer/Counter with 3 Compare/Capture/PWM channels
 - 32-bit Real Time Counter
 - 24-bit Low Energy Timer for waveform generation
 - 1 \times Watchdog Timer
 - 2 \times Universal Synchronous/Asynchronous Receiver/Transmitter (UART/SPI/SmartCard (ISO 7816)/IrDA/I²S)
 - 1 \times Enhanced Universal Asynchronous Receiver/Transmitter (EUSART)
 - 2 \times I²C interface with SMBus support
 - Digital microphone interface (PDM)
 - Precision Low-Frequency RC Oscillator to replace 32 kHz sleep crystal
 - RFSense with selective OOK mode
 - Die temperature sensor with +/-1.5 degree C accuracy after single-point calibration
- **Wide Operating Range**
 - 1.71 V to 3.8 V single power supply
 - -40 °C to 125 °C
- **Security Features**
 - Secure Boot with Root of Trust and Secure Loader (RTSL)
 - Hardware Cryptographic Acceleration for AES128/256, SHA-1, SHA-2 (up to 256-bit), ECC (up to 256-bit), ECDSA, and ECDH
 - True Random Number Generator (TRNG) compliant with NIST SP800-90 and AIS-31
 - ARM® TrustZone®
 - Secure Debug with lock/unlock
- **Packages**
 - **QFN40** 5 mm \times 5 mm \times 0.85 mm
 - **QFN32** 4 mm \times 4 mm \times 0.85 mm
 - **TQFN32** 4 mm \times 4 mm \times 0.30 mm

2. Ordering Information

Table 2.1. Ordering Information

| Ordering Code | Protocol Stack | Max TX Power | Max CPU Speed | LFRCO | Flash (kB) | RAM (kB) | GPIO | Package | Temp Range |
|-------------------------|---|--------------|---------------|-----------|------------|----------|------|---------|---------------|
| EFR32BG22C222F352GM32-C | <ul style="list-style-type: none"> • Bluetooth 5.2 • Proprietary | 6 dBm | 76.8 MHz | Precision | 352 | 32 | 18 | QFN32 | -40 to 85 °C |
| EFR32BG22C222F352GM40-C | <ul style="list-style-type: none"> • Bluetooth 5.2 • Proprietary | 6 dBm | 76.8 MHz | Precision | 352 | 32 | 26 | QFN40 | -40 to 85 °C |
| EFR32BG22C222F352GN32-C | <ul style="list-style-type: none"> • Bluetooth 5.2 • Proprietary | 6 dBm | 76.8 MHz | Precision | 352 | 32 | 18 | TQFN32 | -40 to 85 °C |
| EFR32BG22C224F512GM32-C | <ul style="list-style-type: none"> • Bluetooth 5.2 • Direction finding • Proprietary | 6 dBm | 76.8 MHz | Precision | 512 | 32 | 18 | QFN32 | -40 to 85 °C |
| EFR32BG22C224F512GM40-C | <ul style="list-style-type: none"> • Bluetooth 5.2 • Direction finding • Proprietary | 6 dBm | 76.8 MHz | Precision | 512 | 32 | 26 | QFN40 | -40 to 85 °C |
| EFR32BG22C224F512GN32-C | <ul style="list-style-type: none"> • Bluetooth 5.2 • Direction finding • Proprietary | 6 dBm | 76.8 MHz | Precision | 512 | 32 | 18 | TQFN32 | -40 to 85 °C |
| EFR32BG22C224F512IM32-C | <ul style="list-style-type: none"> • Bluetooth 5.2 • Direction finding • Proprietary | 6 dBm | 76.8 MHz | Precision | 512 | 32 | 18 | QFN32 | -40 to 125 °C |
| EFR32BG22C224F512IM40-C | <ul style="list-style-type: none"> • Bluetooth 5.2 • Direction finding • Proprietary | 6 dBm | 76.8 MHz | Precision | 512 | 32 | 26 | QFN40 | -40 to 125 °C |

LE Long Range (125 kbps and 500 kbps) PHYs are only supported on part numbers which include AoA/AoD direction-finding capability.

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3. System Overview

3.1 Introduction

The EFR32 product family combines an energy-friendly MCU with a high performance radio transceiver. The devices are well suited for secure connected IoT multi-protocol devices requiring high performance and low energy consumption. This section gives a short introduction to the full radio and MCU system. The detailed functional description can be found in the EFR32xG22 Reference Manual.

A block diagram of the EFR32BG22 family is shown in [Figure 3.1 Detailed EFR32BG22 Block Diagram on page 7](#). The diagram shows a superset of features available on the family, which vary by OPN. For more information about specific device features, consult [Ordering Information](#).

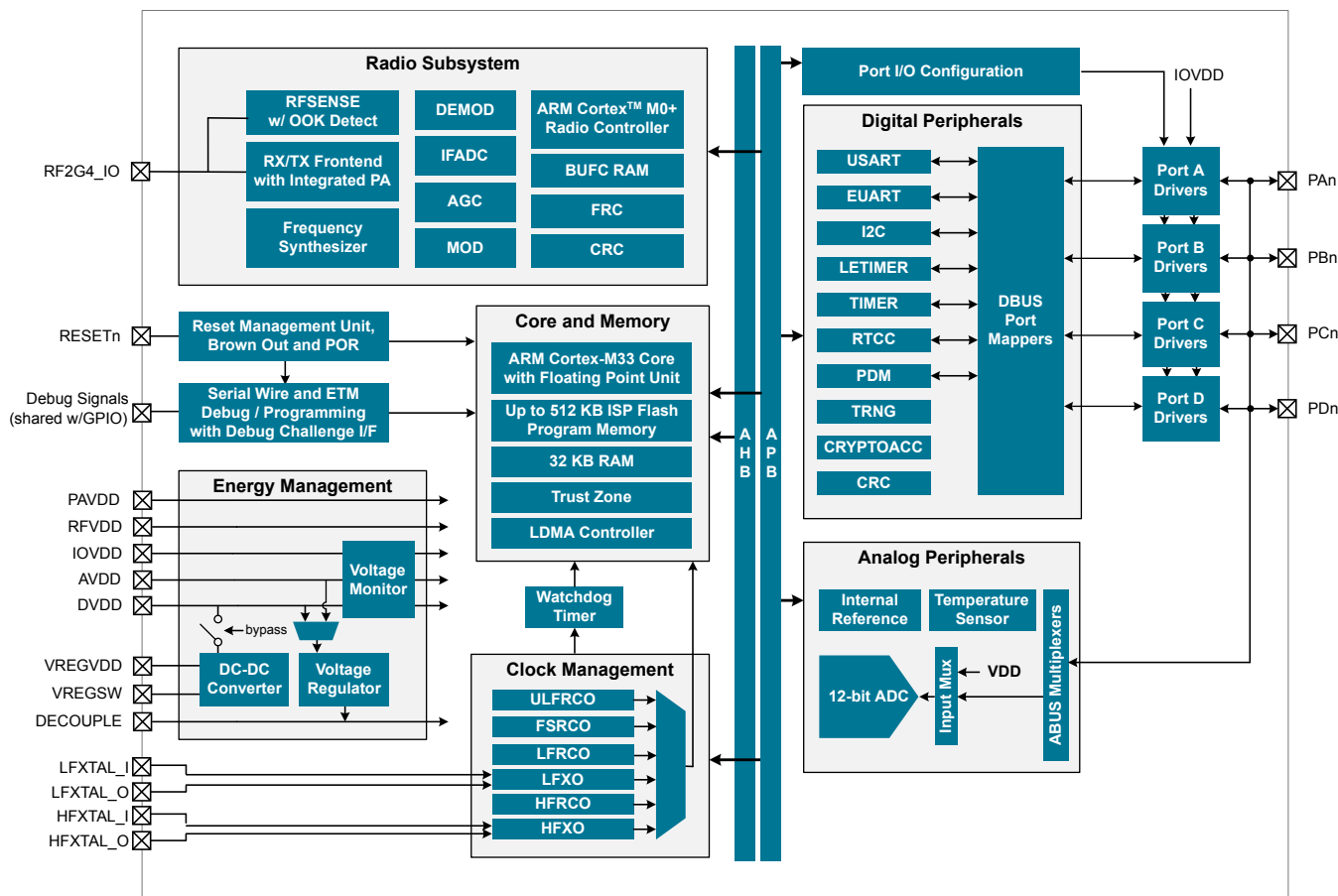


Figure 3.1. Detailed EFR32BG22 Block Diagram

3.2 Radio

The EFR32BG22 Wireless Gecko features a highly configurable radio transceiver supporting the Bluetooth Low Energy wireless protocol.

3.2.1 Antenna Interface

The 2.4 GHz antenna interface consists of a single-ended pin (RF2G4_IO). The external components for the antenna interface in typical applications are shown in the RF Matching Networks section.

3.2.2 Fractional-N Frequency Synthesizer

The EFR32BG22 contains a high performance, low phase noise, fully integrated fractional-N frequency synthesizer. The synthesizer is used in receive mode to generate the LO frequency for the down-conversion mixer. It is also used in transmit mode to directly generate the modulated RF carrier.

The fractional-N architecture provides excellent phase noise performance, frequency resolution better than 100 Hz, and low energy consumption. The synthesizer's fast frequency settling allows for very short receiver and transmitter wake up times to reduce system energy consumption.

3.2.3 Receiver Architecture

The EFR32BG22 uses a low-IF receiver architecture, consisting of a Low-Noise Amplifier (LNA) followed by an I/Q down-conversion mixer. The I/Q signals are further filtered and amplified before being sampled by the IF analog-to-digital converter (IFADC).

The IF frequency is configurable from 150 kHz to 1371 kHz. The IF can further be configured for high-side or low-side injection, providing flexibility with respect to known interferers at the image frequency.

The Automatic Gain Control (AGC) module adjusts the receiver gain to optimize performance and avoid saturation for excellent selectivity and blocking performance. The 2.4 GHz radio is calibrated at production to improve image rejection performance.

Demodulation is performed in the digital domain. The demodulator performs configurable decimation and channel filtering to allow receive bandwidths ranging from 0.1 to 2530 kHz. High carrier frequency and baud rate offsets are tolerated by active estimation and compensation. Advanced features supporting high quality communication under adverse conditions include forward error correction by block and convolutional coding as well as Direct Sequence Spread Spectrum (DSSS).

A Received Signal Strength Indicator (RSSI) is available for signal quality metrics, for level-based proximity detection, and for RF channel access by Collision Avoidance (CA) or Listen Before Talk (LBT) algorithms. An RSSI capture value is associated with each received frame and the dynamic RSSI measurement can be monitored throughout reception.

3.2.4 Transmitter Architecture

The EFR32BG22 uses a direct-conversion transmitter architecture. For constant envelope modulation formats, the modulator controls phase and frequency modulation in the frequency synthesizer. Transmit symbols or chips are optionally shaped by a digital shaping filter. The shaping filter is fully configurable, including the BT product, and can be used to implement Gaussian or Raised Cosine shaping.

Carrier Sense Multiple Access - Collision Avoidance (CSMA-CA) or Listen Before Talk (LBT) algorithms can be automatically timed by the EFR32BG22. These algorithms are typically defined by regulatory standards to improve inter-operability in a given bandwidth between devices that otherwise lack synchronized RF channel access.

3.2.5 Packet and State Trace

The EFR32BG22 Frame Controller has a packet and state trace unit that provides valuable information during the development phase. It features:

- Non-intrusive trace of transmit data, receive data and state information
- Data observability on a single-pin UART data output, or on a two-pin SPI data output
- Configurable data output bitrate / baudrate
- Multiplexed transmitted data, received data and state / meta information in a single serial data stream

3.2.6 Data Buffering

The EFR32BG22 features an advanced Radio Buffer Controller (BUFC) capable of handling up to 4 buffers of adjustable size from 64 bytes to 4096 bytes. Each buffer can be used for RX, TX or both. The buffer data is located in RAM, enabling zero-copy operations.

3.2.7 Radio Controller (RAC)

The Radio Controller controls the top level state of the radio subsystem in the EFR32BG22. It performs the following tasks:

- Precisely-timed control of enabling and disabling of the receiver and transmitter circuitry
- Run-time calibration of receiver, transmitter and frequency synthesizer
- Detailed frame transmission timing, including optional LBT or CSMA-CA

3.2.8 RFSENSE Interface

The RFSENSE block allows the device to remain in EM2, EM3 or EM4 and wake when RF energy above a specified threshold is detected. When operated in selective mode, the RFSENSE block performs OOK preamble and sync word detection, preventing false wake-up events.

3.3 General Purpose Input/Output (GPIO)

EFR32BG22 has up to 26 General Purpose Input/Output pins. Each GPIO pin can be individually configured as either an output or input. More advanced configurations including open-drain, open-source, and glitch-filtering can be configured for each individual GPIO pin. The GPIO pins can be overridden by peripheral connections, like SPI communication. Each peripheral connection can be routed to several GPIO pins on the device. The input value of a GPIO pin can be routed through the Peripheral Reflex System to other peripherals. The GPIO subsystem supports asynchronous external pin interrupts.

All of the pins on ports A and port B are EM2 capable. These pins may be used by Low-Energy peripherals in EM2/3 and may also be used as EM2/3 pin wake-ups. Pins on ports C and D are latched/retained in their current state when entering EM2 until EM2 exit upon which internal peripherals could once again drive those pads.

A few GPIOs also have EM4 wake functionality. These pins are listed in the Alternate Function Table.

3.4 Clocking

3.4.1 Clock Management Unit (CMU)

The Clock Management Unit controls oscillators and clocks in the EFR32BG22. Individual enabling and disabling of clocks to all peripheral modules is performed by the CMU. The CMU also controls enabling and configuration of the oscillators. A high degree of flexibility allows software to optimize energy consumption in any specific application by minimizing power dissipation in unused peripherals and oscillators.

3.4.2 Internal and External Oscillators

The EFR32BG22 supports two crystal oscillators and fully integrates four RC oscillators, listed below.

- A high frequency crystal oscillator (HFXO) with integrated load capacitors, tunable in small steps, provides a precise timing reference for the MCU. The HFXO provides excellent RF clocking performance using a 38.4 MHz crystal. The HFXO can also support an external clock source such as a TCXO for applications that require an extremely accurate clock frequency over temperature.
- A 32.768 kHz crystal oscillator (LFXO) provides an accurate timing reference for low energy modes.
- An integrated high frequency RC oscillator (HFRCO) is available for the MCU system, when crystal accuracy is not required. The HFRCO employs fast start-up at minimal energy consumption combined with a wide frequency range, from 1 MHz to 76.8 MHz.
- An integrated fast start-up RC oscillator (FSRCO) that runs at a fixed 20 MHz
- An integrated low frequency 32.768 kHz RC oscillator (LFRCO) for low power operation without an external crystal. Precision mode enables periodic recalibration against the 38.4 MHz HFXO crystal to improve accuracy to +/- 500 ppm, suitable for BLE sleep interval timing.
- An integrated ultra-low frequency 1 kHz RC oscillator (ULFRCO) is available to provide a timing reference at the lowest energy consumption in low energy modes.

3.5 Counters/Timers and PWM

3.5.1 Timer/Counter (TIMER)

TIMER peripherals keep track of timing, count events, generate PWM outputs and trigger timed actions in other peripherals through the Peripheral Reflex System (PRS). The core of each TIMER is a 16-bit or 32-bit counter with up to 3 compare/capture channels. Each channel is configurable in one of three modes. In capture mode, the counter state is stored in a buffer at a selected input event. In compare mode, the channel output reflects the comparison of the counter to a programmed threshold value. In PWM mode, the TIMER supports generation of pulse-width modulation (PWM) outputs of arbitrary waveforms defined by the sequence of values written to the compare registers. In addition some timers offer dead-time insertion.

See [3.13 Configuration Summary](#) for information on the feature set of each timer.

3.5.2 Low Energy Timer (LETIMER)

The unique LETIMER is a 24-bit timer that is available in energy mode EM0 Active, EM1 Sleep, EM2 Deep Sleep, and EM3 Stop. This allows it to be used for timing and output generation when most of the device is powered down, allowing simple tasks to be performed while the power consumption of the system is kept at an absolute minimum. The LETIMER can be used to output a variety of waveforms with minimal software intervention. The LETIMER is connected to the Peripheral Reflex System (PRS), and can be configured to start counting on compare matches from other peripherals such as the RTCC.

3.5.3 Real Time Clock with Capture (RTCC)

The Real Time Clock with Capture (RTCC) is a 32-bit counter providing timekeeping down to EM3. The RTCC can be clocked by any of the on-board low-frequency oscillators, and it is capable of providing system wake-up at user defined intervals.

A secondary RTC is used by the RF protocol stack for event scheduling, leaving the primary RTCC block available exclusively for application software.

3.5.4 Back-Up Real Time Counter

The Back-Up Real Time Counter (BURTC) is a 32-bit counter providing timekeeping in all energy modes, including EM4. The BURTC can be clocked by any of the on-board low-frequency oscillators, and it is capable of providing system wake-up at user defined intervals.

3.5.5 Watchdog Timer (WDOG)

The watchdog timer can act both as an independent watchdog or as a watchdog synchronous with the CPU clock. It has windowed monitoring capabilities, and can generate a reset or different interrupts depending on the failure mode of the system. The watchdog can also monitor autonomous systems driven by the Peripheral Reflex System (PRS).

3.6 Communications and Other Digital Peripherals

3.6.1 Universal Synchronous/Asynchronous Receiver/Transmitter (USART)

The Universal Synchronous/Asynchronous Receiver/Transmitter is a flexible serial I/O module. It supports full duplex asynchronous UART communication with hardware flow control as well as RS-485, SPI, MicroWire and 3-wire. It can also interface with devices supporting:

- ISO7816 SmartCards
- IrDA
- I²S

3.6.2 Enhanced Universal Asynchronous Receiver/Transmitter (EUSART)

The Enhanced Universal Asynchronous Receiver/Transmitter supports full duplex asynchronous UART communication with hardware flow control, RS-485 and IrDA support. In EM0 and EM1 the EUSART provides a high-speed, buffered communication interface.

When routed to GPIO ports A or B, the EUSART may also be used in a low-energy mode and operate in EM2. A 32.768 kHz clock source allows full duplex UART communication up to 9600 baud.

3.6.3 Inter-Integrated Circuit Interface (I²C)

The I²C module provides an interface between the MCU and a serial I²C bus. It is capable of acting as both a master and a slave and supports multi-master buses. Standard-mode, fast-mode and fast-mode plus speeds are supported, allowing transmission rates from 10 kbit/s up to 1 Mbit/s. Slave arbitration and timeouts are also available, allowing implementation of an SMBus-compliant system. The interface provided to software by the I²C module allows precise timing control of the transmission process and highly automated transfers. Automatic recognition of slave addresses is provided in active and low energy modes. Note that not all instances of I²C are available in all energy modes.

3.6.4 Peripheral Reflex System (PRS)

The Peripheral Reflex System provides a communication network between different peripheral modules without software involvement. Peripheral modules producing Reflex signals are called producers. The PRS routes Reflex signals from producers to consumer peripherals which in turn perform actions in response. Edge triggers and other functionality such as simple logic operations (AND, OR, NOT) can be applied by the PRS to the signals. The PRS allows peripherals to act autonomously without waking the MCU core, saving power.

3.6.5 Pulse Density Modulation (PDM) Interface

The PDM module provides a serial interface and decimation filter for Pulse Density Modulation (PDM) microphones, isolated Sigma-delta ADCs, digital sensors and other PDM or sigma delta bit stream peripherals. A programmable Cascaded Integrator Comb (CIC) filter is used to decimate the incoming bit streams. PDM supports stereo or mono input data and DMA transfer.

3.7 Security Features

The following security features are available on the EFR32BG22:

- Secure Boot with Root of Trust and Secure Loader (RTSL)
- Cryptographic Accelerator
- True Random Number Generator (TRNG)
- Secure Debug with Lock/Unlock

3.7.1 Secure Boot with Root of Trust and Secure Loader (RTSL)

The Secure Boot with RTSL authenticates a chain of trusted firmware that begins from an immutable memory (ROM).

It prevents malware injection, prevents rollback, ensures that only authentic firmware is executed and protects Over The Air updates.

More information on this feature can be found in the Application Note *AN1218: Series 2 Secure Boot with RTSL*.

3.7.2 Cryptographic Accelerator

The Cryptographic Accelerator is an autonomous hardware accelerator with Differential Power Analysis (DPA) countermeasures to protect keys.

It supports AES encryption and decryption with 128/192/256-bit keys, Elliptic Curve Cryptography(ECC) to support public key operations and hashes.

Supported block cipher modes of operation for AES include:

- ECB (Electronic Code Book)
- CTR (Counter Mode)
- CBC (Cipher Block Chaining)
- CFB (Cipher Feedback)
- GCM (Galois Counter Mode)
- CBC-MAC (Cipher Block Chaining Message Authentication Code)
- GMAC (Galois Message Authentication Code)
- CCM (Counter with CBC-MAC)

The Cryptographic Accelerator accelerates Elliptical Curve Cryptography and supports the NIST (National Institute of Standards and Technology) recommended curves including P-192 and P-256 for ECDH(Elliptic Curve Diffie-Hellman) key derivation and ECDSA (Elliptic Curve Digital Signature Algorithm) sign and verify operations.

Supported hashes include SHA-1, SHA2/224, and SHA-2/256.

This implementation provides a fast and energy efficient solution to state of the art cryptographic needs.

3.7.3 True Random Number Generator

The True Random Number Generator module is a non-deterministic random number generator that harvests entropy from a thermal energy source. It includes start-up health tests for the entropy source as required by NIST SP800-90B and AIS-31 as well as online health tests required for NIST SP800-90C.

The TRNG is suitable for periodically generating entropy to seed an approved pseudo random number generator.

3.7.4 Secure Debug with Lock/Unlock

For obvious security reasons, it is critical for a product to have its debug interface locked before being released in the field.

In addition, the Secure Element also provides a secure debug unlock function that allows authenticated access based on public key cryptography. This functionality is particularly useful for supporting failure analysis while maintaining confidentiality of IP and sensitive end-user data.

More information on this feature can be found in the Application Note *AN1190: EFR32xG2x Secure Debug*.

3.8 Analog

3.8.1 Analog to Digital Converter (IADC)

The IADC is a hybrid architecture combining techniques from both SAR and Delta-Sigma style converters. It has a resolution of up to 12 bits at up to 1 Msps. Hardware oversampling reduces system-level noise over multiple front-end samples. The IADC includes integrated voltage references. Inputs are selectable from a wide range of sources, including pins configurable as either single-ended or differential.

3.9 Power

The EFR32BG22 has an Energy Management Unit (EMU) and efficient integrated regulators to generate internal supply voltages. Only a single external supply voltage is required, from which all internal voltages are created. An optional integrated DC-DC buck regulator can be utilized to further reduce the current consumption. The DC-DC regulator requires one external inductor and one external capacitor.

The EFR32BG22 device family includes support for internal supply voltage scaling, as well as two different power domains groups for peripherals. These enhancements allow for further supply current reductions and lower overall power consumption.

3.9.1 Energy Management Unit (EMU)

The Energy Management Unit manages transitions of energy modes in the device. Each energy mode defines which peripherals and features are available and the amount of current the device consumes. The EMU can also be used to implement system-wide voltage scaling and turn off the power to unused RAM blocks to optimize the energy consumption in the target application. The DC-DC regulator operation is tightly integrated with the EMU.

3.9.2 Voltage Scaling

The EFR32BG22 supports supply voltage scaling for the LDO powering DECOUPLE, with independent selections for EM0 / EM1 and EM2 / EM3. Voltage scaling helps to optimize the energy efficiency of the system by operating at lower voltages when possible. The default EM0 / EM1 voltage scaling level is VSCALE2, which allows the core to operate in active mode at full speed. The intermediate level, VSCALE1, allows operation in EM0 and EM1 at up to 40 MHz. The lowest level, VSCALE0, can be used to conserve power in EM2 and EM3. The EMU will automatically switch the target voltage scaling level when transitioning between energy modes.

3.9.3 DC-DC Converter

The DC-DC buck converter covers a wide range of load currents, provides high efficiency in energy modes EM0, EM1, EM2 and EM3, and can supply up to 60 mA for device and radio operation. RF noise mitigation allows operation of the DC-DC converter without significantly degrading sensitivity of radio components. An on-chip supply-monitor signals when the supply voltage is low to allow bypass of the regulator via programmable software interrupt. It employs soft switching at boot and DCDC regulating-to-bypass transitions to limit the max supply slew-rate and mitigate inrush current.

3.9.4 Power Domains

The EFR32BG22 has three peripheral power domains for operation in EM2 and EM3, as well as the ability to selectively retain configurations for EM0/EM1 peripherals. A small set of peripherals always remain powered on in EM2 and EM3, including all peripherals which are available in EM4. If all of the peripherals in PD0B or PD0C are configured as unused, that power domain will be powered off in EM2 or EM3, reducing the overall current consumption of the device. Likewise, if the application can tolerate the setup time to re-configure used EM0/EM1 peripherals on wake, register retention for these peripherals can be disabled to further reduce the EM2 or EM3 current.

Table 3.1. Peripheral Power Subdomains

| Always available in EM2/EM3 | Power Domain PD0B | Power Domain PD0C |
|---|-------------------|------------------------|
| RTCC | LETIMER0 | LFRCO (Precision Mode) |
| LFRCO (Non-precision mode) ¹ | IADC0 | |
| LFXO ¹ | I2C0 | |
| BURTC ¹ | WDOG0 | |
| RFSENSE ¹ | EUART0 | |
| ULFRCO ¹ | PRS | |
| FSRCO | DEBUG | |
| Note: | | |
| 1. Peripheral also available in EM4. | | |

3.10 Reset Management Unit (RMU)

The RMU is responsible for handling reset of the EFR32BG22. A wide range of reset sources are available, including several power supply monitors, pin reset, software controlled reset, core lockup reset, and watchdog reset.

3.11 Core and Memory

3.11.1 Processor Core

The ARM Cortex-M processor includes a 32-bit RISC processor integrating the following features and tasks in the system:

- ARM Cortex-M33 RISC processor achieving 1.50 Dhrystone MIPS/MHz
- ARM TrustZone security technology
- Embedded Trace Macrocell (ETM) for real-time trace and debug
- Up to 512 kB flash program memory
- Up to 32 kB RAM data memory
- Configuration and event handling of all modules
- 2-pin Serial-Wire debug interface

3.11.2 Memory System Controller (MSC)

The Memory System Controller (MSC) is the program memory unit of the microcontroller. The flash memory is readable and writable from both the Cortex-M and DMA. In addition to the main flash array where Program code is normally written the MSC also provides an Information block where additional information such as special user information or flash-lock bits are stored. There is also a read-only page in the information block containing system and device calibration data. Read and write operations are supported in energy modes EM0 Active and EM1 Sleep.

3.11.3 Linked Direct Memory Access Controller (LDMA)

The Linked Direct Memory Access (LDMA) controller allows the system to perform memory operations independently of software. This reduces both energy consumption and software workload. The LDMA allows operations to be linked together and staged, enabling sophisticated operations to be implemented.

3.12 Memory Map

The EFR32BG22 memory map is shown in the figures below. RAM and flash sizes are for the largest memory configuration.

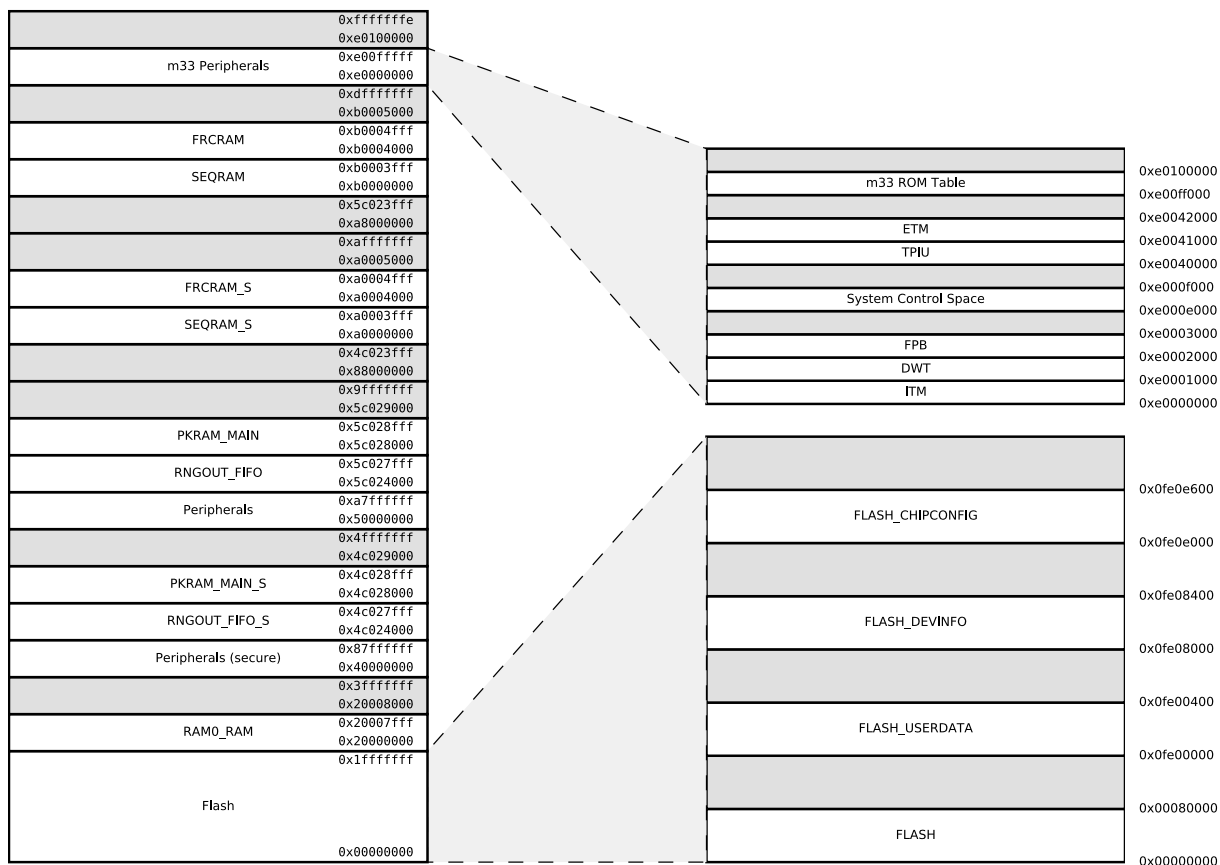


Figure 3.2. EFR32BG22 Memory Map — Core Peripherals and Code Space

3.13 Configuration Summary

The features of the EFR32BG22 are a subset of the feature set described in the device reference manual. The table below describes device specific implementation of the features. Remaining modules support full configuration.

Table 3.2. Configuration Summary

| Module | Lowest Energy Mode | Configuration |
|---|--|--------------------------|
| I2C0 | EM2 ¹ | |
| I2C1 | EM1 | |
| IADC0 | EM2 | |
| LETIMER0 | EM2 ¹ | |
| PDM | EM1 | 2-channel |
| TIMER0 | EM1 | 32-bit, 3-channels, +DTI |
| TIMER1 | EM1 | 16-bit, 3-channels, +DTI |
| TIMER2 | EM1 | 16-bit, 3-channels, +DTI |
| TIMER3 | EM1 | 16-bit, 3-channels, +DTI |
| TIMER4 | EM1 | 16-bit, 3-channels, +DTI |
| EUART0 | EM1 - Full high-speed operation | |
| | EM2 ¹ - Low-energy operation, 9600 Baud | |
| USART0 | EM1 | +IrDA, +I2S, +SmartCard |
| USART1 | EM1 | +IrDA, +I2S, +SmartCard |
| Note: | | |
| 1. EM2 and EM3 operation is only supported for digital peripheral I/O on Port A and Port B. All GPIO ports support digital peripheral operation in EM0 and EM1. | | |

4. Electrical Specifications

4.1 Electrical Characteristics

All electrical parameters in all tables are specified under the following conditions, unless stated otherwise:

- Typical values are based on $T_A=25\text{ }^\circ\text{C}$ and all supplies at 3.0 V, by production test and/or technology characterization.
- Radio performance numbers are measured in conducted mode, based on Silicon Laboratories reference designs using output power-specific external RF impedance-matching networks for interfacing to a 50 Ω antenna.
- Minimum and maximum values represent the worst conditions across supply voltage, process variation, and operating temperature, unless stated otherwise.

When assigning supply sources, the following requirements must be observed:

- $V_{REGVDD} \geq DVDD$
 - In systems not using the DCDC converter, DVDD should be shorted to VREGVDD
- $PAVDD \geq RFVDD$
- AVDD and IOVDD: No dependency with each other or any other supply pin

4.2 Absolute Maximum Ratings

Stresses beyond those listed below may cause permanent damage to the device. This is a stress rating only and functional operation of the devices at those or any other conditions beyond those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability. For more information on the available quality and reliability data, see the Quality and Reliability Monitor Report at <http://www.silabs.com/support/quality/pages/default.aspx>.

Table 4.1. Absolute Maximum Ratings

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|-------------------------|----------------|------|-----|--------------------------|--------|
| Storage temperature range | T _{STG} | | -50 | — | +150 | °C |
| Voltage on any supply pin ¹ | V _{DDMAX} | | -0.3 | — | 3.8 | V |
| Junction temperature | T _{JMAX} | -G grade | — | — | +105 | °C |
| | | -I grade | — | — | +125 | °C |
| Voltage ramp rate on any supply pin | V _{DDRAMP} MAX | | — | — | 1.0 | V / μs |
| Voltage on HFXO pins | V _{HFXO} PIN | | -0.3 | — | 1.4 | V |
| DC voltage on any GPIO pin | V _{DIG} PIN | | -0.3 | — | V _{IOVDD} + 0.3 | V |
| DC voltage on RESETn pin | V _{RESETn} | | -0.3 | — | 3.8 | V |
| Absolute voltage on RF pin RF2G4_IO | V _{MAX2G4} | | -0.3 | — | V _{PAVDD} + 0.3 | V |
| Total current into VDD power lines | I _{VDDMAX} | Source | — | — | 200 | mA |
| Total current into VSS ground lines | I _{VSSMAX} | Sink | — | — | 200 | mA |
| Current per I/O pin | I _{IO} MAX | Sink | — | — | 50 | mA |
| | | Source | — | — | 50 | mA |
| Current for all I/O pins | I _{IOALL} MAX | Sink | — | — | 200 | mA |
| | | Source | — | — | 200 | mA |

Note:

- The maximum supply voltage on VREGVDD is limited under certain conditions when using the DC-DC. See the DC-DC specifications for more details.

4.3 General Operating Conditions

Table 4.2. General Operating Conditions

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|-------------------|--|------|------|-------------|---------|
| Operating ambient temperature range | T_A | -G temperature grade ¹ | -40 | — | +85 | °C |
| | | -I temperature grade ¹ | -40 | — | +125 | °C |
| DVDD supply voltage | V_{DVDD} | EM0/1 | 1.71 | 3.0 | 3.8 | V |
| | | EM2/3/4 ² | 1.71 | 3.0 | 3.8 | V |
| AVDD supply voltage | V_{AVDD} | | 1.71 | 3.0 | 3.8 | V |
| IOVDDx operating supply voltage (All IOVDD pins) | V_{IOVDDx} | | 1.71 | 3.0 | 3.8 | V |
| PAVDD operating supply voltage | V_{PAVDD} | | 1.71 | 3.0 | 3.8 | V |
| VREGVDD operating supply voltage | $V_{VREGVDD}$ | DC-DC in regulation ³ | 2.2 | 3.0 | 3.8 | V |
| | | DC-DC in bypass 60 mA load | 1.8 | 3.0 | 3.8 | V |
| | | DC-DC not in use. DVDD externally shorted to VREGVDD | 1.71 | 3.0 | 3.8 | V |
| RFVDD operating supply voltage | V_{RFVDD} | | 1.71 | 3.0 | V_{PAVDD} | V |
| DECOUPLE output capacitor ⁴ | $C_{DECOUPLE}$ | 1.0 μ F \pm 10% X8L capacitor used for performance characterization. | 1.0 | — | 2.75 | μ F |
| HCLK and SYSCLK frequency | f_{HCLK} | VSCALE2, MODE = WS1 | — | — | 76.8 | MHz |
| | | VSCALE2, MODE = WS0 | — | — | 40 | MHz |
| | | VSCALE1, MODE = WS0 | — | — | 40 | MHz |
| PCLK frequency | f_{PCLK} | VSCALE2 | — | — | 50 | MHz |
| | | VSCALE1 | — | — | 40 | MHz |
| EM01 Group A clock frequency | $f_{EM01GRPACLK}$ | VSCALE2 | — | — | 76.8 | MHz |
| | | VSCALE1 | — | — | 40 | MHz |
| EM01 Group B clock frequency | $f_{EM01GRPBCLK}$ | VSCALE2 | — | — | 76.8 | MHz |
| | | VSCALE1 | — | — | 40 | MHz |
| Radio HCLK frequency ⁵ | f_{RHCLK} | VSCALE2 or VSCALE1 | — | 38.4 | — | MHz |

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|--------|----------------|-----|-----|-----|------|
| Note: | | | | | | |
| <ol style="list-style-type: none"> 1. The device may operate continuously at the maximum allowable ambient T_A rating as long as the absolute maximum T_{JMAX} is not exceeded. For an application with significant power dissipation, the allowable T_A may be lower than the maximum T_A rating. $T_A = T_{JMAX} - (\text{THETA}_{JA} \times \text{PowerDissipation})$. Refer to the Absolute Maximum Ratings table and the Thermal Characteristics table for T_{JMAX} and THETA_{JA}. 2. The DVDD supply is monitored by the DVDD BOD in EM0/1 and the LE DVDD BOD in EM2/3/4. 3. The maximum supply voltage on VREGVDD is limited under certain conditions when using the DC-DC. See the DC-DC specifications for more details. 4. Murata GCM21BL81C105KA58L used for performance characterization. Actual capacitor values can be significantly de-rated from their specified nominal value by the rated tolerance, as well as the application's AC voltage, DC bias, and temperature. The minimum capacitance counting all error sources should be no less than 0.6 μF. 5. The recommended radio crystal frequency is 38.4 MHz. Any crystal frequency other than 38.4 is expressly not supported. See HFXO specifications for more detail on crystal tolerance. | | | | | | |

4.4 DC-DC Converter

Test conditions: $L_{DCDC} = 2.2 \mu\text{H}$ (Samsung CIG22H2R2MNE), $C_{DCDC} = 4.7 \mu\text{F}$ (Samsung CL10B475KQ8NQNC), $V_{VREGVDD} = 3.0 \text{ V}$, $V_{OUT} = 1.8 \text{ V}$, IPKVAL in EM0/1 modes is set to 150 mA, and in EM2/3 modes is set to 90 mA, unless otherwise indicated.

Table 4.3. DC-DC Converter

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|----------------|--|------------|------|------|---------------|
| Input voltage range at VREGVDD pin ¹ | $V_{VREGVDD}$ | DCDC in regulation, $I_{LOAD} = 60 \text{ mA}$, EM0/EM1 mode | 2.2 | 3.0 | 3.8* | V |
| | | DCDC in regulation, $I_{LOAD} = 5 \text{ mA}$, EM0/EM1 or EM2/EM3 mode | 1.8 | 3.0 | 3.8* | V |
| | | Bypass mode | 1.8 | 3.0 | 3.8 | V |
| Regulated output voltage | V_{OUT} | | — | 1.8 | — | V |
| Regulation DC accuracy | ACC_{DC} | $V_{VREGVDD} \geq 2.2 \text{ V}$, Steady state in EM0/EM1 mode or EM2/EM3 mode | -2.5 | — | 3.3 | % |
| Regulation total accuracy | ACC_{TOT} | With mode transitions between EM0/EM1 and EM2/EM3 modes | -5 | — | 7 | % |
| Steady-state output ripple | V_R | $I_{LOAD} = 20 \text{ mA}$ in EM0/EM1 mode | — | 14.3 | — | mVpp |
| DC line regulation | V_{REG} | $I_{LOAD} = 60 \text{ mA}$ in EM0/EM1 mode, $V_{VREGVDD} \geq 2.2 \text{ V}$ | — | 5.5 | — | mV/V |
| DC load regulation | I_{REG} | Load current between 100 μA and 60 mA in EM0/EM1 mode | — | 0.27 | — | mV/mA |
| Efficiency | EFF | Load current between 100 μA and 60 mA in EM0/EM1 mode, or between 10 μA and 5 mA in EM2/EM3 mode | — | 91 | — | % |
| Output load current | I_{LOAD} | EM0/EM1 mode, DCDC in regulation | — | — | 60 | mA |
| | | EM2/EM3 mode, DCDC in regulation | — | — | 5 | mA |
| | | Bypass mode | — | — | 60 | mA |
| Nominal output capacitor | C_{DCDC} | 4.7 $\mu\text{F} \pm 10\%$ X7R capacitor used for performance characterization ² | 4.7 | — | 10 | μF |
| Nominal inductor | L_{DCDC} | $\pm 20\%$ tolerance | — | 2.2 | — | μH |
| Nominal input capacitor | C_{IN} | | C_{DCDC} | — | — | μF |
| Resistance in bypass mode | R_{BYP} | Bypass switch from VREGVDD to DVDD, $V_{VREGVDD} = 1.8 \text{ V}$ | — | 1.75 | 3 | Ω |
| | | Powertrain PFET switch from VREGVDD to VREGSW, $V_{VREGVDD} = 1.8 \text{ V}$ | — | 0.86 | 1.5 | Ω |
| Supply monitor threshold programming range | V_{CMP_RNG} | Programmable in 0.1 V steps | 2.0 | — | 2.3 | V |
| Supply monitor threshold accuracy | V_{CMP_ACC} | Supply falling edge trip point | TBD | — | TBD | % |

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|-------------------------------------|-------------------------|---|-----|-----|-----|---------------|
| Supply monitor threshold hysteresis | $V_{\text{CMP_HYST}}$ | Positive hysteresis on the supply rising edge referred to the falling edge trip point | — | 4 | — | % |
| Supply monitor response time | $t_{\text{CMP_DELAY}}$ | Supply falling edge at -100 mV / μs | — | 0.6 | — | μs |

Note:

1. The supported maximum V_{VREGVDD} in regulation mode is a function of temperature and 10-year lifetime average load current. See more details in [4.4.1 DC-DC Operating Limits](#).
2. Samsung CL10B475KQ8NQNC used for performance characterization. Actual capacitor values can be significantly de-rated from their specified nominal value by the rated tolerance, as well as the application's AC voltage, DC bias, and temperature. The minimum capacitance counting all error sources should be no less than 2.4 μF .

4.4.1 DC-DC Operating Limits

The maximum supported voltage on the VREGVDD supply pin is limited under certain conditions. Maximum input voltage is a function of temperature and the average load current over a 10-year lifetime. [Figure 4.1 Lifetime average load current limit vs. Maximum input voltage on page 23](#) shows the safe operating region under specific conditions. Exceeding this safe operating range may impact the reliability and performance of the DC-DC converter.

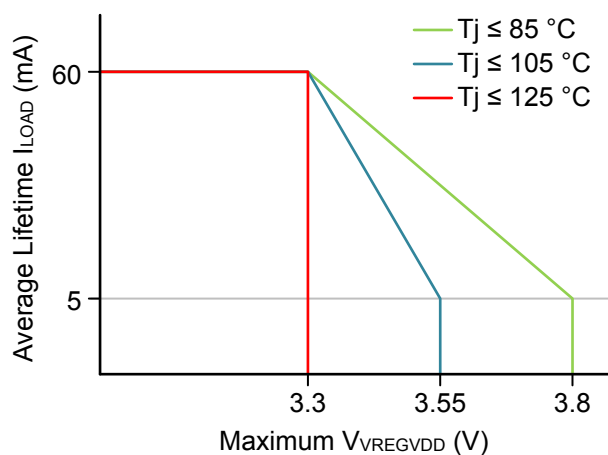


Figure 4.1. Lifetime average load current limit vs. Maximum input voltage

The minimum input voltage for the DC-DC in EM0/EM1 mode is a function of the maximum load current, and the peak current setting. [Figure 4.2 Transient maximum load current vs. Minimum input voltage on page 23](#) shows the max load current vs. input voltage for different DC-DC peak inductor current settings.

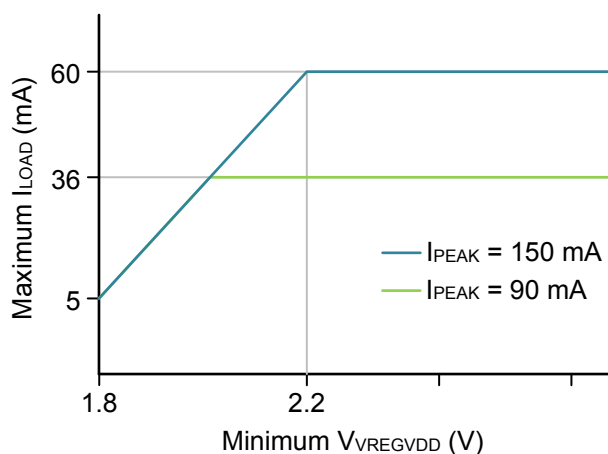


Figure 4.2. Transient maximum load current vs. Minimum input voltage

4.5 Thermal Characteristics

Table 4.4. Thermal Characteristics

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|---------------------------------|--|-----|------|-----|------|
| Thermal Resistance Junction to Ambient QFN32 (4x4mm) Package | THE-TA _{JA_QFN32_4X4} | 4-Layer PCB, Natural Convection ¹ | — | 35.4 | — | °C/W |
| Thermal Resistance Junction to Ambient TQFN32 (4x4mm) Package | THE-TA _{JA_TQFN32_4X4} | 4-Layer PCB, Natural Convection ¹ | — | 40.2 | — | °C/W |
| Thermal Resistance, Junction to Ambient, QFN40 (5x5mm) Package | THE-TA _{JA_QFN40_5X5} | 4-Layer PCB, Natural Convection ¹ | — | 32.6 | — | °C/W |

Note:

1. Measured according to JEDEC standard JESD51-2A. Integrated Circuit Thermal Test Method Environmental Conditions - Natural Convection (Still Air).

4.6 Current Consumption

4.6.1 MCU current consumption using DC-DC at 3.0 V input

Unless otherwise indicated, typical conditions are: VREGVDD = 3.0 V. AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8 V from DC-DC. Voltage scaling level = VSCALE1. T_A = 25 °C. Minimum and maximum values in this table represent the worst conditions across process variation at T_A = 25 °C.

Table 4.5. MCU current consumption using DC-DC at 3.0 V input

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---------------------|--|-----|-----|-----|--------|
| Current consumption in EM0 mode with all peripherals disabled | I _{ACTIVE} | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, CPU running Prime from flash, VSCALE2 | — | 28 | — | μA/MHz |
| | | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, CPU running while loop from flash, VSCALE2 | — | 27 | — | μA/MHz |
| | | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, CPU running CoreMark loop from flash, VSCALE2 | — | 37 | — | μA/MHz |
| | | 38.4 MHz crystal, CPU running Prime from flash | — | 28 | — | μA/MHz |
| | | 38.4 MHz crystal, CPU running while loop from flash | — | 26 | — | μA/MHz |
| | | 38.4 MHz crystal, CPU running CoreMark loop from flash | — | 38 | — | μA/MHz |
| | | 38 MHz HFRCO, CPU running while loop from flash | — | 22 | — | μA/MHz |
| | | 26 MHz HFRCO, CPU running while loop from flash | — | 24 | — | μA/MHz |
| | | 16 MHz HFRCO, CPU running while loop from flash | — | 27 | — | μA/MHz |
| | | 1 MHz HFRCO, CPU running while loop from flash | — | 159 | — | μA/MHz |
| Current consumption in EM1 mode with all peripherals disabled | I _{EM1} | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, VSCALE2 | — | 17 | — | μA/MHz |
| | | 38.4 MHz crystal | — | 17 | — | μA/MHz |
| | | 38 MHz HFRCO | — | 13 | — | μA/MHz |
| | | 26 MHz HFRCO | — | 15 | — | μA/MHz |
| | | 16 MHz HFRCO | — | 18 | — | μA/MHz |
| | | 1 MHz HFRCO | — | 150 | — | μA/MHz |

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|----------------------|--|-----|------|-----|------|
| Current consumption in EM2 mode, VSCALE0 | I _{EM2_VS} | Full RAM retention and RTC running from LFXO | — | 1.40 | — | μA |
| | | Full RAM retention and RTC running from LFRCO | — | 1.40 | — | μA |
| | | Full RAM retention and RTC running from LFRCO in precision mode | — | 1.75 | — | μA |
| | | 24 kB RAM retention and RTC running from LFXO | — | 1.32 | — | μA |
| | | 24 kB RAM retention and RTC running from LFRCO in precision mode | — | 1.66 | — | μA |
| | | 8 kB RAM retention and RTC running from LFXO | — | 1.21 | — | μA |
| | | 8 kB RAM retention and RTC running from LFRCO | — | 1.20 | — | μA |
| | | 8 kB RAM retention and RTC running from LFXO, Radio RAM and CPU cache not retained | — | 1.03 | — | μA |
| Current consumption in EM3 mode, VSCALE0 | I _{EM3_VS} | 8 kB RAM retention and RTC running from ULFRCO | — | 1.05 | — | μA |
| Additional current in EM2 or EM3 when any peripheral in PD0B is enabled ¹ | I _{PD0B_VS} | | — | 0.37 | — | μA |
| Note: 1. Extra current consumed by power domain. Does not include current associated with the enabled peripherals. See for a list of the peripherals in each power domain. | | | | | | |

4.6.2 MCU current consumption at 3.0 V

Unless otherwise indicated, typical conditions are: AVDD = DVDD = RFVDD = PAVDD = VREGVDD = 3.0 V. DC-DC not used. Voltage scaling level = VSCALE1. T_A = 25 °C. Minimum and maximum values in this table represent the worst conditions across process variation at T_A = 25 °C.

Table 4.6. MCU current consumption at 3.0 V

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---------------------|--|-----|-----|-----|--------|
| Current consumption in EM0 mode with all peripherals disabled | I _{ACTIVE} | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, CPU running Prime from flash, VSCALE2 | — | 42 | — | μA/MHz |
| | | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, CPU running while loop from flash, VSCALE2 | — | 39 | — | μA/MHz |
| | | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, CPU running CoreMark loop from flash, VSCALE2 | — | 54 | — | μA/MHz |
| | | 38.4 MHz crystal, CPU running Prime from flash | — | 40 | — | μA/MHz |
| | | 38.4 MHz crystal, CPU running while loop from flash | — | 39 | — | μA/MHz |
| | | 38.4 MHz crystal, CPU running CoreMark loop from flash | — | 55 | — | μA/MHz |
| | | 38 MHz HFRCO, CPU running while loop from flash | — | 33 | TBD | μA/MHz |
| | | 26 MHz HFRCO, CPU running while loop from flash | — | 35 | — | μA/MHz |
| | | 16 MHz HFRCO, CPU running while loop from flash | — | 40 | — | μA/MHz |
| | | 1 MHz HFRCO, CPU running while loop from flash | — | 228 | TBD | μA/MHz |
| Current consumption in EM1 mode with all peripherals disabled | I _{EM1} | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, VSCALE2 | — | 24 | — | μA/MHz |
| | | 38.4 MHz crystal | — | 25 | — | μA/MHz |
| | | 38 MHz HFRCO | — | 19 | TBD | μA/MHz |
| | | 26 MHz HFRCO | — | 21 | — | μA/MHz |
| | | 16 MHz HFRCO | — | 27 | — | μA/MHz |
| | | 1 MHz HFRCO | — | 215 | TBD | μA/MHz |

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|----------------------|--|-----|------|-----|------|
| Current consumption in EM2 mode, VSCALE0 | I _{EM2_VS} | Full RAM retention and RTC running from LFXO | — | 1.94 | — | μA |
| | | Full RAM retention and RTC running from LFRCO | — | 1.95 | — | μA |
| | | 24 kB RAM retention and RTC running from LFXO | — | 1.81 | — | μA |
| | | 24 kB RAM retention and RTC running from LFRCO in precision mode | — | 2.34 | — | μA |
| | | 8 kB RAM retention and RTC running from LFXO | — | 1.64 | — | μA |
| | | 8 kB RAM retention and RTC running from LFRCO | — | 1.65 | TBD | μA |
| | | 8 kB RAM retention and RTC running from LFXO, Radio RAM and CPU cache not retained | — | 1.39 | — | μA |
| Current consumption in EM3 mode, VSCALE0 | I _{EM3_VS} | 8 kB RAM retention and RTC running from ULFRCO | — | 1.41 | TBD | μA |
| Current consumption in EM4 mode | I _{EM4} | No BURTC, no LF oscillator | — | 0.17 | TBD | μA |
| | | BURTC with LFXO | — | 0.50 | — | μA |
| Current consumption during reset | I _{RST} | Hard pin reset held | — | 234 | — | μA |
| Additional current in EM2 or EM3 when any peripheral in PD0B is enabled ¹ | I _{PD0B_VS} | | — | 0.56 | — | μA |

Note:

1. Extra current consumed by power domain. Does not include current associated with the enabled peripherals. See for a list of the peripherals in each power domain.

4.6.3 MCU current consumption at 1.8 V

Unless otherwise indicated, typical conditions are: AVDD = DVDD = RFVDD = PAVDD = VREGVDD = 1.8 V. DC-DC not used. Voltage scaling level = VSCALE1. T_A = 25 °C. Minimum and maximum values in this table represent the worst conditions across process variation at T_A = 25 °C.

Table 4.7. MCU current consumption at 1.8 V

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---------------------|--|-----|-----|-----|--------|
| Current consumption in EM0 mode with all peripherals disabled | I _{ACTIVE} | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, CPU running Prime from flash, VSCALE2 | — | 42 | — | μA/MHz |
| | | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, CPU running while loop from flash, VSCALE2 | — | 39 | — | μA/MHz |
| | | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, CPU running CoreMark loop from flash, VSCALE2 | — | 54 | — | μA/MHz |
| | | 38.4 MHz crystal, CPU running Prime from flash | — | 41 | — | μA/MHz |
| | | 38.4 MHz crystal, CPU running while loop from flash | — | 39 | — | μA/MHz |
| | | 38.4 MHz crystal, CPU running CoreMark loop from flash | — | 55 | — | μA/MHz |
| | | 38 MHz HFRCO, CPU running while loop from flash | — | 33 | — | μA/MHz |
| | | 26 MHz HFRCO, CPU running while loop from flash | — | 35 | — | μA/MHz |
| | | 16 MHz HFRCO, CPU running while loop from flash | — | 40 | — | μA/MHz |
| | | 1 MHz HFRCO, CPU running while loop from flash | — | 227 | — | μA/MHz |
| Current consumption in EM1 mode with all peripherals disabled | I _{EM1} | 76.8 MHz HFRCO w/ DPLL referenced to 38.4 MHz crystal, VSCALE2 | — | 24 | — | μA/MHz |
| | | 38.4 MHz crystal | — | 25 | — | μA/MHz |
| | | 38 MHz HFRCO | — | 19 | — | μA/MHz |
| | | 26 MHz HFRCO | — | 21 | — | μA/MHz |
| | | 16 MHz HFRCO | — | 27 | — | μA/MHz |
| | | 1 MHz HFRCO | — | 213 | — | μA/MHz |

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|----------------------|--|-----|------|-----|------|
| Current consumption in EM2 mode, VSCALE0 | I _{EM2_VS} | Full RAM retention and RTC running from LFXO | — | 1.87 | — | μA |
| | | Full RAM retention and RTC running from LFRCO | — | 1.86 | — | μA |
| | | 24 kB RAM retention and RTC running from LFXO | — | 1.73 | — | μA |
| | | 24 kB RAM retention and RTC running from LFRCO in precision mode | — | 2.26 | — | μA |
| | | 8 kB RAM retention and RTC running from LFXO | — | 1.57 | — | μA |
| | | 8 kB RAM retention and RTC running from LFRCO | — | 1.56 | — | μA |
| | | 8 kB RAM retention and RTC running from LFXO, Radio RAM and CPU cache not retained | — | 1.32 | — | μA |
| Current consumption in EM3 mode, VSCALE0 | I _{EM3_VS} | 8 kB RAM retention and RTC running from ULFRCO | — | 1.34 | — | μA |
| Current consumption in EM4 mode | I _{EM4} | No BURTC, no LF oscillator | — | 0.13 | — | μA |
| | | BURTC with LFXO | — | 0.44 | — | μA |
| Current consumption during reset | I _{RST} | Hard pin reset held | — | 190 | — | μA |
| Additional current in EM2 or EM3 when any peripheral in PD0B is enabled ¹ | I _{PD0B_VS} | | — | 0.54 | — | μA |

Note:

1. Extra current consumed by power domain. Does not include current associated with the enabled peripherals. See for a list of the peripherals in each power domain.

4.6.4 Radio current consumption at 3.0V using DCDC

RF current consumption measured with MCU in EM1, HCLK = 38.4 MHz, and all MCU peripherals disabled. Unless otherwise indicated, typical conditions are: VREGVDD = 3.0V. AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8 V powered from DCDC. T_A = 25 °C. Minimum and maximum values in this table represent the worst conditions across process variation at T_A = 25 °C.

Table 4.8. Radio current consumption at 3.0V using DCDC

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|------------------------|--|-----|-----|-----|------|
| System current consumption in receive mode, active packet reception | I _{RX_ACTIVE} | 125 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE1, EM1P (Radio clocks only) | — | 3.7 | — | mA |
| | | 125 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE1 | — | 4.0 | — | mA |
| | | 125 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE2 | — | 4.1 | — | mA |
| | | 500 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE1, EM1P (Radio clocks only) | — | 3.8 | — | mA |
| | | 500 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE1 | — | 4.0 | — | mA |
| | | 500 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE2 | — | 4.2 | — | mA |
| | | 1 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE1, EM1P (Radio clocks only) ¹ | — | 3.6 | — | mA |
| | | 1 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE1 ¹ | — | 3.8 | — | mA |
| | | 1 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE2 ¹ | — | 3.9 | — | mA |
| | | 2 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE1, EM1P (Radio clocks only) | — | 4.0 | — | mA |
| | | 2 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE1 | — | 4.2 | — | mA |
| | | 2 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE2 | — | 4.4 | — | mA |

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|------------------------|--|-----|-----|-----|------|
| System current consumption in receive mode, listening for packet | I _{RX_LISTEN} | 125 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE1, EM1P (Radio clocks only) | — | 3.8 | — | mA |
| | | 125 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE1 | — | 4.0 | — | mA |
| | | 125 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE2 | — | 4.1 | — | mA |
| | | 500 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE1, EM1P (Radio clocks only) | — | 3.8 | — | mA |
| | | 500 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE1 | — | 4.0 | — | mA |
| | | 500 kbit/s, 2GFSK, f = 2.4 GHz, VSCALE2 | — | 4.1 | — | mA |
| | | 1 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE1, EM1P (Radio clocks only) ¹ | — | 3.6 | — | mA |
| | | 1 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE1 ¹ | — | 3.8 | — | mA |
| | | 1 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE2 ¹ | — | 4.0 | — | mA |
| | | 2 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE1, EM1P (Radio clocks only) | — | 4.1 | — | mA |
| | | 2 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE1 | — | 4.3 | — | mA |
| | | 2 Mbit/s, 2GFSK, f = 2.4 GHz, VSCALE2 | — | 4.5 | — | mA |
| System current consumption in transmit mode | I _{TX} | f = 2.4 GHz, CW, 0 dBm PA, 0 dBm output power, VSCALE1, EM1P (Radio clocks only) | — | 4.1 | — | mA |
| | | f = 2.4 GHz, CW, 6 dBm PA, 6 dBm output power, VSCALE1, EM1P (Radio clocks only) | — | 8.2 | — | mA |
| | | f = 2.4 GHz, CW, 0 dBm PA, 0 dBm output power, VSCALE1 | — | 4.3 | — | mA |
| | | f = 2.4 GHz, CW, 6 dBm PA, 6 dBm output power, VSCALE1 | — | 8.4 | — | mA |
| | | f = 2.4 GHz, CW, 0 dBm PA, 0 dBm output power, VSCALE2 | — | 4.4 | — | mA |
| | | f = 2.4 GHz, CW, 6 dBm PA, 6 dBm output power, VSCALE2 | — | 8.5 | — | mA |
| Note: | | | | | | |
| 1. Direction-finding phy adds approximately 150 µA to the receive current. | | | | | | |

4.7 Flash Characteristics

Table 4.9. Flash Characteristics

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|---------------|--------------------------------------|--------|------|------|--------|
| Flash Supply voltage during write or erase | V_{FLASH} | | 1.71 | — | 3.8 | V |
| Flash erase cycles before failure ¹ | EC_{FLASH} | $T_A \leq 125\text{ }^\circ\text{C}$ | 10,000 | — | — | cycles |
| Flash data retention ¹ | RET_{FLASH} | $T_A \leq 125\text{ }^\circ\text{C}$ | 10 | — | — | years |
| Program Time | t_{PROG} | one word (32-bits) | 42.1 | 44 | 45.6 | uSec |
| | | average per word over 128 words | 10.3 | 10.9 | 11.3 | uSec |
| Page Erase Time | t_{PERASE} | | 11.4 | 12.9 | 14.4 | ms |
| Mass Erase Time | t_{MERASE} | Erases all of User Code area | 11.7 | 13 | 14.3 | ms |
| Program Current | I_{PROG} | | — | — | 1.45 | mA |
| Page Erase Current | I_{PERASE} | Page Erase | — | — | 1.34 | mA |
| Mass Erase Current | I_{MERASE} | Mass Erase | — | — | 1.28 | mA |

Note:

1. Flash data retention information is published in the Quarterly Quality and Reliability Report.

4.8 Wake Up, Entry, and Exit times

Unless otherwise specified, these times are measured using the HFRCO at 19 MHz.

Table 4.10. Wake Up, Entry, and Exit times

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|----------------|---|-----|-------|-----|---------------|
| WakeupTime from EM1 | t_{EM1_WU} | Code execution from flash | — | 3 | — | AHB Clocks |
| | | Code execution from RAM | — | 1.42 | — | μs |
| WakeupTime from EM2 | t_{EM2_WU} | Code execution from flash, No Voltage Scaling | — | 13.22 | — | μs |
| | | Code execution from RAM, No Voltage Scaling | — | 5.15 | — | μs |
| | | Voltage scaling up one level ¹ | — | 37.89 | — | μs |
| | | Voltage scaling up two levels ² | — | 50.56 | — | μs |
| WakeupTime from EM3 | t_{EM3_WU} | Code execution from flash, No Voltage Scaling | — | 13.21 | — | μs |
| | | Code execution from RAM, No Voltage Scaling | — | 5.15 | — | μs |
| | | Voltage scaling up one level ¹ | — | 37.90 | — | μs |
| | | Voltage scaling up two levels ² | — | 50.55 | — | μs |
| WakeupTime from EM4 | t_{EM4_WU} | Code execution from flash | — | 8.81 | — | ms |
| Entry time to EM1 | t_{EM1_ENT} | Code execution from flash | — | 1.29 | — | μs |
| Entry time to EM2 | t_{EM2_ENT} | Code execution from flash | — | 5.23 | — | μs |
| Entry time to EM3 | t_{EM3_ENT} | Code execution from flash | — | 5.23 | — | μs |
| Entry time to EM4 | t_{EM4_ENT} | Code execution from flash | — | 9.96 | — | μs |
| Voltage scaling in time in EM0 ³ | t_{SCALE} | Up from VSCALE1 to VSCALE2 | — | 32 | — | μs |
| | | Down from VSCALE2 to VSCALE1 | — | 172 | — | μs |

Note:

1. Voltage scaling one level is between VSCALE0 and VSCALE1 or between VSCALE1 and VSCALE2.
2. Voltage scaling two levels is between VSCALE0 and VSCALE2.
3. During voltage scaling in EM0, RAM is inaccessible and processor will be halted until complete.

4.9 RFSENSE Low-energy Wake-on-RF

Table 4.11. RFSENSE Low-energy Wake-on-RF

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|-------------------------|--|-----|-----|-----|------|
| Average current | I _{RFSENSE} | RF energy below wake threshold | — | 138 | — | nA |
| | | Selective mode, RF energy above threshold but no OOK sync detected | — | 131 | — | nA |
| RF level above which RFSENSE will detect signal ¹ | THRES _{TRIG} | Threshold set to -34 dBm | -28 | — | — | dBm |
| | | Threshold set to -22 dBm | -19 | — | — | dBm |
| RF level below which RFSENSE will not detect signal ¹ | THRES _{NOTRIG} | Threshold set to -34 dBm | — | — | -40 | dBm |
| | | Threshold set to -22 dBm | — | — | -26 | dBm |
| Sensitivity in selective OOK mode ¹ | SENS _{OOK} | Sensitivity for > 90% probability of OOK detection ² , threshold set to -34 dBm | -28 | — | — | dBm |
| | | Sensitivity for > 90% probability of OOK detection ² , threshold set to -22 dBm | -19 | — | — | dBm |

Note:

1. Values collected with conducted measurements performed at the end of the matching network.
2. Selective wake signal is 1 kHz OOK Manchester-coded, 8 bits of preamble, 32-bit sync word.

4.10 2.4 GHz RF Transceiver Characteristics

4.10.1 RF Transmitter Characteristics

4.10.1.1 RF Transmitter General Characteristics for the 2.4 GHz Band

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, $V_{REGVDD} = 3.0\text{V}$, $AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8\text{ V}$ powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz.

Table 4.12. RF Transmitter General Characteristics for the 2.4 GHz Band

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|----------------------|--|------|------|--------|------|
| RF tuning frequency range | F_{RANGE} | | 2400 | — | 2483.5 | MHz |
| Radio-only current consumption while transmitting ¹ | I_{TX_RADIO} | f = 2.4 GHz, CW, 0 dBm PA, 0 dBm output power | — | 3.4 | — | mA |
| | | f = 2.4 GHz, CW, 6 dBm PA, 6 dBm output power | — | 7.5 | — | mA |
| Maximum TX power ² | $POUT_{MAX}$ | 6 dBm PA ³ | — | 6 | — | dBm |
| | | 0 dBm PA | — | 0 | — | dBm |
| Minimum active TX power | $POUT_{MIN}$ | 6 dBm PA | — | -27 | — | dBm |
| | | 0 dBm PA | — | -28 | — | dBm |
| Output power variation vs supply voltage variation, frequency = 2450 MHz | $POUT_{VAR_V}$ | 6 dBm PA output power, using DCDC with VREGVDD swept from 1.8 to 3.0 V | — | 0.04 | — | dB |
| | | 0 dBm PA output power, using DCDC with VREGVDD swept from 1.8 to 3.0 V | — | 0.03 | — | dB |
| Output power variation vs temperature, Frequency = 2450 MHz | $POUT_{VAR_T}$ | 6 dBm PA at 6 dBm, (-40 to +125 °C) | — | 0.18 | — | dB |
| | | 0 dBm PA at 0 dBm, (-40 to +125 °C) | — | 1.4 | — | dB |
| | | 6 dBm PA at 6 dBm, (-40 to +85 °C) | — | 0.17 | — | dB |
| | | 0 dBm PA at 0 dBm, (-40 to +85 °C) | — | 1.0 | — | dB |
| Output power variation vs RF frequency | $POUT_{VAR_F}$ | 6 dBm PA, 6 dBm | — | 0.20 | — | dB |
| | | 0 dBm PA, 0 dBm | — | 0.19 | — | dB |
| Spurious emissions of harmonics in restricted bands per FCC Part 15.205/15.209 | $SPUR_{HRM_FCC_R}$ | Continuous transmission of CW carrier, $P_{out} = POUT_{MAX}$, Test Frequency = 2450 MHz. | — | -47 | — | dBm |

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|----------------------------|--|-----|-----|-----|------|
| Spurious emissions out-of-band (above 2.483 GHz or below 2.4 GHz) in restricted bands, per FCC part 15.205/15.209 | SPUR _{OOB_FCC_R} | Restricted bands 30-88 MHz, Continuous transmission of CW carrier, P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -47 | — | dBm |
| | | Restricted bands 88 - 216 MHz, Continuous transmission of CW carrier, P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -47 | — | dBm |
| | | Restricted bands 216 - 960 MHz, Continuous transmission of CW carrier, P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -47 | — | dBm |
| | | Restricted bands > 960 MHz, Continuous transmission of CW carrier, P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -47 | — | dBm |
| Spurious emissions out-of-band in non-restricted bands per FCC Part 15.247 | SPUR _{OOB_FCC_NR} | Frequencies above 2.483 GHz or below 2.4 GHz, continuous transmission CW carrier, P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -26 | — | dBc |
| Spurious emissions per ETSI EN300.440 | SPUR _{ETSI440} | 47-74 MHz, 87.5-108 MHz, 174-230 MHz, 470-862 MHz, P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -60 | — | dBm |
| | | 25-1000 MHz, excluding above frequencies. P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -42 | — | dBm |
| | | 1G-14G, P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -36 | — | dBm |
| Spurious emissions out-of-band, per ETSI 300.328 | SPUR _{ETSI328} | [2400-2BW to 2400-BW], [2483.5+BW to 2483.5+2BW], P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -26 | — | dBm |
| | | 47-74 MHz, 87.5-118 MHz, 174-230 MHz, 470-862 MHz, P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -60 | — | dBm |
| | | 30-47 MHz, 74-87.5 MHz, 118-174 MHz, 230-470 MHz, 862-1000 MHz, P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -42 | — | dBm |
| | | 1G-12.75 GHz, excluding bands listed above, P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -36 | — | dBm |
| | | [2400-BW to 2400], [2483.5 to 2483.5+BW] P _{out} = POUT _{MAX} , Test Frequency = 2450 MHz | — | -16 | — | dBm |

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|-----------|--------|----------------|-----|-----|-----|------|
|-----------|--------|----------------|-----|-----|-----|------|

Note:

1. Supply current to radio, supplied by DC-DC with 3.0 V, measured at VREGVDD.
2. Supported transmit power levels are determined by the ordering part number (OPN). Transmit power ratings for all devices covered in this data sheet can be found in the Max TX Power column of the Ordering Information Table.
3. The PA is capable of delivering higher than 6 dBm output power (see [Figure 4.9 Transmitter Output Power on page 71](#)). However, all transmitter characteristics and recommended application circuits are specified at 6 dBm output. If used with the recommended application circuits above 6 dBm, harmonics may be higher than regulatory limits.

4.10.1.2 RF Transmitter Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 1 Mbps Data Rate

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, VREGVDD = 3.0V, AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8 V powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz.

Table 4.13. RF Transmitter Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 1 Mbps Data Rate

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|------------------------|--|-----|------|-----|----------|
| Transmit 6 dB bandwidth | TXBW | $P_{out} = 6\text{ dBm}$ | — | 630 | — | kHz |
| | | $P_{out} = 0\text{ dBm}$ | — | 640 | — | kHz |
| Power spectral density limit | PSD _{LIMIT} | $P_{out} = 6\text{ dBm}$, Per FCC part 15.247 at 6 dBm | — | 2.9 | — | dBm/3kHz |
| | | $P_{out} = 0\text{ dBm}$, Per FCC part 15.247 at 0 dBm | — | -3.2 | — | dBm/3kHz |
| | | Per ETSI 300.328 at 10 dBm/1 MHz | — | 7.1 | — | dBm |
| Occupied channel bandwidth per ETSI EN300.328 | OCP _{ETSI328} | $P_{out} = 6\text{ dBm}$ 99% BW at highest and lowest channels in band | — | 1.1 | — | MHz |
| | | $P_{out} = 0\text{ dBm}$ 99% BW at highest and lowest channels in band | — | 1.1 | — | MHz |
| In-band spurious emissions, with allowed exceptions ¹ | SPUR _{INB} | $P_{out} = 6\text{ dbm}$, Inband spurs at $\pm 2\text{ MHz}$ | — | -41 | — | dBm |
| | | $P_{out} = 0\text{ dbm}$, Inband spurs at $\pm 2\text{ MHz}$ | — | -48 | — | dBm |
| | | $P_{out} = 6\text{ dBm}$ Inband spurs at $\pm 3\text{ MHz}$ | — | -47 | — | dBm |
| | | $P_{out} = 0\text{dbm}$ Inband spurs at $\pm 3\text{ MHz}$ | — | -54 | — | dBm |

Note:

1. Per Bluetooth Core_5.1, Vol.6 Part A, Section 3.2.2, exceptions are allowed in up to three bands of 1 MHz width, centered on a frequency which is an integer multiple of 1 MHz. These exceptions shall have an absolute value of -20 dBm or less.

4.10.1.3 RF Transmitter Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 2 Mbps Data Rate

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, $V_{REGVDD} = 3.0\text{V}$, $AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8\text{ V}$ powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz.

Table 4.14. RF Transmitter Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 2 Mbps Data Rate

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|------------------------|--|-----|------|-----|----------|
| Transmit 6 dB bandwidth | TXBW | $P_{out} = 6\text{ dBm}$ | — | 1250 | — | kHz |
| | | $P_{out} = 0\text{ dBm}$ | — | 1220 | — | kHz |
| Power spectral density limit | PSD _{LIMIT} | $P_{out} = 6\text{ dBm}$, Per FCC part 15.247 at 6 dBm | — | 0.5 | — | dBm/3kHz |
| | | $P_{out} = 0\text{ dBm}$, Per FCC part 15.247 at 0 dBm | — | -5.7 | — | dBm/3kHz |
| | | Per ETSI 300.328 at 10 dBm/1 MHz | — | 6.3 | — | dBm |
| Occupied channel bandwidth per ETSI EN300.328 | OCP _{ETSI328} | $P_{out} = 6\text{ dBm}$ 99% BW at highest and lowest channels in band | — | 2.1 | — | MHz |
| | | $P_{out} = 0\text{ dBm}$ 99% BW at highest and lowest channels in band | — | 2.1 | — | MHz |
| In-band spurious emissions, with allowed exceptions ¹ | SPUR _{INB} | $P_{out} = 6\text{ dBm}$, Inband spurs at $\pm 4\text{ MHz}$ | — | -41 | — | dBm |
| | | $P_{out} = 0\text{ dBm}$, Inband spurs at $\pm 4\text{ MHz}$ | — | -47 | — | dBm |
| | | $P_{out} = 6\text{ dBm}$ Inband spurs at $\pm 6\text{ MHz}$ | — | -46 | — | dBm |
| | | $P_{out} = 0\text{ dBm}$ Inband spurs at $\pm 6\text{ MHz}$ | — | -53 | — | dBm |

Note:

1. Per Bluetooth Core_5.1, Vol.6 Part A, Section 3.2.2, exceptions are allowed in up to three bands of 1 MHz width, centered on a frequency which is an integer multiple of 1 MHz. These exceptions shall have an absolute value of -20 dBm or less.

4.10.1.4 RF Transmitter Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 500 kbps Data Rate

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, $V_{REGVDD} = 3.0\text{V}$, $AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8\text{ V}$ powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz.

Table 4.15. RF Transmitter Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 500 kbps Data Rate

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|------------------------|--|-----|------|-----|----------|
| Transmit 6 dB bandwidth | TXBW | $P_{out} = 6\text{ dBm}$ | — | 640 | — | kHz |
| | | $P_{out} = 0\text{ dBm}$ | — | 650 | — | kHz |
| Power spectral density limit | PSD _{LIMIT} | $P_{out} = 6\text{ dBm}$, Per FCC part 15.247 at 6 dBm | — | 2.8 | — | dBm/3kHz |
| | | $P_{out} = 0\text{ dBm}$, Per FCC part 15.247 at 0 dBm | — | -3.5 | — | dBm/3kHz |
| | | Per ETSI 300.328 at 10 dBm/1 MHz | — | 7.1 | — | dBm |
| Occupied channel bandwidth per ETSI EN300.328 | OCP _{ETSI328} | $P_{out} = 6\text{ dBm}$ 99% BW at highest and lowest channels in band | — | 1.1 | — | MHz |
| | | $P_{out} = 0\text{ dBm}$ 99% BW at highest and lowest channels in band | — | 1.1 | — | MHz |
| In-band spurious emissions, with allowed exceptions ¹ | SPUR _{INB} | $P_{out} = 6\text{ dbm}$, Inband spurs at $\pm 2\text{ MHz}$ | — | -41 | — | dBm |
| | | $P_{out} = 0\text{ dbm}$, Inband spurs at $\pm 2\text{ MHz}$ | — | -48 | — | dBm |
| | | $P_{out} = 6\text{ dBm}$ Inband spurs at $\pm 3\text{ MHz}$ | — | -47 | — | dBm |
| | | $P_{out} = 0\text{dbm}$ Inband spurs at $\pm 3\text{ MHz}$ | — | -54 | — | dBm |

Note:

1. Per Bluetooth Core_5.1, Vol.6 Part A, Section 3.2.2, exceptions are allowed in up to three bands of 1 MHz width, centered on a frequency which is an integer multiple of 1 MHz. These exceptions shall have an absolute value of -20 dBm or less.

4.10.1.5 RF Transmitter Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 125 kbps Data Rate

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, $V_{REGVDD} = 3.0\text{V}$, $AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8\text{ V}$ powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz.

Table 4.16. RF Transmitter Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 125 kbps Data Rate

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|------------------------|--|-----|------|-----|----------|
| Transmit 6 dB bandwidth | TXBW | $P_{out} = 6\text{ dBm}$ | — | 600 | — | kHz |
| | | $P_{out} = 0\text{ dBm}$ | — | 600 | — | kHz |
| Power spectral density limit | PSD _{LIMIT} | $P_{out} = 6\text{ dBm}$, Per FCC part 15.247 at 6 dBm | — | 2.0 | — | dBm/3kHz |
| | | $P_{out} = 0\text{ dBm}$, Per FCC part 15.247 at 0 dBm | — | -4.2 | — | dBm/3kHz |
| | | Per ETSI 300.328 at 10 dBm/1 MHz | — | 7.1 | — | dBm |
| Occupied channel bandwidth per ETSI EN300.328 | OCP _{ETSI328} | $P_{out} = 6\text{ dBm}$ 99% BW at highest and lowest channels in band | — | 1.1 | — | MHz |
| | | $P_{out} = 0\text{ dBm}$ 99% BW at highest and lowest channels in band | — | 1.1 | — | MHz |
| In-band spurious emissions, with allowed exceptions ¹ | SPUR _{INB} | $P_{out} = 6\text{ dbm}$, Inband spurs at $\pm 2\text{ MHz}$ | — | -41 | — | dBm |
| | | $P_{out} = 0\text{ dbm}$, Inband spurs at $\pm 2\text{ MHz}$ | — | -47 | — | dBm |
| | | $P_{out} = 6\text{ dBm}$ Inband spurs at $\pm 3\text{ MHz}$ | — | -47 | — | dBm |
| | | $P_{out} = 0\text{dbm}$ Inband spurs at $\pm 3\text{ MHz}$ | — | -54 | — | dBm |

Note:

1. Per Bluetooth Core_5.1, Vol.6 Part A, Section 3.2.2, exceptions are allowed in up to three bands of 1 MHz width, centered on a frequency which is an integer multiple of 1 MHz. These exceptions shall have an absolute value of -20 dBm or less.

4.10.1.6 RF Transmitter Characteristics for 802.15.4 DSSS-OQPSK in the 2.4 GHz Band

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, $V_{REGVDD} = 3.0\text{V}$, $AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8\text{ V}$ powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz.

Table 4.17. RF Transmitter Characteristics for 802.15.4 DSSS-OQPSK in the 2.4 GHz Band

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|------------------------|---|-----|-------|-----|------------|
| Error vector magnitude per 802.15.4-2011 | EVM | Average across frequency, signal is DSSS-OQPSK reference packet, $P_{out} = 6\text{ dBm}$ | — | 3.0 | — | % rms |
| | | Average across frequency, signal is DSSS-OQPSK reference packet, $P_{out} = 0\text{ dBm}$ | — | 3.0 | — | % rms |
| Power spectral density limit | PSD _{LIMIT} | Relative, at carrier $\pm 3.5\text{ MHz}$, $P_{out} = 6\text{ dBm}$ | — | -50.7 | — | dBc/100kHz |
| | | Relative, at carrier $\pm 3.5\text{ MHz}$, $P_{out} = 0\text{ dBm}$ | — | -50.8 | — | dBc/100kHz |
| | | Absolute, at carrier $\pm 3.5\text{ MHz}$, $P_{out} = 6\text{ dBm}$ | — | -52.5 | — | dBm/100kHz |
| | | Absolute, at carrier $\pm 3.5\text{ MHz}$, $P_{out} = 0\text{ dBm}$ | — | -58.3 | — | dBm/100kHz |
| | | Per FCC part 15.247, $P_{out} = 6\text{ dBm}$ | — | -1.4 | — | dBm/3kHz |
| | | Per FCC part 15.247, $P_{out} = 0\text{ dBm}$ | — | -7.4 | — | dBm/3kHz |
| | | ETSI 300.328 $P_{out} = 6\text{ dBm}$ | — | 5.6 | — | dBm |
| | | ETSI 300.328 $P_{out} = 0\text{ dBm}$ | — | -1.0 | — | dBm |
| Occupied channel bandwidth per ETSI EN300.328 | OCP _{ETSI328} | 99% BW at highest and lowest channels in band, $P_{out} = 6\text{ dBm}$ | — | 2.2 | — | MHz |
| | | 99% BW at highest and lowest channels in band, $P_{out} = 0\text{ dBm}$ | — | 2.2 | — | MHz |

4.10.2 RF Receiver Characteristics

4.10.2.1 RF Receiver General Characteristics for the 2.4 GHz Band

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, $V_{REGVDD} = 3.0\text{V}$, $AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8\text{ V}$ powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz.

Table 4.18. RF Receiver General Characteristics for the 2.4 GHz Band

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|------------------|---|------|------|--------|------|
| RF tuning frequency range | F_{RANGE} | | 2400 | — | 2483.5 | MHz |
| Radio-only current consumption in receive mode ¹ | I_{RX_RADIO} | | — | 2.5 | — | mA |
| Receive mode maximum spurious emission | $SPUR_{RX}$ | 30 MHz to 1 GHz | — | -63 | — | dBm |
| | | 1 GHz to 12 GHz | — | -53 | — | dBm |
| Max spurious emissions during active receive mode, per FCC Part 15.109(a) | $SPUR_{RX_FCC}$ | 216 MHz to 960 MHz, conducted measurement | — | -47 | — | dBm |
| | | Above 960 MHz, conducted measurement. | — | -47 | — | dBm |
| 2GFSK Sensitivity | $SENS_{2GFSK}$ | 2 Mbps 2GFSK signal, 1% PER | — | -93 | — | dBm |
| | | 250 kbps 2GFSK signal, 0.1% BER | — | -104 | — | dBm |

Note:

1. Supply current to radio, supplied by DC-DC with 3.0 V, measured at V_{REGVDD} .

4.10.2.2 RF Receiver Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 1 Mbps Data Rate

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, $V_{REGVDD} = 3.0\text{V}$, $AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8\text{ V}$ powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz, Packet length is 255 bytes.

Table 4.19. RF Receiver Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 1 Mbps Data Rate

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|---------------|--|-----|-------|-----|------|
| Max usable receiver input level | SAT | Signal is reference signal ¹ | — | 10 | — | dBm |
| Sensitivity | SENS | Signal is reference signal, 37 byte payload ¹ | — | -98.9 | — | dBm |
| | | Signal is reference signal, 255 byte payload ¹ | — | -97.4 | — | dBm |
| | | With non-ideal signals ^{2 1} | — | -96.9 | — | dBm |
| Signal to co-channel interferer | C/I_{CC} | (see notes) ^{1 3} | — | 8.7 | — | dB |
| $N \pm 1$ Adjacent channel selectivity | C/I_1 | Interferer is reference signal at +1 MHz offset ^{1 4 3 5} | — | -6.6 | — | dB |
| | | Interferer is reference signal at -1 MHz offset ^{1 4 3 5} | — | -6.5 | — | dB |
| $N \pm 2$ Alternate channel selectivity | C/I_2 | Interferer is reference signal at +2 MHz offset ^{1 4 3 5} | — | -40.9 | — | dB |
| | | Interferer is reference signal at -2 MHz offset ^{1 4 3 5} | — | -39.9 | — | dB |
| $N \pm 3$ Alternate channel selectivity | C/I_3 | Interferer is reference signal at +3 MHz offset ^{1 4 3 5} | — | -45.9 | — | dB |
| | | Interferer is reference signal at -3 MHz offset ^{1 4 3 5} | — | -46.2 | — | dB |
| Selectivity to image frequency | C/I_{IM} | Interferer is reference signal at image frequency with 1 MHz precision ^{1 5} | — | -23.5 | — | dB |
| Selectivity to image frequency ± 1 MHz | C/I_{IM_1} | Interferer is reference signal at image frequency +1 MHz with 1 MHz precision ^{1 5} | — | -40.9 | — | dB |
| | | Interferer is reference signal at image frequency -1 MHz with 1 MHz precision ^{1 5} | — | -6.6 | — | dB |
| Intermodulation performance | IM | $n = 3$ (see note ⁶) | — | -17.1 | — | dBm |

Note:

- 0.1% Bit Error Rate.
- With non-ideal signals as specified in Bluetooth Test Specification RF-PHY.TS.5.0.1 section 4.7.1
- Desired signal -67 dBm.
- Desired frequency $2402\text{ MHz} \leq F_c \leq 2480\text{ MHz}$.
- With allowed exceptions.
- As specified in Bluetooth Core specification version 5.1, Vol 6, Part A, Section 4.4

4.10.2.3 RF Receiver Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 2 Mbps Data Rate

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, $V_{REGVDD} = 3.0\text{V}$, $AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8\text{ V}$ powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz, Packet length is 255 bytes.

Table 4.20. RF Receiver Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 2 Mbps Data Rate

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|---------------|--|-----|-------|-----|------|
| Max usable receiver input level | SAT | Signal is reference signal ¹ | — | 10 | — | dBm |
| Sensitivity | SENS | Signal is reference signal, 37 byte payload ¹ | — | -96.2 | — | dBm |
| | | Signal is reference signal, 255 byte payload ¹ | — | -94.6 | — | dBm |
| | | With non-ideal signals ^{2 1} | — | -94.4 | — | dBm |
| Signal to co-channel interferer | C/I_{CC} | (see notes) ^{1 3} | — | 8.8 | — | dB |
| $N \pm 1$ Adjacent channel selectivity | C/I_1 | Interferer is reference signal at +2 MHz offset ^{1 4 3 5} | — | -9.2 | — | dB |
| | | Interferer is reference signal at -2 MHz offset ^{1 4 3 5} | — | -6.6 | — | dB |
| $N \pm 2$ Alternate channel selectivity | C/I_2 | Interferer is reference signal at +4 MHz offset ^{1 4 3 5} | — | -43.3 | — | dB |
| | | Interferer is reference signal at -4 MHz offset ^{1 4 3 5} | — | -44.0 | — | dB |
| $N \pm 3$ Alternate channel selectivity | C/I_3 | Interferer is reference signal at +6 MHz offset ^{1 4 3 5} | — | -48.6 | — | dB |
| | | Interferer is reference signal at -6 MHz offset ^{1 4 3 5} | — | -50.7 | — | dB |
| Selectivity to image frequency | C/I_{IM} | Interferer is reference signal at image frequency with 1 MHz precision ^{1 5} | — | -23.8 | — | dB |
| Selectivity to image frequency ± 2 MHz | C/I_{IM_1} | Interferer is reference signal at image frequency +2 MHz with 1 MHz precision ^{1 5} | — | -43.3 | — | dB |
| | | Interferer is reference signal at image frequency -2 MHz with 1 MHz precision ^{1 5} | — | -9.2 | — | dB |
| Intermodulation performance | IM | $n = 3$ (see note ⁶) | — | -18.8 | — | dBm |

Note:

- 0.1% Bit Error Rate.
- With non-ideal signals as specified in Bluetooth Test Specification RF-PHY.TS.5.0.1 section 4.7.1
- Desired signal -64 dBm.
- Desired frequency $2402\text{ MHz} \leq F_c \leq 2480\text{ MHz}$.
- With allowed exceptions.
- As specified in Bluetooth Core specification version 5.1, Vol 6, Part A, Section 4.4

4.10.2.4 RF Receiver Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 500 kbps Data Rate

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, $V_{REGVDD} = 3.0\text{V}$, $AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8\text{ V}$ powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz, Packet length is 255 bytes.

Table 4.21. RF Receiver Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 500 kbps Data Rate

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|---------------|--|-----|--------|-----|------|
| Max usable receiver input level | SAT | Signal is reference signal ¹ | — | 10 | — | dBm |
| Sensitivity | SENS | Signal is reference signal, 37 byte payload ¹ | — | -102.5 | — | dBm |
| | | Signal is reference signal, 255 byte payload ¹ | — | -101.2 | — | dBm |
| | | With non-ideal signals ^{2 1} | — | -100.2 | — | dBm |
| Signal to co-channel interferer | C/I_{CC} | (see notes) ^{1 3} | — | 2.7 | — | dB |
| $N \pm 1$ Adjacent channel selectivity | C/I_1 | Interferer is reference signal at +1 MHz offset ^{1 4 3 5} | — | -8.0 | — | dB |
| | | Interferer is reference signal at -1 MHz offset ^{1 4 3 5} | — | -7.9 | — | dB |
| $N \pm 2$ Alternate channel selectivity | C/I_2 | Interferer is reference signal at +2 MHz offset ^{1 4 3 5} | — | -46.5 | — | dB |
| | | Interferer is reference signal at -2 MHz offset ^{1 4 3 5} | — | -49.9 | — | dB |
| $N \pm 3$ Alternate channel selectivity | C/I_3 | Interferer is reference signal at +3 MHz offset ^{1 4 3 5} | — | -48.9 | — | dB |
| | | Interferer is reference signal at -3 MHz offset ^{1 4 3 5} | — | -53.8 | — | dB |
| Selectivity to image frequency | C/I_{IM} | Interferer is reference signal at image frequency with 1 MHz precision ^{1 5} | — | -48.3 | — | dB |
| Selectivity to image frequency ± 1 MHz | C/I_{IM_1} | Interferer is reference signal at image frequency +1 MHz with 1 MHz precision ^{1 5} | — | -49.9 | — | dB |
| | | Interferer is reference signal at image frequency -1 MHz with 1 MHz precision ^{1 5} | — | -46.5 | — | dB |

Note:

1. 0.1% Bit Error Rate.
2. With non-ideal signals as specified in Bluetooth Test Specification RF-PHY.TS.5.0.1 section 4.7.1
3. Desired signal -72 dBm.
4. Desired frequency $2402\text{ MHz} \leq F_c \leq 2480\text{ MHz}$.
5. With allowed exceptions.

4.10.2.5 RF Receiver Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 125 kbps Data Rate

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, $V_{REGVDD} = 3.0\text{V}$, $AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8\text{ V}$ powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz, Packet length is 255 bytes.

Table 4.22. RF Receiver Characteristics for Bluetooth Low Energy in the 2.4 GHz Band 125 kbps Data Rate

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|---------------|--|-----|--------|-----|------|
| Max usable receiver input level | SAT | Signal is reference signal ¹ | — | 10 | — | dBm |
| Sensitivity | SENS | Signal is reference signal, 37 byte payload ¹ | — | -106.7 | — | dBm |
| | | Signal is reference signal, 255 byte payload ¹ | — | -106.4 | — | dBm |
| | | With non-ideal signals ^{2 1} | — | -105.8 | — | dBm |
| Signal to co-channel interferer | C/I_{CC} | (see notes) ^{1 3} | — | 0.9 | — | dB |
| $N \pm 1$ Adjacent channel selectivity | C/I_1 | Interferer is reference signal at +1 MHz offset ^{1 4 3 5} | — | -13.6 | — | dB |
| | | Interferer is reference signal at -1 MHz offset ^{1 4 3 5} | — | -13.4 | — | dB |
| $N \pm 2$ Alternate channel selectivity | C/I_2 | Interferer is reference signal at +2 MHz offset ^{1 4 3 5} | — | -52.6 | — | dB |
| | | Interferer is reference signal at -2 MHz offset ^{1 4 3 5} | — | -55.8 | — | dB |
| $N \pm 3$ Alternate channel selectivity | C/I_3 | Interferer is reference signal at +3 MHz offset ^{1 4 3 5} | — | -53.7 | — | dB |
| | | Interferer is reference signal at -3 MHz offset ^{1 4 3 5} | — | -59.0 | — | dB |
| Selectivity to image frequency | C/I_{IM} | Interferer is reference signal at image frequency with 1 MHz precision ^{1 5} | — | -52.7 | — | dB |
| Selectivity to image frequency ± 1 MHz | C/I_{IM_1} | Interferer is reference signal at image frequency +1 MHz with 1 MHz precision ^{1 5} | — | -53.7 | — | dB |
| | | Interferer is reference signal at image frequency -1 MHz with 1 MHz precision ^{1 5} | — | -52.6 | — | dB |

Note:

1. 0.1% Bit Error Rate.
2. With non-ideal signals as specified in Bluetooth Test Specification RF-PHY.TS.5.0.1 section 4.7.1
3. Desired signal -79 dBm.
4. Desired frequency $2402\text{ MHz} \leq F_c \leq 2480\text{ MHz}$.
5. With allowed exceptions.

4.10.2.6 RF Receiver Characteristics for 802.15.4 DSSS-OQPSK in the 2.4 GHz Band

Unless otherwise indicated, typical conditions are: $T_A = 25\text{ }^\circ\text{C}$, $V_{REGVDD} = 3.0\text{V}$, $AVDD = DVDD = IOVDD = RFVDD = PAVDD = 1.8\text{V}$ powered from DCDC. Crystal frequency=38.4 MHz. RF center frequency 2.45 GHz.

Table 4.23. RF Receiver Characteristics for 802.15.4 DSSS-OQPSK in the 2.4 GHz Band

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---------------------|--|-----|--------|-----|------|
| Max usable receiver input level, 1% PER | SAT | Signal is reference signal ¹ . Packet length is 20 octets | — | 10 | — | dBm |
| Sensitivity, 1% PER | SENS | Signal is reference signal. Packet length is 20 octets | — | -102.3 | — | dBm |
| Co-channel interferer rejection, 1% PER | CCR | Desired signal 3 dB above sensitivity limit | — | -1.7 | — | dB |
| High-side adjacent channel rejection, 1% PER. Desired is reference signal at 3 dB above reference sensitivity level ² | ACR _{P1} | Interferer is reference signal at +1 channel-spacing | — | 34.9 | — | dB |
| Low-side adjacent channel rejection, 1% PER. Desired is reference signal at 3 dB above reference sensitivity level ² | ACR _{M1} | Interferer is reference signal at -1 channel-spacing | — | 34.8 | — | dB |
| Alternate channel rejection, 1% PER. Desired is reference signal at 3 dB above reference sensitivity level ² | ACR ₂ | Interferer is reference signal at ± 2 channel-spacing | — | 47.1 | — | dB |
| Image rejection , 1% PER. Desired is reference signal at 3 dB above reference sensitivity level ² | IR | Interferer is CW in image band ³ | — | 34.1 | — | dB |
| Blocking rejection of all other channels, 1% PER. Desired is reference signal at 3 dB above reference sensitivity level ² . Interferer is reference signal | BLOCK | Interferer frequency < Desired frequency - 3 channel-spacing | — | 53.2 | — | dB |
| | | Interferer frequency > Desired frequency + 3 channel-spacing | — | 53.1 | — | dB |
| RSSI resolution | RSSI _{RES} | -100 dBm to +5 dBm | — | 0.25 | — | dB |
| RSSI accuracy in the linear region as defined by 802.15.4-2003 | RSSI _{LIN} | | — | +/-6 | — | dB |

Note:

- Reference signal is defined as O-QPSK DSSS per 802.15.4, Frequency range = 2400-2483.5 MHz, Symbol rate = 62.5 ksymbols/s.
- Reference sensitivity level is -85 dBm.
- Due to low-IF frequency, there is some overlap of adjacent channel and image channel bands. Adjacent channel CW blocker tests place the Interferer center frequency at the Desired frequency ± 5 MHz on the channel raster, whereas the image rejection test places the CW interferer near the image frequency of the Desired signal carrier, regardless of the channel raster.

4.11 Oscillators

4.11.1 High Frequency Crystal Oscillator

Unless otherwise indicated, typical conditions are: AVDD = DVDD = 3.0 V. T_A = 25 °C. Minimum and maximum values in this table represent the worst conditions across process variation, operating supply voltage range, and operating temperature range.

Table 4.24. High Frequency Crystal Oscillator

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|--------------------------|-------------------------------------|-----|------|-----|------|
| Crystal Frequency | F _{HFXO} | see note ¹ | — | 38.4 | — | MHz |
| Supported crystal equivalent series resistance (ESR) | ESR _{HFXO_38M4} | 38.4 MHz, CL = 10 pF ^{2 3} | — | 40 | TBD | Ω |
| Supported range of crystal load capacitance ⁴ | C _{HFXO_LC} | 38.4 MHz, ESR = 40 Ohm ³ | — | 10 | — | pF |
| Supply Current | I _{HFXO} | | — | 415 | — | μA |
| Startup Time | T _{STARTUP} | 38.4 MHz, ESR = 40 Ohm, CL = 10 pF | — | 160 | — | μs |
| On-chip tuning cap step size ⁵ | SS _{HFXO} | | — | 0.04 | — | pF |

Note:

1. The BLE radio requires a 38.4 MHz crystal with a tolerance of ± 50 ppm over temperature and aging. Please use the recommended crystal.
2. The crystal should have a maximum ESR less than or equal to this maximum rating.
3. RF performance characteristics have been determined using crystals with an ESR of 40 Ω and CL of 10 pF.
4. Total load capacitance as seen by the crystal.
5. The tuning step size is the effective step size when incrementing one of the tuning capacitors by one count. The step size for the each of the individual tuning capacitors is twice this value.

4.11.2 Low Frequency Crystal Oscillator

Table 4.25. Low Frequency Crystal Oscillator

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|-----------------|---|------|--------|------|------------|
| Crystal Frequency | F_{LFXO} | | — | 32.768 | — | kHz |
| Supported Crystal equivalent series resistance (ESR) | ESR_{LFXO} | GAIN = 0 | — | — | 80 | k Ω |
| | | GAIN = 1 to 3 | — | — | 100 | k Ω |
| Supported range of crystal load capacitance ¹ | C_{LFXO_CL} | GAIN = 0 | 4 | — | 6 | pF |
| | | GAIN = 1 | 6 | — | 10 | pF |
| | | GAIN = 2 | 10 | — | 12.5 | pF |
| | | GAIN = 3 (see note ²) | 12.5 | — | 18 | pF |
| Current consumption | I_{CL12p5} | ESR = 70 k Ω , CL = 12.5 pF, GAIN ³ = 2, AGC ⁴ = 1 | — | 357 | — | nA |
| Startup Time | $T_{STARTUP}$ | ESR = 70 k Ω , CL = 7 pF, GAIN ³ = 1, AGC ⁴ = 1 | — | 63 | — | ms |
| On-chip tuning cap step size | SS_{LFXO} | | — | 0.26 | — | pF |
| On-chip tuning capacitor value at minimum setting ⁵ | C_{LFXO_MIN} | CAPTUNE = 0 | — | 4 | — | pF |
| On-chip tuning capacitor value at maximum setting ⁵ | C_{LFXO_MAX} | CAPTUNE = 0x4F | — | 24.5 | — | pF |

Note:

1. Total load capacitance seen by the crystal
2. Crystals with a load capacitance of greater than 12 pF require external load capacitors.
3. In LFXO_CAL Register
4. In LFXO_CFG Register
5. The effective load capacitance seen by the crystal will be $C_{LFXO}/2$. This is because each XTAL pin has a tuning cap and the two caps will be seen in series by the crystal

4.11.3 High Frequency RC Oscillator (HFRCO)

Unless otherwise indicated, typical conditions are: AVDD = DVDD = 3.0 V. T_A = 25 °C. Minimum and maximum values in this table represent the worst conditions across process variation, operating supply voltage range, and operating temperature range.

Table 4.26. High Frequency RC Oscillator (HFRCO)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|-------------------------------|--|-----|------|-----|--------|
| Frequency Accuracy | F _{HFRCO_ACC} | For all production calibrated frequencies | -3 | — | 3 | % |
| Current consumption on all supplies ¹ | I _{HFRCO} | F _{HFRCO} = 1 MHz | — | 28 | — | μA |
| | | F _{HFRCO} = 2 MHz | — | 28 | — | μA |
| | | F _{HFRCO} = 4 MHz | — | 28 | — | μA |
| | | F _{HFRCO} = 5 MHz | — | 30 | — | μA |
| | | F _{HFRCO} = 7 MHz | — | 60 | — | μA |
| | | F _{HFRCO} = 10 MHz | — | 66 | — | μA |
| | | F _{HFRCO} = 13 MHz | — | 79 | — | μA |
| | | F _{HFRCO} = 16 MHz | — | 88 | — | μA |
| | | F _{HFRCO} = 19 MHz | — | 92 | — | μA |
| | | F _{HFRCO} = 20 MHz | — | 105 | — | μA |
| | | F _{HFRCO} = 26 MHz | — | 118 | — | μA |
| | | F _{HFRCO} = 32 MHz | — | 141 | — | μA |
| | | F _{HFRCO} = 38 MHz | — | 172 | — | μA |
| Clock out current for HFRCODPLL ² | I _{CLKOUT_HFRCODPLL} | FORECEEN bit of CTRL = 1 and the CLKOUTDIS0 bit of TEST = 1. | — | 2.72 | — | μA/MHz |
| | | FORECEEN bit of CTRL = 1 and the CLKOUTDIS1 bit of TEST = 1. | — | 0.36 | — | μA/MHz |
| Startup Time ³ | T _{STARTUP} | FREQRANGE = 0 to 7 | — | 1.2 | — | μs |
| | | FREQRANGE = 8 to 15 | — | 0.6 | — | μs |

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|------------------------------------|-------------------------|----------------|------|-----|------|------|
| Band Frequency Limits ⁴ | f _{HFRCO_BAND} | FREQRANGE = 0 | 3.71 | — | 5.24 | MHz |
| | | FREQRANGE = 1 | 4.39 | — | 6.26 | MHz |
| | | FREQRANGE = 2 | 5.25 | — | 7.55 | MHz |
| | | FREQRANGE = 3 | 6.22 | — | 9.01 | MHz |
| | | FREQRANGE = 4 | 7.88 | — | 11.6 | MHz |
| | | FREQRANGE = 5 | 9.9 | — | 14.6 | MHz |
| | | FREQRANGE = 6 | 11.5 | — | 17.0 | MHz |
| | | FREQRANGE = 7 | 14.1 | — | 20.9 | MHz |
| | | FREQRANGE = 8 | 16.4 | — | 24.7 | MHz |
| | | FREQRANGE = 9 | 19.8 | — | 30.4 | MHz |
| | | FREQRANGE = 10 | 22.7 | — | 34.9 | MHz |
| | | FREQRANGE = 11 | 28.6 | — | 44.4 | MHz |
| | | FREQRANGE = 12 | 33.0 | — | 51.0 | MHz |
| | | FREQRANGE = 13 | 42.2 | — | 64.6 | MHz |
| | | FREQRANGE = 14 | 48.8 | — | 74.8 | MHz |
| FREQRANGE = 15 | 57.6 | — | 87.4 | MHz | | |

Note:

1. Does not include additional clock tree current. See specifications for additional current when selected as a clock source for a particular clock multiplexer.
2. When the HFRCO is enabled for characterization using the FORCEEN bit, the total current will be the HFRCO core current plus the specified CLKOUT current. When the HFRCO is enabled on demand, the clock current may be different.
3. Hardware delay ensures settling to within ± 0.5%. Hardware also enforces this delay on a band change.
4. The frequency band limits represent the lowest and highest frequency which each band can achieve over the operating range.

4.11.4 Fast Start_Up RC Oscillator (FSRCO)

Table 4.27. Fast Start_Up RC Oscillator (FSRCO)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|-----------------|--------------------|----------------|------|-----|------|------|
| FSRCO frequency | F _{FSRCO} | | 17.2 | 20 | 21.2 | MHz |

4.11.5 Precision Low Frequency RC Oscillator (LFRCO)

Table 4.28. Precision Low Frequency RC Oscillator (LFRCO)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|-------------------------------|------------------|---|------|--------|-----|---------|
| Nominal oscillation frequency | F_{LFRCO} | | — | 32.768 | — | kHz |
| Frequency accuracy | F_{LFRCO_ACC} | Normal mode | -3 | — | 3 | % |
| | | Precision mode ¹ , across operating temperature range ² | -500 | — | 500 | ppm |
| Startup time | $t_{STARTUP}$ | Normal mode | — | 204 | — | μ s |
| | | Precision mode ¹ | — | 11.7 | — | ms |
| Current consumption | I_{LFRCO} | Normal mode | — | 175 | — | nA |
| | | Precision mode ¹ , T = stable at 25 °C ³ | — | 655 | — | nA |

Note:

1. The LFRCO operates in high-precision mode when CFG_HIGHPRECEN is set to 1. High-precision mode is not available in EM4.
2. Includes ± 40 ppm frequency tolerance of the HFXO crystal.
3. Includes periodic re-calibration against HFXO crystal oscillator.

4.11.6 Ultra Low Frequency RC Oscillator

Table 4.29. Ultra Low Frequency RC Oscillator

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|-----------------------|--------------|----------------|-------|-----|-------|------|
| Oscillation Frequency | F_{ULFRCO} | | 0.944 | 1.0 | 1.095 | kHz |

4.12 GPIO Pins (3V GPIO pins)

Table 4.30. GPIO Pins (3V GPIO pins)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--------------------------------------|------------------------|--|-------------|------|-------------|------|
| Leakage current | I _{LEAK_IO} | MODEx = DISABLED, IOVDD = 1.71 V | — | 1.9 | — | nA |
| | | MODEx = DISABLED, IOVDD = 3.0 V | — | 2.5 | — | nA |
| | | MODEx = DISABLED, IOVDD = 3.8 V T _A = 85 °C | — | — | TBD | nA |
| | | Pins other than PA00, PA03, PB00, PC03, PC04 and PD00; MODEx = DISABLED, IOVDD = 3.8 V T _A = 125 °C | — | — | 200 | nA |
| | | Pins PA00, PA03, PB00, PC03, PC04 and PD00; MODEx = DISABLED, IOVDD = 3.8 V T _A = 125 °C | — | — | 400 | nA |
| Input low voltage ¹ | V _{IL} | Any GPIO pin | — | — | 0.3*IOVDD | V |
| | | RESETn | — | — | 0.3*DVDD | V |
| Input high voltage ¹ | V _{IH} | Any GPIO pin | 0.7*IOVDD | — | — | V |
| | | RESETn | 0.7*DVDD | — | — | V |
| Output high voltage | V _{OH} | Sourcing 20mA, IOVDD = 3.0 V | 0.8 * IOVDD | — | — | V |
| | | Sourcing 8mA, IOVDD = 1.71 V | 0.6 * IOVDD | — | — | V |
| Output low voltage | V _{OL} | Sinking 20mA, IOVDD = 3.0 V | — | — | 0.2 * IOVDD | V |
| | | Sinking 8mA, IOVDD = 1.71 V | — | — | 0.4 * IOVDD | V |
| GPIO rise time | T _{GPIO_RISE} | IOVDD = 3.0 V, C _{load} = 50pF, SLEWRATE = 4, 10% to 90% | — | 8.4 | — | ns |
| | | IOVDD = 1.71 V, C _{load} = 50pF, SLEWRATE = 4, 10% to 90% | — | 13 | — | ns |
| GPIO fall time | T _{GPIO_FALL} | IOVDD = 3.0 V, C _{load} = 50pF, SLEWRATE = 4, 90% to 10% | — | 7.1 | — | ns |
| | | IOVDD = 1.71 V, C _{load} = 50pF, SLEWRATE = 4, 90% to 10% | — | 11.9 | — | ns |
| Pull up/down resistance ² | R _{PULL} | Any GPIO pin. Pull-up to IOVDD: MODEn = DISABLE DOUT=1. Pull-down to VSS: MODEn = WIREDORPULLDOWN DOUT = 0. | 35 | 44 | 55 | kΩ |
| | | RESETn pin. Pull-up to DVDD | 35 | 44 | 55 | kΩ |
| Maximum filtered glitch width | T _{GF} | MODE = INPUT, DOUT = 1 | — | 27 | — | ns |

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|--------|----------------|-----|-----|-----|------|
| Note: | | | | | | |
| 1. GPIO input thresholds are proportional to the IOVDD pin. RESETn input thresholds are proportional to DVDD. | | | | | | |
| 2. GPIO pull-ups connect to IOVDD supply, pull-downs connect to VSS. RESETn pull-up connects to DVDD. | | | | | | |

4.13 Analog to Digital Converter (IADC)

Specified at 1 Msps, ADCCLK = 10 MHz, OSR=2, unless otherwise indicated.

Table 4.31. Analog to Digital Converter (IADC)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|-----------------------|---|------------------|-------------------------|------------------|-------|
| Main analog supply | V _{AVDD} | Normal Mode | 1.71 | — | 3.8 | V |
| Maximum Input Range | V _{IN_MAX} | Maximum allowable input voltage | 0 | — | AVDD | V |
| Full-Scale Voltage | V _{FS} | Voltage required for Full-Scale measurement | — | V _{REF} / Gain | — | |
| Input Measurement Range | V _{IN} | Differential Mode - Plus and Minus inputs | -V _{FS} | — | +V _{FS} | V |
| | | Single Ended Mode - One input tied to ground | 0 | — | V _{FS} | V |
| Input Sampling Capacitance | C _s | Analog Gain = 1x | — | 1.8 | — | pF |
| | | Analog Gain = 2x | — | 3.6 | — | pF |
| | | Analog Gain = 4x | — | 7.2 | — | pF |
| | | Analog Gain = 0.5x | — | 0.9 | — | pF |
| ADC clock frequency | f _{CLK} | Normal Mode | — | — | 10 | MHz |
| Throughput rate | f _{SAMPLE} | f _{CLK} = 10 MHz | — | — | 1 | Msps |
| Current from all supplies, Continuous operation | I _{ADC_CONT} | Normal Mode, 1 Msps, OSR=2, f _{CLK} = 10 MHz | — | 290 | 385 | μA |
| Current in Standby mode. ADC is not functional but can wake up in 1us. | I _{STBY} | Normal Mode | — | 16 | — | μA |
| ADC Startup Time | t _{startup} | From power down state | — | 5 | — | μs |
| | | From Standby state | — | 1 | — | μs |
| ADC Resolution | Resolution | | — | 12 | — | bits |
| Differential Nonlinearity | DNL | Differential Input. (No missing codes OSR =2) | -1 | +/- 0.25 | 1.5 | LSB12 |
| Integral Nonlinearity | INL | Normal Mode. Differential Input. | -2.5 | +/- 0.65 | 2.5 | LSB12 |
| Effective number of bits | ENOB | Differential Input. Gain=1x, f _{IN} = 10 kHz, Internal VREF=1.21V. OSR=2 | 10.5 | 11.18 | — | bits |
| Signal to Noise + Distortion Ratio Normal Mode | SNDR | Differential Input. Gain=1x, f _{IN} = 10 kHz, Internal VREF=1.21V | 65 | 69.1 | — | dB |
| | | Differential Input. Gain=2x, f _{IN} = 10 kHz, Internal VREF=1.21V | — | 68.8 | — | dB |
| | | Differential Input. Gain=4x, f _{IN} = 10 kHz, Internal VREF=1.21V | — | 66.9 | — | dB |
| | | Differential Input. Gain=0.5x, f _{IN} = 10 kHz, Internal VREF=1.21V | — | 69.2 | — | dB |
| Total Harmonic Distortion | THD | Differential Input. Gain=1x, f _{IN} = 10 kHz, Internal VREF=1.21V | — | -80.3 | -70 | dB |

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|----------------------------------|-------------|---|------|-------|------|------|
| Spurious-Free Dynamic Range | SFDR | Differential Input. Gain=1x, $f_{IN} = 10$ kHz, Internal VREF=1.21V | 72 | 86.5 | — | dB |
| Common Mode Rejection Ratio | CMRR | Normal Mode. DC to 100 Hz | — | 87.0 | — | dB |
| | | Normal Mode. AC high frequency | — | 68.6 | — | dB |
| Power Supply Rejection Ratio | PSRR | Normal mode. DC to 100 Hz | — | 80.4 | — | dB |
| | | Normal mode. AC high frequency, using VREF pad. | — | 33.4 | — | dB |
| | | Normal mode. AC high frequency, using internal VBGR. | — | 65.2 | — | dB |
| Gain Error | GE | GAIN=1 and 0.5, using external VREF, direct mode. | -0.3 | 0.069 | 0.3 | % |
| | | GAIN=2, using external VREF, direct mode. | -0.4 | 0.151 | 0.4 | % |
| | | GAIN=3, using external VREF, direct mode. | -0.7 | 0.186 | 0.7 | % |
| | | GAIN=4, using external VREF, direct mode. | -1.1 | 0.227 | 1.1 | % |
| | | Internal VREF, Gain = 1 | — | 0.023 | — | % |
| Offset | OFFSET | GAIN=1 and 0.5, Differential Input | -3 | 0.27 | 3 | LSB |
| | | GAIN=2, Differential Input | -4 | 0.27 | 4 | LSB |
| | | GAIN=3, Differential Input | -4 | 0.25 | 4 | LSB |
| | | GAIN=4, Differential Input | -4 | 0.29 | 4 | LSB |
| External reference voltage range | V_{EVREF} | | 1.0 | — | AVDD | V |
| Internal Reference voltage | V_{IVREF} | | — | 1.21 | — | V |

4.14 Temperature Sense

Table 4.32. Temperature Sense

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|-------------------------|--|-----|--------|-----|------|
| Temperature sensor range ¹ | T _{RANGE} | | -40 | — | 125 | °C |
| Temperature sensor resolution | T _{RESOLUTION} | | — | 0.25 | — | °C |
| Measurement noise (RMS) | T _{NOISE} | Single measurement | — | 0.6 | — | °C |
| | | 16-sample average (TEMPAVG- NUM = 0) | — | 0.17 | — | °C |
| | | 64-sample average (TEMPAVG- NUM = 1) | — | 0.12 | — | °C |
| Temperature offset | T _{OFF} | Mean error of uncorrected output across full temperature range | — | 3.14 | — | °C |
| Temperature sensor accuracy ^{2 3} | T _{ACC} | Direct output accuracy after mean error (T _{OFF}) removed | TBD | +/-3 | TBD | °C |
| | | After linearization in software, no calibration | TBD | +/-2.2 | TBD | °C |
| | | After linearization in software, with single-temperature calibration at 25 °C ⁴ | TBD | +/-1.5 | TBD | °C |
| Measurement interval | t _{MEAS} | | — | 250 | — | ms |

Note:

1. The sensor reports absolute die temperature in °K. All specifications are in °C to match the units of the specified product temperature range.
2. Error is measured as the deviation of the mean temperature reading from the expected die temperature. Accuracy numbers represent statistical minimum and maximum using ± 4 standard deviations of measured error.
3. The raw output of the temperature sensor is a predictable curve. It can be linearized with a polynomial function for additional accuracy.
4. Assuming calibration accuracy of ± 0.25 °C.

4.15 Brown Out Detectors

4.15.1 DVDD BOD

BOD Thresholds on DVDD in EM0 and EM1 only, unless otherwise noted. Typical conditions are at $T_A = 25\text{ }^\circ\text{C}$. Minimum and maximum values in this table represent the worst conditions across process variation, operating supply voltage range, and operating temperature range.

Table 4.33. DVDD BOD

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|-------------------|-------------------------|--|------|------|------|---------|
| BOD threshold | V_{DVDD_BOD} | Supply Rising | — | 1.64 | 1.71 | V |
| | | Supply Falling | 1.62 | 1.65 | — | V |
| BOD response time | $t_{DVDD_BOD_DELAY}$ | Supply dropping at 100mV/ μ s slew rate ¹ | — | 0.95 | — | μ s |
| BOD hysteresis | $V_{DVDD_BOD_HYS_T}$ | | — | 20 | — | mV |

Note:

1. If the supply slew rate exceeds the specified slew rate, the BOD may trip later than expected (at a threshold below the minimum specified threshold), or the BOD may not trip at all (e.g., if the supply ramps down and then back up at a very fast rate)

4.15.2 LE DVDD BOD

BOD thresholds on DVDD pin for low energy modes EM2 to EM4, unless otherwise noted.

Table 4.34. LE DVDD BOD

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|-------------------|----------------------------|--|-----|-----|------|---------|
| BOD threshold | $V_{DVDD_LE_BOD}$ | Supply Falling | 1.5 | — | 1.71 | V |
| BOD response time | $t_{DVDD_LE_BOD_DELAY}$ | Supply dropping at 2mV/ μ s slew rate ¹ | — | 50 | — | μ s |
| BOD hysteresis | $V_{DVDD_LE_BOD_HYST}$ | | — | 20 | — | mV |

Note:

1. If the supply slew rate exceeds the specified slew rate, the BOD may trip later than expected (at a threshold below the minimum specified threshold), or the BOD may not trip at all (e.g., if the supply ramps down and then back up at a very fast rate)

4.15.3 AVDD and IOVDD BODs

BOD thresholds for AVDD BOD and IOVDD BOD. Available in all energy modes.

Table 4.35. AVDD and IOVDD BODs

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|-------------------|------------------|--|------|-----|------|---------|
| BOD threshold | V_{BOD} | Supply falling | 1.45 | — | 1.71 | V |
| BOD response time | t_{BOD_DELAY} | Supply dropping at 2mV/ μ s slew rate ¹ | — | 50 | — | μ s |
| BOD hysteresis | V_{BOD_HYST} | | — | 20 | — | mV |

Note:

1. If the supply slew rate exceeds the specified slew rate, the BOD may trip later than expected (at a threshold below the minimum specified threshold), or the BOD may not trip at all (e.g., if the supply ramps down and then back up at a very fast rate)

4.16 PDM Timing Specifications

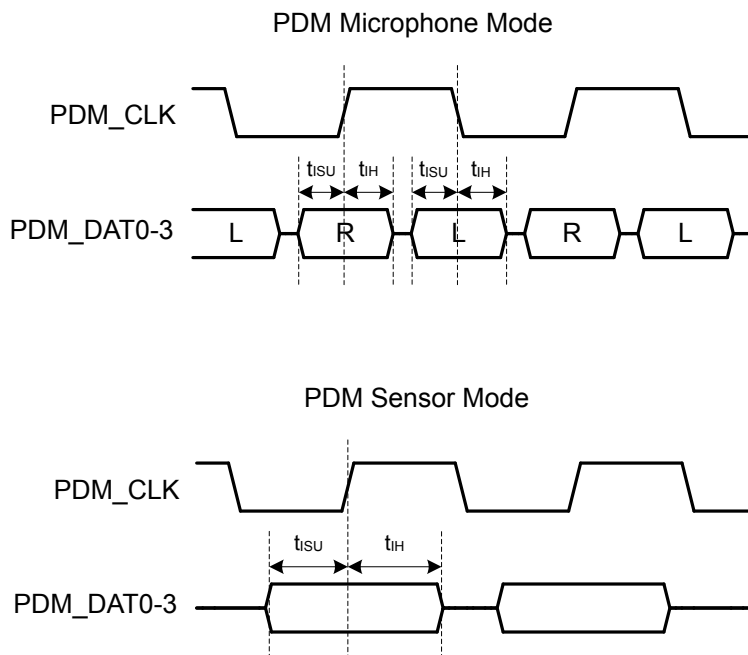


Figure 4.3. PDM Timing Diagrams

4.16.1 Pulse Density Modulator (PDM), Common DBUS

Timing specifications are for all PDM signals routed to the same DBUS (DBUSAB or DBUSCD), though routing to the same GPIO port is the optimal configuration. $C_{LOAD} < 20$ pF. System voltage scaling = VSCALE1 or VSCALE2. All GPIO set to slew rate = 6. Data delay (PDM_CFG1_DLYMUXSEL) = 0.

Table 4.36. Pulse Density Modulator (PDM), Common DBUS

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|-----------------|-----------------|------|-----|------|------|
| PDM_CLK frequency during data transfer | F_{PDM_CLK} | Microphone mode | — | — | 5 | MHz |
| | | Sensor mode | — | — | 20 | MHz |
| PDM_CLK duty cycle | DC_{PDM_CLK} | | 47.5 | — | 52.5 | % |
| PDM_CLK rise time | t_R | | — | — | 5.5 | ns |
| PDM_CLK fall time | t_F | | — | — | 5.5 | ns |
| Input setup time | t_{ISU} | Microphone mode | 30 | — | — | ns |
| | | Sensor mode | 20 | — | — | ns |
| Input hold time | t_{IH} | | 3 | — | — | ns |

4.17 USART SPI Master Timing

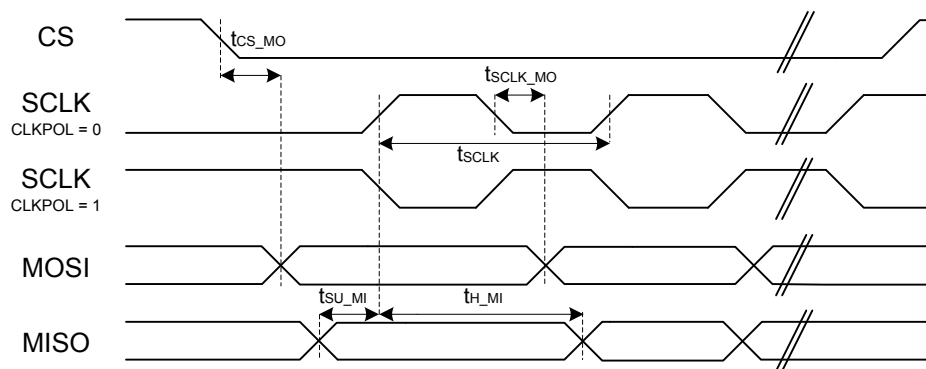


Figure 4.4. SPI Master Timing (SMSDELAY = 0)

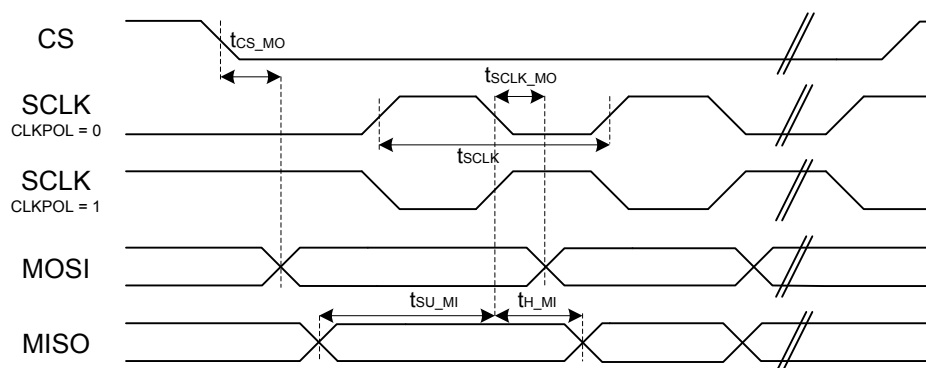


Figure 4.5. SPI Master Timing (SMSDELAY = 1)

4.17.1 SPI Master Timing, Voltage Scaling = VSCALE2

Table 4.37. SPI Master Timing, Voltage Scaling = VSCALE2

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--------------------------------|----------------------|----------------|--|-----|------|------|
| SCLK period ^{1 2 3} | t _{SCLK} | | 2*t _{H_{FFPERCLK}} K | — | — | ns |
| CS to MOSI ^{1 2} | t _{CS_MO} | | -22 | — | 22.5 | ns |
| SCLK to MOSI ^{1 2} | t _{SCLK_MO} | | -14.5 | — | 14.5 | ns |
| MISO setup time ^{1 2} | t _{SU_MI} | IOVDD = 1.62 V | 38.5 | — | — | ns |
| | | IOVDD = 3.0 V | 28.5 | — | — | ns |
| MISO hold time ^{1 2} | t _{H_MI} | | -8.5 | — | — | ns |

Note:

1. Applies for both CLKPHA = 0 and CLKPHA = 1
2. Measurement done with 8 pF output loading at 10% and 90% of V_{DD}.
3. t_{H_{FFPERCLK}} is one period of the selected H_{FFPERCLK}.

4.17.2 SPI Master Timing, Voltage Scaling = VSCALE1

Table 4.38. SPI Master Timing, Voltage Scaling = VSCALE1

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--------------------------------|----------------------|----------------|--|-----|------|------|
| SCLK period ^{1 2 3} | t _{SCLK} | | 2*t _{H_{FFPERCLK}} K | — | — | ns |
| CS to MOSI ^{1 2} | t _{CS_MO} | | -33 | — | 34.5 | ns |
| SCLK to MOSI ^{1 2} | t _{SCLK_MO} | | -15 | — | 26 | ns |
| MISO setup time ^{1 2} | t _{SU_MI} | IOVDD = 1.62 V | 47 | — | — | ns |
| | | IOVDD = 3.0 V | 39 | — | — | ns |
| MISO hold time ^{1 2} | t _{H_MI} | | -9.5 | — | — | ns |

Note:

1. Applies for both CLKPHA = 0 and CLKPHA = 1
2. Measurement done with 8 pF output loading at 10% and 90% of V_{DD}.
3. t_{H_{FFPERCLK}} is one period of the selected H_{FFPERCLK}.

4.18 USART SPI Slave Timing

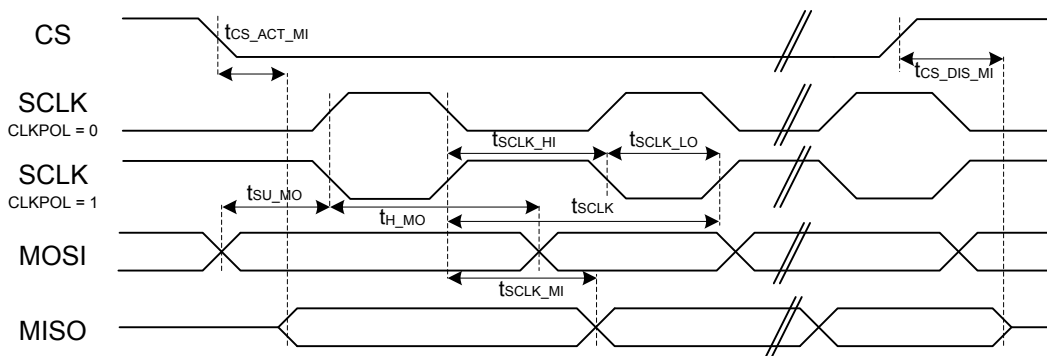


Figure 4.6. SPI Slave Timing

4.18.1 SPI Slave Timing, Voltage Scaling = VSCALE2

Table 4.39. SPI Slave Timing, Voltage Scaling = VSCALE2

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|-----------------------------------|-------------------|----------------|-------------------------------|-----|---------------------------------|------|
| SCLK period ^{1 2 3} | t_{SCLK} | | $6 \cdot t_{HFPERCLK}$ | — | — | ns |
| SCLK high time ^{1 2 3} | t_{SCLK_HI} | | $2.5 \cdot t_{HFPERCLK}$ | — | — | ns |
| SCLK low time ^{1 2 3} | t_{SCLK_LO} | | $2.5 \cdot t_{HFPERCLK}$ | — | — | ns |
| CS active to MISO ^{1 2} | $t_{CS_ACT_MI}$ | | 25 | — | 47.5 | ns |
| CS disable to MISO ^{1 2} | $t_{CS_DIS_MI}$ | | 19.5 | — | 38.5 | ns |
| MOSI setup time ^{1 2} | t_{SU_MO} | | 4.5 | — | — | ns |
| MOSI hold time ^{1 2 3} | t_{H_MO} | | 5 | — | — | ns |
| SCLK to MISO ^{1 2 3} | t_{SCLK_MI} | | $22 + 1.5 \cdot t_{HFPERCLK}$ | — | $33.5 + 2.5 \cdot t_{HFPERCLK}$ | ns |

Note:

1. Applies for both CLKPHA = 0 and CLKPHA = 1 (figure only shows CLKPHA = 0).
2. Measurement done with 8 pF output loading at 10% and 90% of V_{DD} (figure shows 50% of V_{DD}).
3. $t_{HFPERCLK}$ is one period of the selected HFPERCLK.

4.18.2 SPI Slave Timing, Voltage Scaling = VSCALE1

Table 4.40. SPI Slave Timing, Voltage Scaling = VSCALE1

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|-----------------------------------|------------------------|----------------|-------------------------------------|-----|-------------------------------------|------|
| SCLK period ^{1 2 3} | t _{SCLK} | | 6*t _{HFPERCLK} | — | — | ns |
| SCLK high time ^{1 2 3} | t _{SCLK_HI} | | 2.5*t _{HFPERCLK} | — | — | ns |
| SCLK low time ^{1 2 3} | t _{SCLK_LO} | | 2.5*t _{HFPERCLK} | — | — | ns |
| CS active to MISO ^{1 2} | t _{CS_ACT_MI} | | 30.5 | — | 57.5 | ns |
| CS disable to MISO ^{1 2} | t _{CS_DIS_MI} | | 25 | — | 55 | ns |
| MOSI setup time ^{1 2} | t _{SU_MO} | | 7.5 | — | — | ns |
| MOSI hold time ^{1 2 3} | t _{H_MO} | | 8.5 | — | — | ns |
| SCLK to MISO ^{1 2 3} | t _{SCLK_MI} | | 24.5 + 1.5*t _{HFPERCLK} | — | 45.5 + 2.5*t _{HFPERCLK} | ns |

Note:

1. Applies for both CLKPHA = 0 and CLKPHA = 1 (figure only shows CLKPHA = 0).
2. Measurement done with 8 pF output loading at 10% and 90% of V_{DD} (figure shows 50% of V_{DD}).
3. t_{HFPERCLK} is one period of the selected HFPERCLK.

4.19 I2C Electrical Specifications

4.19.1 I2C Standard-mode (Sm)

CLHR set to 0 in the I2Cn_CTRL register.

Table 4.41. I2C Standard-mode (Sm)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|---------------|----------------|-----|-----|-----|---------|
| SCL clock frequency ¹ | f_{SCL} | | 0 | — | 100 | kHz |
| SCL clock low time | t_{LOW} | | 4.7 | — | — | μs |
| SCL clock high time | t_{HIGH} | | 4 | — | — | μs |
| SDA set-up time | t_{SU_DAT} | | 250 | — | — | ns |
| SDA hold time | t_{HD_DAT} | | 0 | — | — | ns |
| Repeated START condition set-up time | t_{SU_STA} | | 4.7 | — | — | μs |
| Repeated START condition hold time | t_{HD_STA} | | 4.0 | — | — | μs |
| STOP condition set-up time | t_{SU_STO} | | 4.0 | — | — | μs |
| Bus free time between a STOP and START condition | t_{BUF} | | 4.7 | — | — | μs |

Note:

1. The maximum SCL clock frequency listed is assuming that an arbitrary clock frequency is available. The maximum attainable SCL clock frequency may be slightly less using the HFXO or HFRCO due to the limited frequencies available. The CLKDIV should be set to a value that keeps the SCL clock frequency below the max value listed.

4.19.2 I2C Fast-mode (Fm)

CLHR set to 1 in the I2Cn_CTRL register.

Table 4.42. I2C Fast-mode (Fm)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|---------------|----------------|-----|-----|-----|---------|
| SCL clock frequency ¹ | f_{SCL} | | 0 | — | 400 | kHz |
| SCL clock low time | t_{LOW} | | 1.3 | — | — | μs |
| SCL clock high time | t_{HIGH} | | 0.6 | — | — | μs |
| SDA set-up time | t_{SU_DAT} | | 100 | — | — | ns |
| SDA hold time | t_{HD_DAT} | | 0 | — | — | ns |
| Repeated START condition set-up time | t_{SU_STA} | | 0.6 | — | — | μs |
| Repeated START condition hold time | t_{HD_STA} | | 0.6 | — | — | μs |
| STOP condition set-up time | t_{SU_STO} | | 0.6 | — | — | μs |
| Bus free time between a STOP and START condition | t_{BUF} | | 1.3 | — | — | μs |

Note:

1. The maximum SCL clock frequency listed is assuming that an arbitrary clock frequency is available. The maximum attainable SCL clock frequency may be slightly less using the HFXO or HFRCO due to the limited frequencies available. The CLKDIV should be set to a value that keeps the SCL clock frequency below the max value listed.

4.19.3 I2C Fast-mode Plus (Fm+)

CLHR set to 1 in the I2Cn_CTRL register.

Table 4.43. I2C Fast-mode Plus (Fm+)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|--|---------------------|----------------|------|-----|------|------|
| SCL clock frequency ¹ | f _{SCL} | | 0 | — | 1000 | kHz |
| SCL clock low time | t _{LOW} | | 0.5 | — | — | μs |
| SCL clock high time | t _{HIGH} | | 0.26 | — | — | μs |
| SDA set-up time | t _{SU_DAT} | | 50 | — | — | ns |
| SDA hold time | t _{HD_DAT} | | 0 | — | — | ns |
| Repeated START condition set-up time | t _{SU_STA} | | 0.26 | — | — | μs |
| Repeated START condition hold time | t _{HD_STA} | | 0.26 | — | — | μs |
| STOP condition set-up time | t _{SU_STO} | | 0.26 | — | — | μs |
| Bus free time between a STOP and START condition | t _{BUF} | | 0.5 | — | — | μs |

Note:

1. The maximum SCL clock frequency listed is assuming that an arbitrary clock frequency is available. The maximum attainable SCL clock frequency may be slightly less using the HFXO or HFRCO due to the limited frequencies available. The CLKDIV should be set to a value that keeps the SCL clock frequency below the max value listed.

4.20 Typical Performance Curves

Typical performance curves indicate typical characterized performance under the stated conditions.

4.20.1 Supply Current

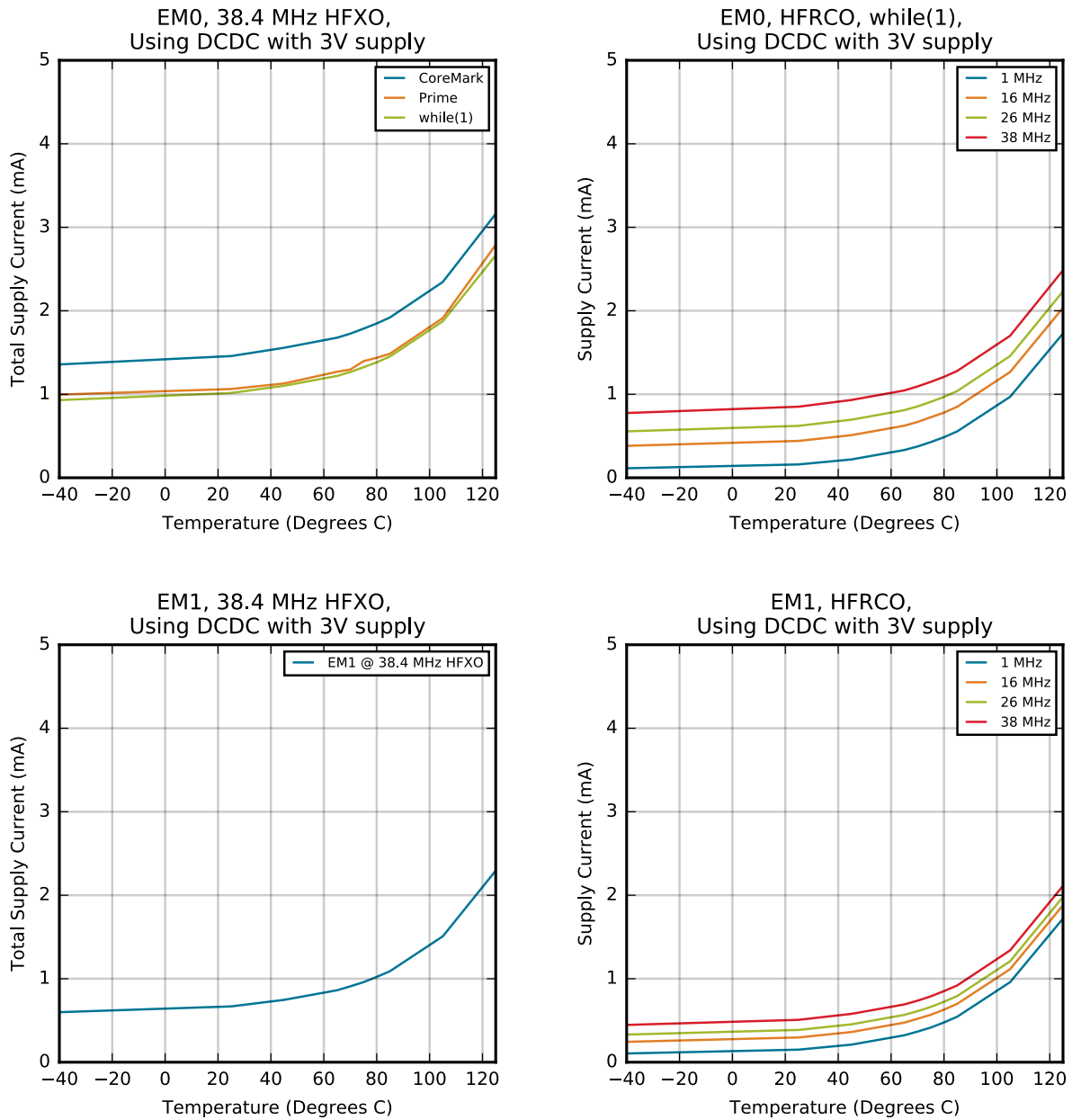


Figure 4.7. EM0 and EM1 Typical Supply Current vs. Temperature

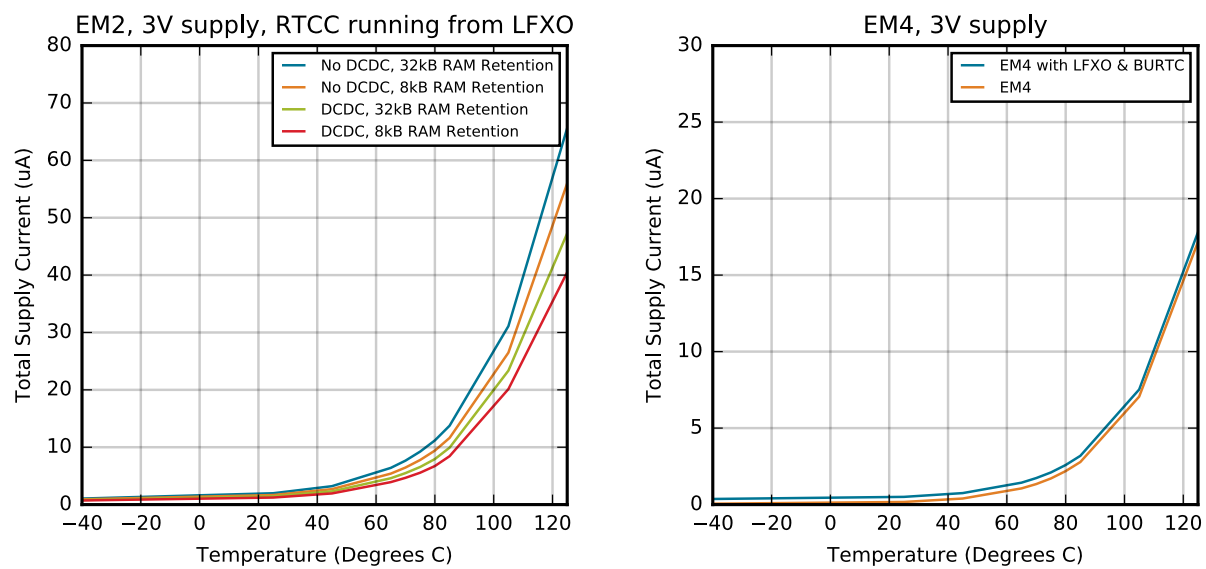


Figure 4.8. EM2 and EM4 Typical Supply Current vs. Temperature

4.20.2 RF Characteristics

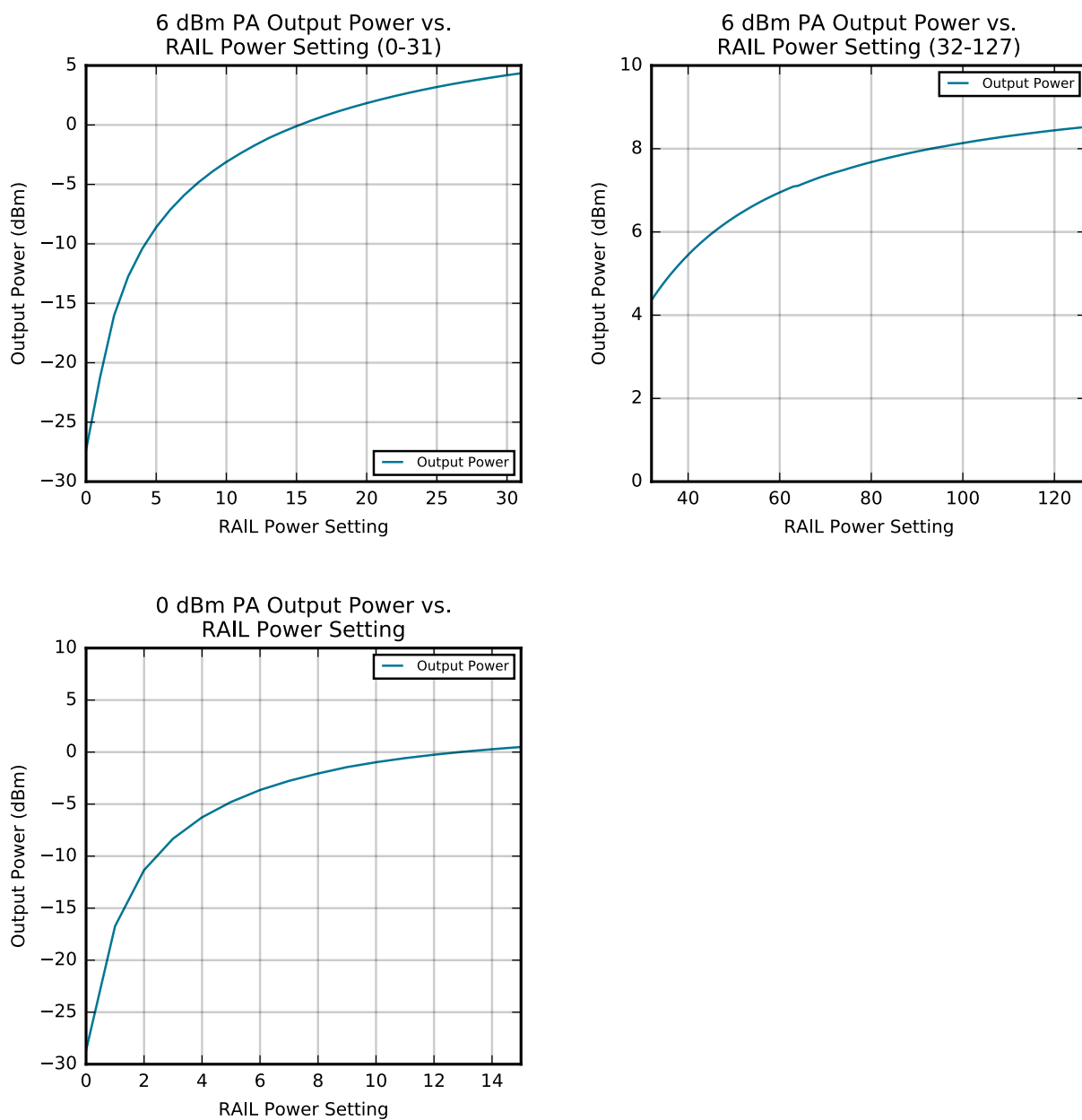


Figure 4.9. Transmitter Output Power

4.20.3 DC-DC Converter

Performance characterized with Samsung CIG22H2R2MNE ($L_{DCDC} = 2.2 \mu\text{H}$) and Samsung CL10B475KQ8NQNC ($C_{DCDC} = 4.7 \mu\text{F}$)

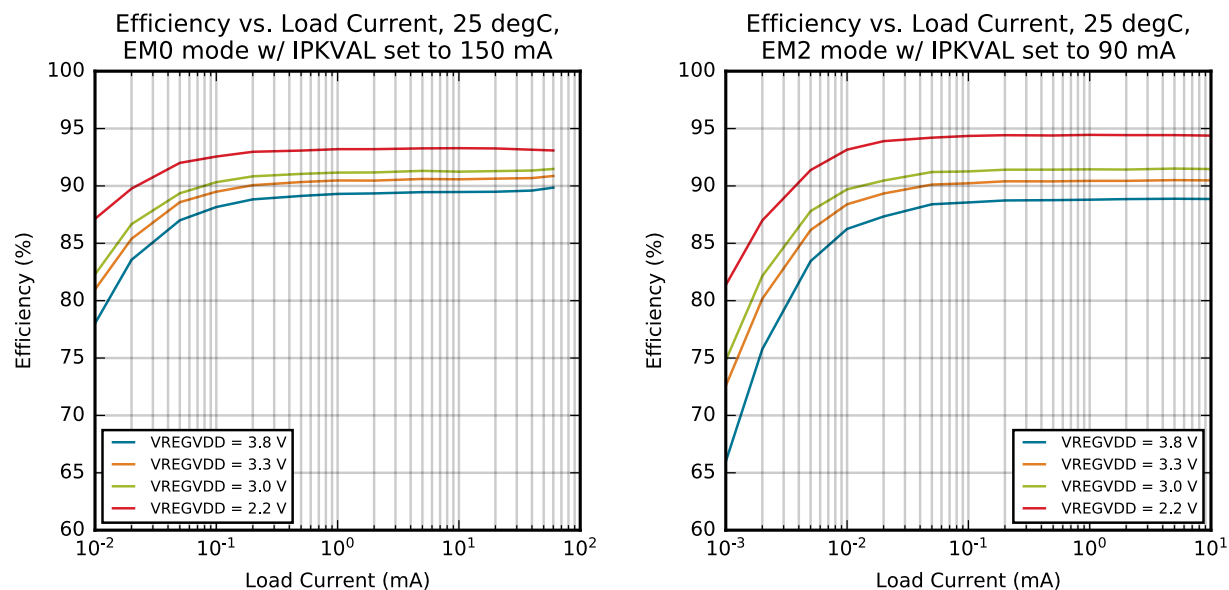


Figure 4.10. DC-DC Efficiency

5. Typical Connections

5.1 Power

Typical power supply connections are shown in the following figures.

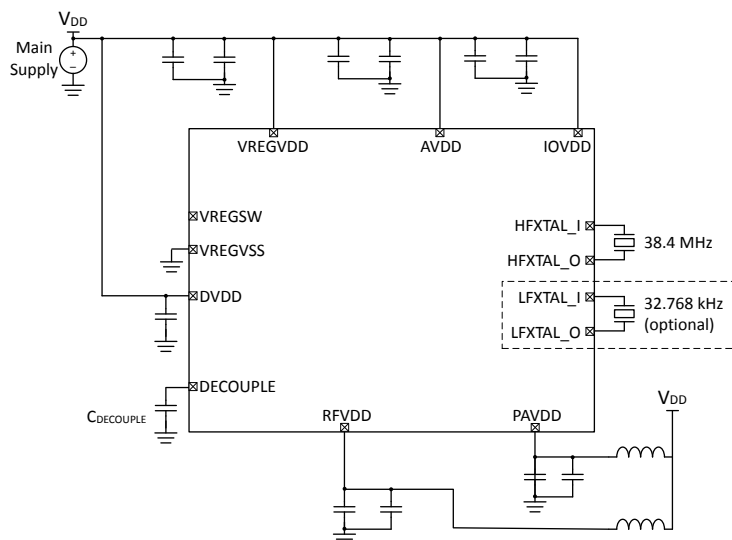


Figure 5.1. EFR32BG22 Typical Application Circuit: Direct Supply Configuration without DCDC

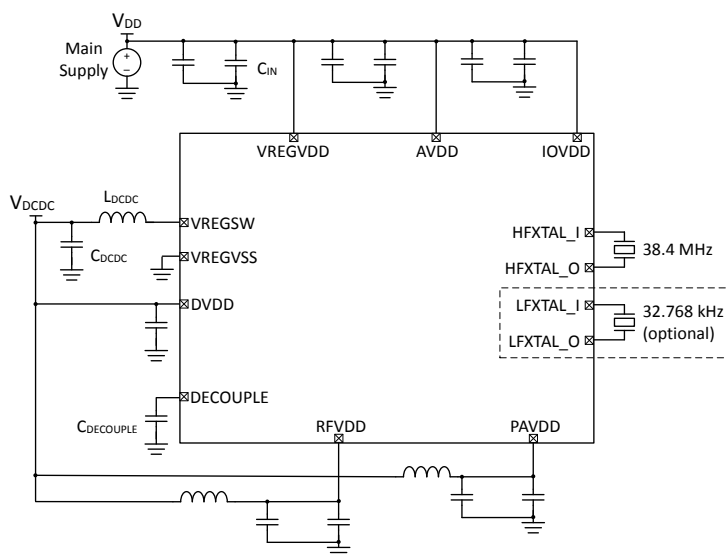


Figure 5.2. EFR32BG22 Typical Application Circuit: DCDC Configuration

5.2 RF Matching Networks

5.2.1 2.4 GHz Matching Network

The recommended RF matching network circuit diagram is shown in Figure 5.3 Typical RF impedance-matching network circuit on page 74. Typical component values are shown in Table 5.1 Component Values on page 74. Please refer to the development board Bill of Materials for specific part recommendation including tolerance, component size, recommended manufacturer, and recommended part number.

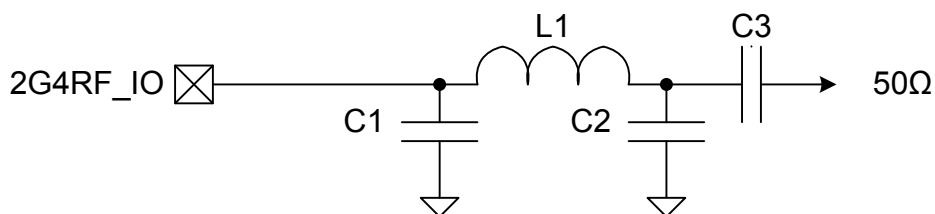


Figure 5.3. Typical RF impedance-matching network circuit

Table 5.1. Component Values

| Designator | Value |
|------------|--------|
| C1 | 1.2 pF |
| C2 | 1.3 pF |
| L1 | 2.6 nH |
| C3 | 18 pF |

5.3 Other Connections

Other components or connections may be required to meet the system-level requirements. Application Note AN0002.2: "EFR32 Wireless Gecko Series 2 Hardware Design Considerations" contains detailed information on these connections. Application Notes can be accessed on the Silicon Labs website (www.silabs.com/32bit-appnotes).

6. Pin Definitions

6.1 QFN32 Device Pinout

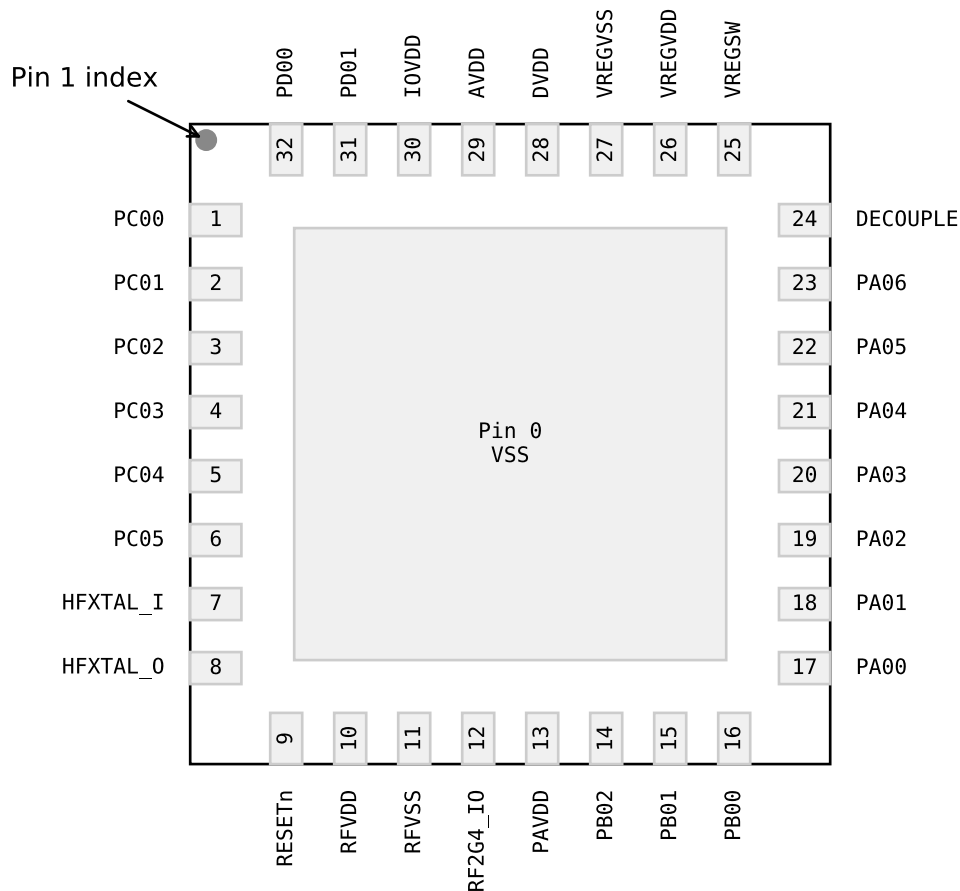


Figure 6.1. QFN32 Device Pinout

The following table provides package pin connections and general descriptions of pin functionality. For detailed information on the supported features for each GPIO pin, see [6.4 Alternate Function Table](#), [6.5 Analog Peripheral Connectivity](#), and [6.6 Digital Peripheral Connectivity](#).

Table 6.1. QFN32 Device Pinout

| Pin Name | Pin(s) | Description | Pin Name | Pin(s) | Description |
|----------|--------|------------------------------|----------|--------|-------------------------------|
| PC00 | 1 | GPIO | PC01 | 2 | GPIO |
| PC02 | 3 | GPIO | PC03 | 4 | GPIO |
| PC04 | 5 | GPIO | PC05 | 6 | GPIO |
| HFXTAL_I | 7 | High Frequency Crystal Input | HFXTAL_O | 8 | High Frequency Crystal Output |

| Pin Name | Pin(s) | Description | Pin Name | Pin(s) | Description |
|----------|--------|--|----------|--------|--|
| RESETn | 9 | Reset Pin. The RESETn pin is internally pulled up to DVDD. | RFVDD | 10 | Radio power supply |
| RFVSS | 11 | Radio Ground | RF2G4_IO | 12 | 2.4 GHz Single-ended RF input/output |
| PAVDD | 13 | Power Amplifier (PA) power supply | PB02 | 14 | GPIO |
| PB01 | 15 | GPIO | PB00 | 16 | GPIO |
| PA00 | 17 | GPIO | PA01 | 18 | GPIO |
| PA02 | 19 | GPIO | PA03 | 20 | GPIO |
| PA04 | 21 | GPIO | PA05 | 22 | GPIO |
| PA06 | 23 | GPIO | DECOUPLE | 24 | Decouple output for on-chip voltage regulator. An external decoupling capacitor is required at this pin. |
| VREGSW | 25 | DCDC regulator switching node | VREGVDD | 26 | DCDC regulator input supply |
| VREGVSS | 27 | DCDC ground | DVDD | 28 | Digital power supply |
| AVDD | 29 | Analog power supply | IOVDD | 30 | I/O power supply |
| PD01 | 31 | GPIO | PD00 | 32 | GPIO |

6.2 QFN40 Device Pinout

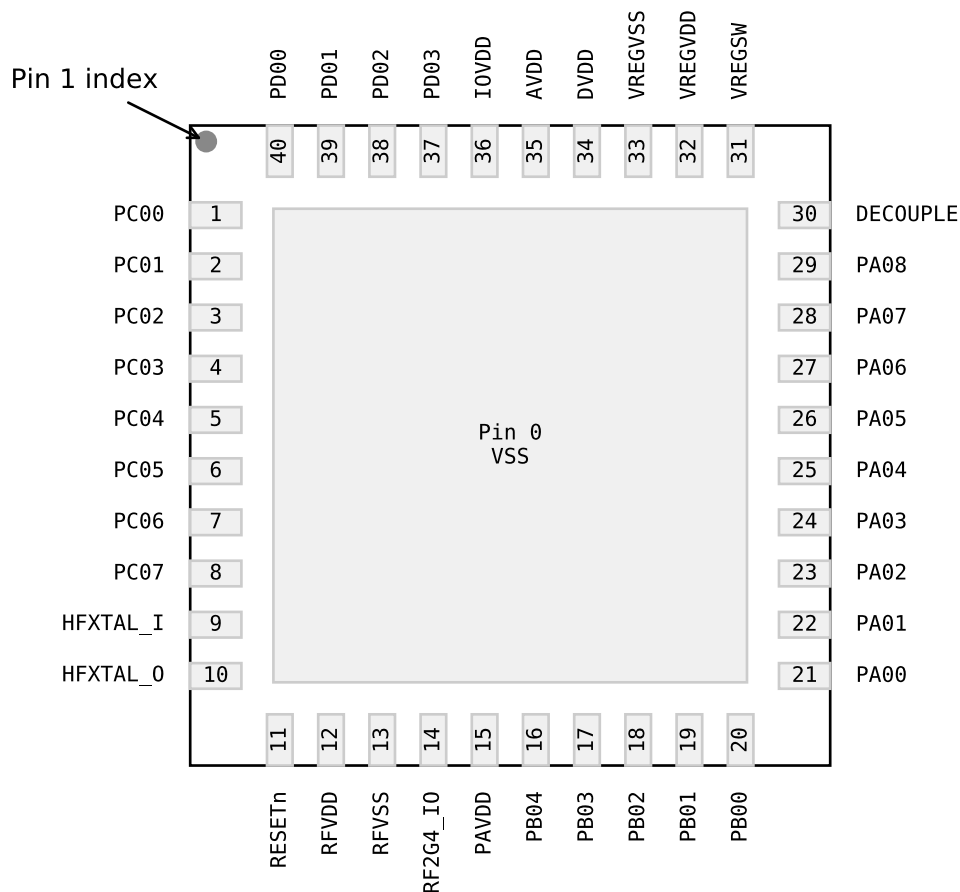


Figure 6.2. QFN40 Device Pinout

The following table provides package pin connections and general descriptions of pin functionality. For detailed information on the supported features for each GPIO pin, see [6.4 Alternate Function Table](#), [6.5 Analog Peripheral Connectivity](#), and [6.6 Digital Peripheral Connectivity](#).

Table 6.2. QFN40 Device Pinout

| Pin Name | Pin(s) | Description | Pin Name | Pin(s) | Description |
|----------|--------|--|----------|--------|-------------------------------|
| PC00 | 1 | GPIO | PC01 | 2 | GPIO |
| PC02 | 3 | GPIO | PC03 | 4 | GPIO |
| PC04 | 5 | GPIO | PC05 | 6 | GPIO |
| PC06 | 7 | GPIO | PC07 | 8 | GPIO |
| HFXTAL_I | 9 | High Frequency Crystal Input | HFXTAL_O | 10 | High Frequency Crystal Output |
| RESETn | 11 | Reset Pin. The RESETn pin is internally pulled up to DVDD. | RFVDD | 12 | Radio power supply |

| Pin Name | Pin(s) | Description | Pin Name | Pin(s) | Description |
|----------|--------|-----------------------------------|----------|--------|--|
| RFVSS | 13 | Radio Ground | RF2G4_IO | 14 | 2.4 GHz Single-ended RF input/output |
| PAVDD | 15 | Power Amplifier (PA) power supply | PB04 | 16 | GPIO |
| PB03 | 17 | GPIO | PB02 | 18 | GPIO |
| PB01 | 19 | GPIO | PB00 | 20 | GPIO |
| PA00 | 21 | GPIO | PA01 | 22 | GPIO |
| PA02 | 23 | GPIO | PA03 | 24 | GPIO |
| PA04 | 25 | GPIO | PA05 | 26 | GPIO |
| PA06 | 27 | GPIO | PA07 | 28 | GPIO |
| PA08 | 29 | GPIO | DECOUPLE | 30 | Decouple output for on-chip voltage regulator. An external decoupling capacitor is required at this pin. |
| VREGSW | 31 | DCDC regulator switching node | VREGVDD | 32 | DCDC regulator input supply |
| VREGVSS | 33 | DCDC ground | DVDD | 34 | Digital power supply |
| AVDD | 35 | Analog power supply | IOVDD | 36 | I/O power supply |
| PD03 | 37 | GPIO | PD02 | 38 | GPIO |
| PD01 | 39 | GPIO | PD00 | 40 | GPIO |

6.3 TQFN32 Device Pinout

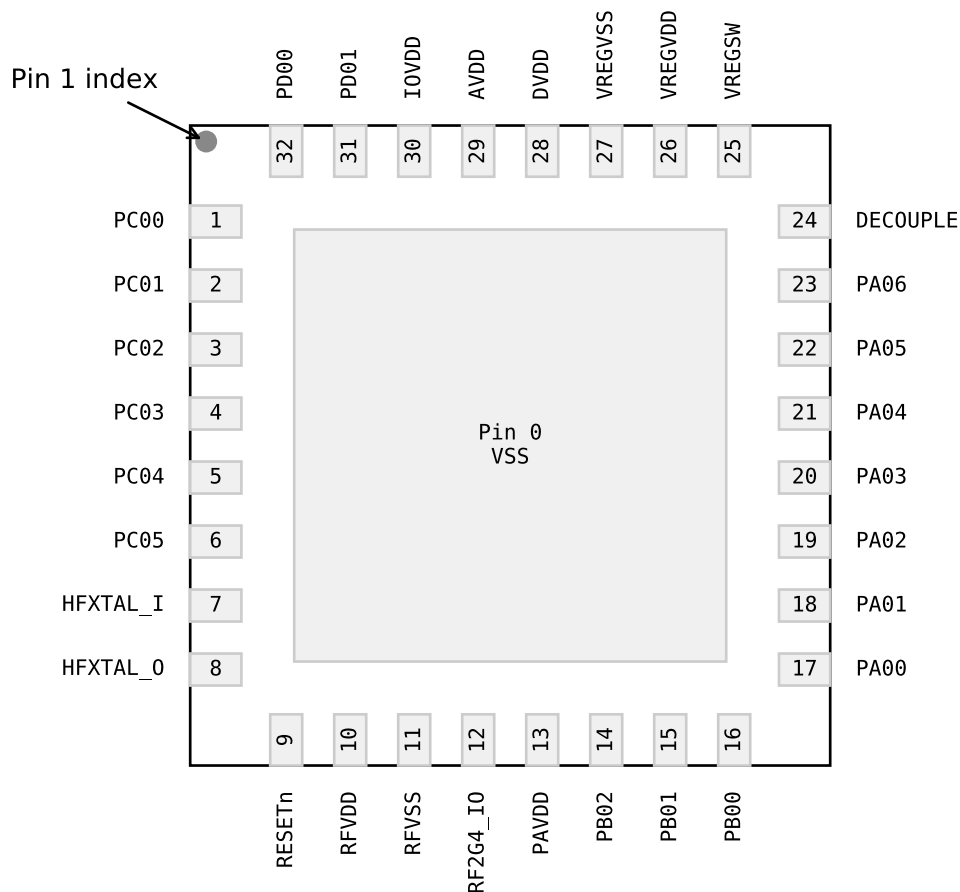


Figure 6.3. TQFN32 Device Pinout

The following table provides package pin connections and general descriptions of pin functionality. For detailed information on the supported features for each GPIO pin, see [6.4 Alternate Function Table](#), [6.5 Analog Peripheral Connectivity](#), and [6.6 Digital Peripheral Connectivity](#).

Table 6.3. TQFN32 Device Pinout

| Pin Name | Pin(s) | Description | Pin Name | Pin(s) | Description |
|----------|--------|--|----------|--------|--------------------------------------|
| PC00 | 1 | GPIO | PC01 | 2 | GPIO |
| PC02 | 3 | GPIO | PC03 | 4 | GPIO |
| PC04 | 5 | GPIO | PC05 | 6 | GPIO |
| HFXTAL_I | 7 | High Frequency Crystal Input | HFXTAL_O | 8 | High Frequency Crystal Output |
| RESETn | 9 | Reset Pin. The RESETn pin is internally pulled up to DVDD. | RFVDD | 10 | Radio power supply |
| RFVSS | 11 | Radio Ground | RF2G4_IO | 12 | 2.4 GHz Single-ended RF input/output |

| Pin Name | Pin(s) | Description | Pin Name | Pin(s) | Description |
|----------|--------|-----------------------------------|----------|--------|--|
| PAVDD | 13 | Power Amplifier (PA) power supply | PB02 | 14 | GPIO |
| PB01 | 15 | GPIO | PB00 | 16 | GPIO |
| PA00 | 17 | GPIO | PA01 | 18 | GPIO |
| PA02 | 19 | GPIO | PA03 | 20 | GPIO |
| PA04 | 21 | GPIO | PA05 | 22 | GPIO |
| PA06 | 23 | GPIO | DECOUPLE | 24 | Decouple output for on-chip voltage regulator. An external decoupling capacitor is required at this pin. |
| VREGSW | 25 | DCDC regulator switching node | VREGVDD | 26 | DCDC regulator input supply |
| VREGVSS | 27 | DCDC ground | DVDD | 28 | Digital power supply |
| AVDD | 29 | Analog power supply | IOVDD | 30 | I/O power supply |
| PD01 | 31 | GPIO | PD00 | 32 | GPIO |

6.4 Alternate Function Table

A wide selection of alternate functionality is available for multiplexing to various pins. The following table shows what functions are available on each device pin.

Table 6.4. GPIO Alternate Function Table

| GPIO | Alternate Function | | | | |
|------|--------------------|----------------|---------------------------|--|--|
| PC00 | GPIO.EM4WU6 | GPIO.THMSW_EN | GPIO.THMSW_HAL FSWITCH | | |
| PC05 | GPIO.EM4WU7 | | | | |
| PC07 | GPIO.EM4WU8 | | | | |
| PB03 | GPIO.EM4WU4 | | | | |
| PB01 | GPIO.EM4WU3 | | | | |
| PB00 | IADC0.VREFN | | | | |
| PA00 | IADC0.VREFP | | | | |
| PA01 | GPIO.SWCLK | | | | |
| PA02 | GPIO.SWDIO | | | | |
| PA03 | GPIO.SWV | GPIO.TDO | GPIO.TRACEDA- TA0 | | |
| PA04 | GPIO.TDI | GPIO.TRACECLK | | | |
| PA05 | GPIO.EM4WU0 | | | | |
| PD02 | GPIO.EM4WU9 | | | | |
| PD01 | LFXO.LFXTAL_I | LFXO.LF_EXTCLK | | | |
| PD00 | LFXO.LFXTAL_O | | | | |

6.5 Analog Peripheral Connectivity

Many analog resources are routable and can be connected to numerous GPIO's. The table below indicates which peripherals are available on each GPIO port. When a differential connection is being used Positive inputs are restricted to the EVEN pins and Negative inputs are restricted to the ODD pins. When a single ended connection is being used positive input is available on all pins. See the device Reference Manual for more details on the ABUS and analog peripherals.

Table 6.5. ABUS Routing Table

| Peripheral | Signal | PA | | PB | | PC | | PD | |
|------------|---------|------|-----|------|-----|------|-----|------|-----|
| | | EVEN | ODD | EVEN | ODD | EVEN | ODD | EVEN | ODD |
| IADC0 | ana_neg | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | ana_pos | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

6.6 Digital Peripheral Connectivity

Many digital resources are routable and can be connected to numerous GPIO's. The table below indicates which peripherals are available on each GPIO port.

Table 6.6. DBUS Routing Table

| Peripheral.Resource | PORT | | | |
|---------------------|-----------|-----------|-----------|-----------|
| | PA | PB | PC | PD |
| CMU.CLKIN0 | | | Available | Available |
| CMU.CLKOUT0 | | | Available | Available |
| CMU.CLKOUT1 | | | Available | Available |
| CMU.CLKOUT2 | Available | Available | | |
| EUART0.CTS | Available | Available | Available | Available |
| EUART0.RTS | Available | Available | Available | Available |
| EUART0.RX | Available | Available | Available | Available |
| EUART0.TX | Available | Available | Available | Available |
| FRC.DCLK | | | Available | Available |
| FRC.DFRAME | | | Available | Available |
| FRC.DOUT | | | Available | Available |
| I2C0.SCL | Available | Available | Available | Available |
| I2C0.SDA | Available | Available | Available | Available |
| I2C1.SCL | | | Available | Available |
| I2C1.SDA | | | Available | Available |
| LETIMER0.OUT0 | Available | Available | | |
| LETIMER0.OUT1 | Available | Available | | |
| MODEM.ANT0 | Available | Available | Available | Available |
| MODEM.ANT1 | Available | Available | Available | Available |
| MODEM.ANT_ROLL_OVER | | | Available | Available |
| MODEM.ANT_RR0 | | | Available | Available |
| MODEM.ANT_RR1 | | | Available | Available |
| MODEM.ANT_RR2 | | | Available | Available |
| MODEM.ANT_RR3 | | | Available | Available |
| MODEM.ANT_RR4 | | | Available | Available |
| MODEM.ANT_RR5 | | | Available | Available |
| MODEM.ANT_SW_EN | | | Available | Available |
| MODEM.ANT_SW_US | | | Available | Available |
| MODEM.ANT_TRIG | | | Available | Available |
| MODEM.ANT_TRIG_STOP | | | Available | Available |
| MODEM.DCLK | Available | Available | | |

| Peripheral.Resource | PORT | | | |
|---------------------|-----------|-----------|-----------|-----------|
| | PA | PB | PC | PD |
| MODEM.DIN | Available | Available | | |
| MODEM.DOUT | Available | Available | | |
| PDM.CLK | Available | Available | Available | Available |
| PDM.DAT0 | Available | Available | Available | Available |
| PDM.DAT1 | Available | Available | Available | Available |
| PRS.ASYNCH0 | Available | Available | | |
| PRS.ASYNCH1 | Available | Available | | |
| PRS.ASYNCH10 | | | Available | Available |
| PRS.ASYNCH11 | | | Available | Available |
| PRS.ASYNCH2 | Available | Available | | |
| PRS.ASYNCH3 | Available | Available | | |
| PRS.ASYNCH4 | Available | Available | | |
| PRS.ASYNCH5 | Available | Available | | |
| PRS.ASYNCH6 | | | Available | Available |
| PRS.ASYNCH7 | | | Available | Available |
| PRS.ASYNCH8 | | | Available | Available |
| PRS.ASYNCH9 | | | Available | Available |
| PRS.SYNCH0 | Available | Available | Available | Available |
| PRS.SYNCH1 | Available | Available | Available | Available |
| PRS.SYNCH2 | Available | Available | Available | Available |
| PRS.SYNCH3 | Available | Available | Available | Available |
| TIMER0.CC0 | Available | Available | Available | Available |
| TIMER0.CC1 | Available | Available | Available | Available |
| TIMER0.CC2 | Available | Available | Available | Available |
| TIMER0.CDTI0 | Available | Available | Available | Available |
| TIMER0.CDTI1 | Available | Available | Available | Available |
| TIMER0.CDTI2 | Available | Available | Available | Available |
| TIMER1.CC0 | Available | Available | Available | Available |
| TIMER1.CC1 | Available | Available | Available | Available |
| TIMER1.CC2 | Available | Available | Available | Available |
| TIMER1.CDTI0 | Available | Available | Available | Available |
| TIMER1.CDTI1 | Available | Available | Available | Available |
| TIMER1.CDTI2 | Available | Available | Available | Available |
| TIMER2.CC0 | Available | Available | | |
| TIMER2.CC1 | Available | Available | | |
| TIMER2.CC2 | Available | Available | | |

| Peripheral.Resource | PORT | | | |
|---------------------|-----------|-----------|-----------|-----------|
| | PA | PB | PC | PD |
| TIMER2.CDTI0 | Available | Available | | |
| TIMER2.CDTI1 | Available | Available | | |
| TIMER2.CDTI2 | Available | Available | | |
| TIMER3.CC0 | | | Available | Available |
| TIMER3.CC1 | | | Available | Available |
| TIMER3.CC2 | | | Available | Available |
| TIMER3.CDTI0 | | | Available | Available |
| TIMER3.CDTI1 | | | Available | Available |
| TIMER3.CDTI2 | | | Available | Available |
| TIMER4.CC0 | Available | Available | | |
| TIMER4.CC1 | Available | Available | | |
| TIMER4.CC2 | Available | Available | | |
| TIMER4.CDTI0 | Available | Available | | |
| TIMER4.CDTI1 | Available | Available | | |
| TIMER4.CDTI2 | Available | Available | | |
| USART0.CLK | Available | Available | Available | Available |
| USART0.CS | Available | Available | Available | Available |
| USART0.CTS | Available | Available | Available | Available |
| USART0.RTS | Available | Available | Available | Available |
| USART0.RX | Available | Available | Available | Available |
| USART0.TX | Available | Available | Available | Available |
| USART1.CLK | Available | Available | | |
| USART1.CS | Available | Available | | |
| USART1.CTS | Available | Available | | |
| USART1.RTS | Available | Available | | |
| USART1.RX | Available | Available | | |
| USART1.TX | Available | Available | | |

7. QFN32 Package Specifications

7.1 QFN32 Package Dimensions

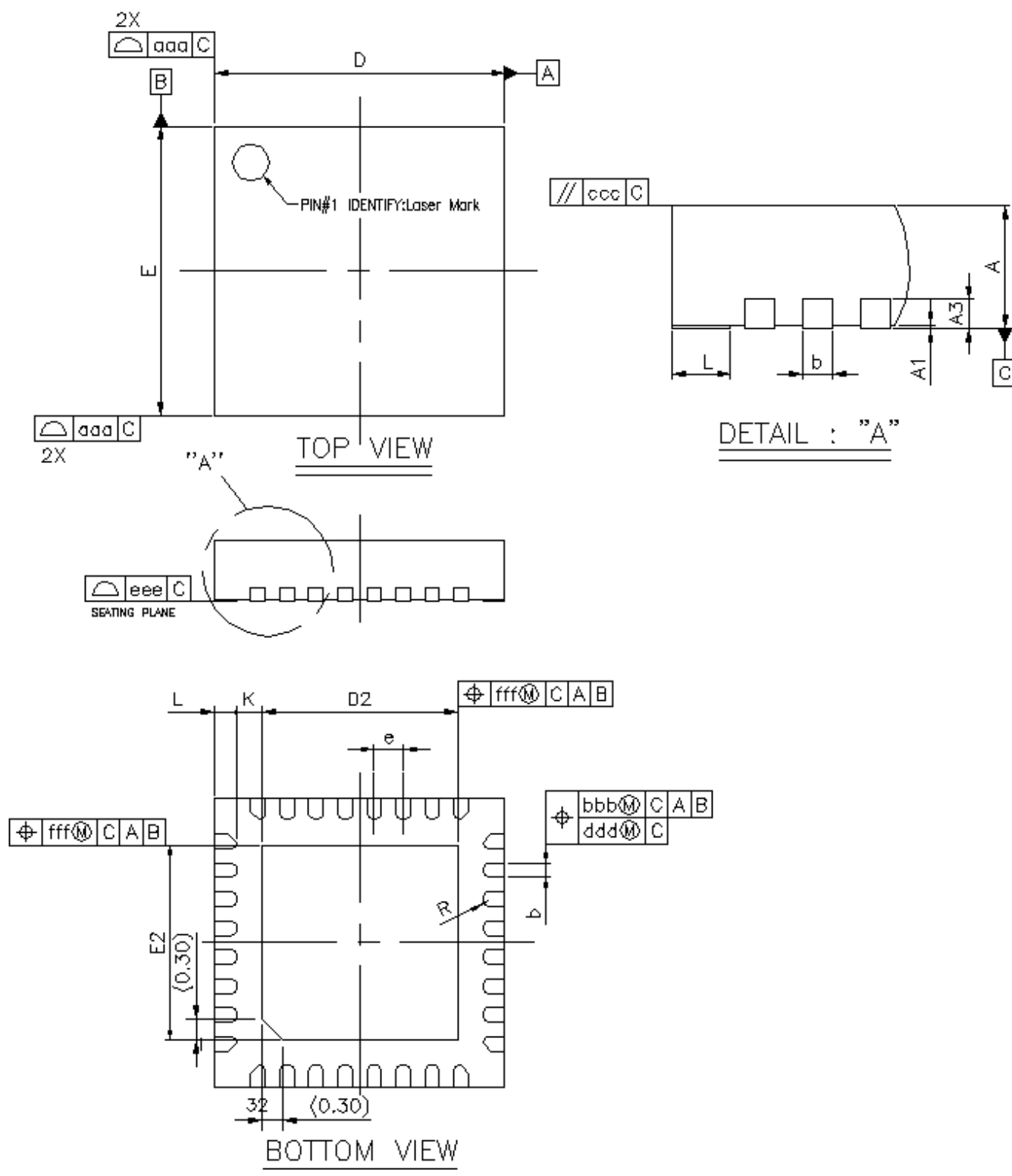


Figure 7.1. QFN32 Package Drawing

Table 7.1. QFN32 Package Dimensions

| Dimension | Min | Typ | Max |
|-----------|----------|------|-------|
| A | 0.80 | 0.85 | 0.90 |
| A1 | 0.00 | 0.02 | 0.05 |
| A3 | 0.20 REF | | |
| b | 0.15 | 0.20 | 0.25 |
| D | 3.90 | 4.00 | 4.10 |
| E | 3.90 | 4.00 | 4.10 |
| D2 | 2.60 | 2.70 | 2.80 |
| E2 | 2.60 | 2.70 | 2.80 |
| e | 0.40 BSC | | |
| L | 0.20 | 0.30 | 0.40 |
| K | 0.20 | — | — |
| R | 0.075 | — | 0.125 |
| aaa | 0.10 | | |
| bbb | 0.07 | | |
| ccc | 0.10 | | |
| ddd | 0.05 | | |
| eee | 0.08 | | |
| fff | 0.10 | | |

Note:

1. All dimensions shown are in millimeters (mm) unless otherwise noted.
2. Dimensioning and Tolerancing per ANSI Y14.5M-1994.
3. This drawing conforms to the JEDEC Solid State Outline MO-220, Variation VKKD-4.
4. Recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components.

7.2 QFN32 PCB Land Pattern

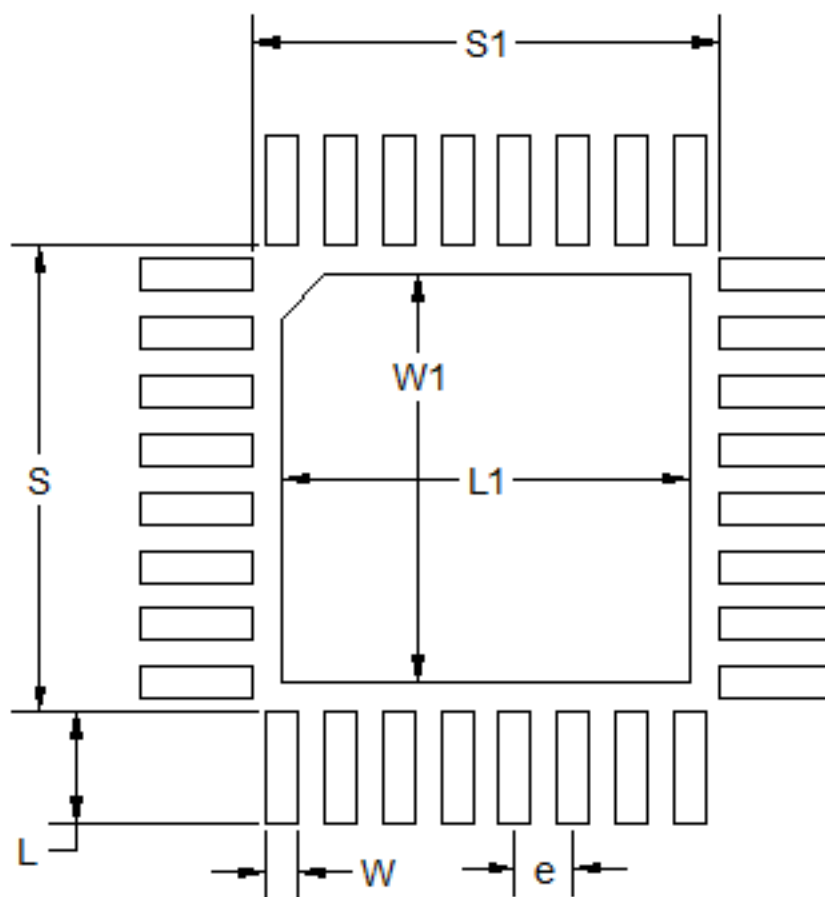


Figure 7.2. QFN32 PCB Land Pattern Drawing

Table 7.2. QFN32 PCB Land Pattern Dimensions

| Dimension | Typ |
|-----------|------|
| L | 0.76 |
| W | 0.22 |
| e | 0.40 |
| S | 3.21 |
| S1 | 3.21 |
| L1 | 2.80 |
| W1 | 2.80 |

Note:

1. All dimensions shown are in millimeters (mm) unless otherwise noted.
2. This Land Pattern Design is based on the IPC-7351 guidelines.
3. All metal pads are to be non-solder mask defined (NSMD). Clearance between the solder mask and the metal pad is to be 60 μm minimum, all the way around the pad.
4. A stainless steel, laser-cut and electro-polished stencil with trapezoidal walls should be used to assure good solder paste release.
5. The stencil thickness should be 0.101 mm (4 mils).
6. The ratio of stencil aperture to land pad size can be 1:1 for all perimeter pads.
7. A 2x2 array of 1.10 mm x 1.10 mm openings on a 1.30 mm pitch can be used for the center ground pad.
8. A No-Clean, Type-3 solder paste is recommended.
9. The recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components.
10. ***Above notes and stencil design are shared as recommendations only. A customer or user may find it necessary to use different parameters and fine tune their SMT process as required for their application and tooling.***

7.3 QFN32 Package Marking

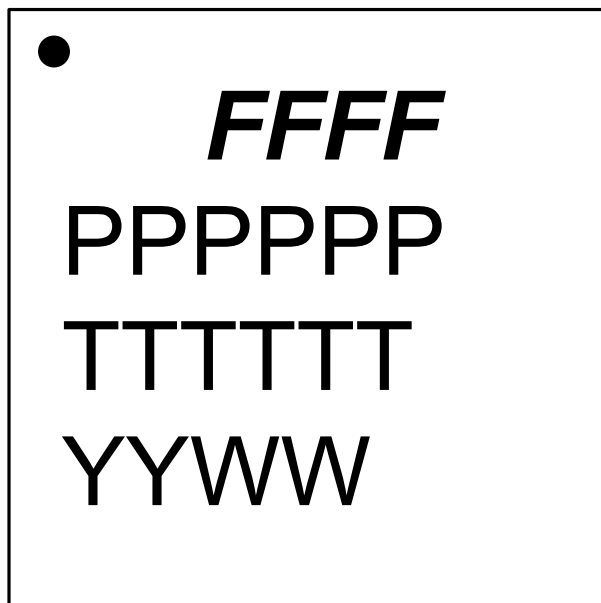


Figure 7.3. QFN32 Package Marking

The package marking consists of:

- FFFF – The product family codes.
 1. Family Code (B | M | F)
 2. G (Gecko)
 3. Series (2)
 4. Device Configuration (1, 2, 3, ...)
- P P P P P P – The product option codes.
 - 1-2. MCU Feature Codes
 - 3-4. Radio Feature Codes
 - 5. Flash (J = 1024k | I = 768k | H = 512k | W= 352k | G = 256k | F = 128k)
 - 6. Temperature grade (G = -40 to 85 °C | I = -40 to 125 °C)
- T T T T T T – A trace or manufacturing code. The first letter is the device revision.
- Y Y – The last 2 digits of the assembly year.
- W W – The 2-digit workweek when the device was assembled.

8. TQFN32 Package Specifications

8.1 TQFN32 Package Dimensions

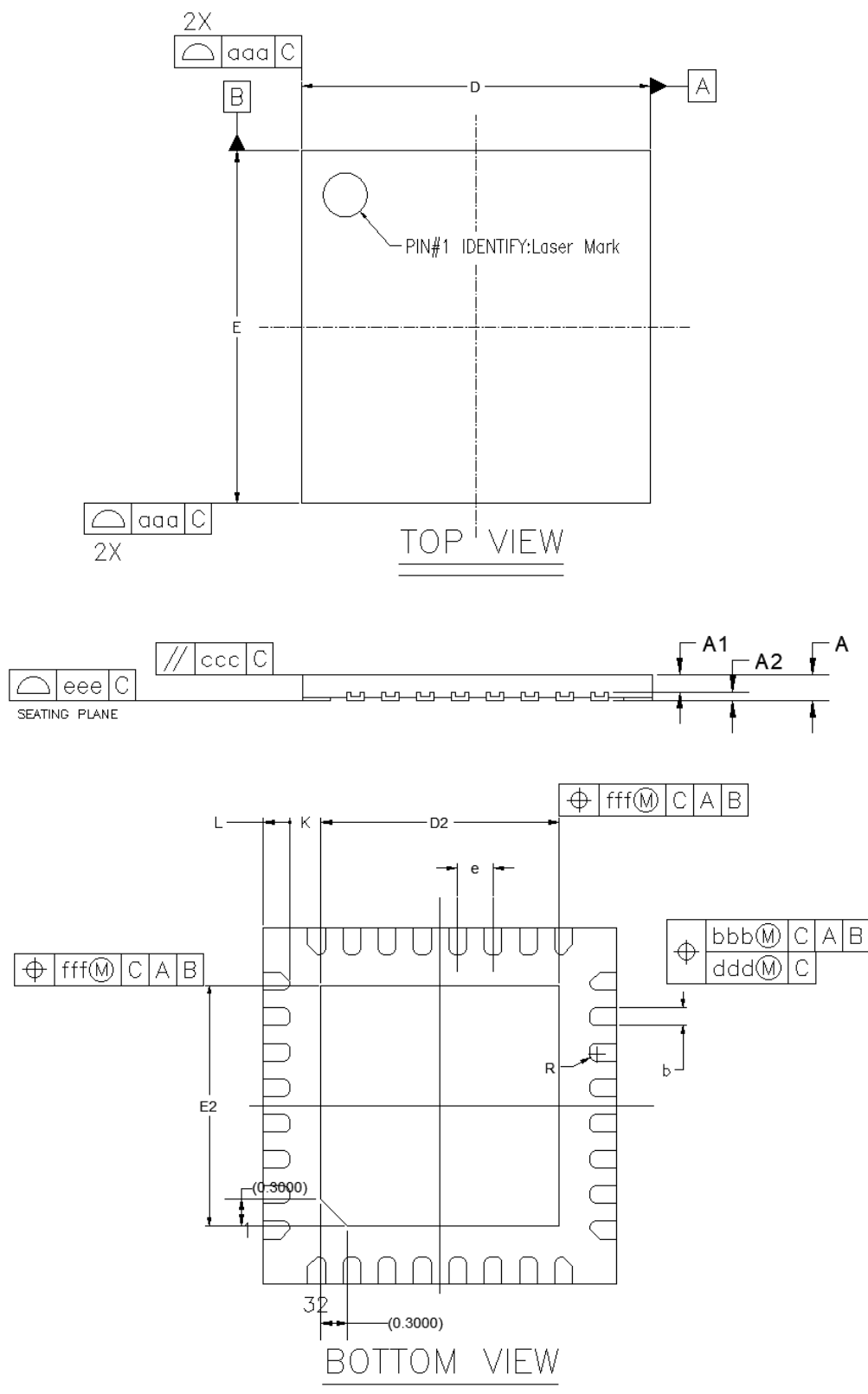


Figure 8.1. TQFN32 Package Drawing

Table 8.1. TQFN32 Package Dimensions

| Dimension | Min | Typ | Max |
|-----------|----------|------|-------|
| A | 0.27 | 0.30 | 0.33 |
| A1 | 0.20 REF | | |
| A2 | 0.10 REF | | |
| b | 0.15 | 0.20 | 0.25 |
| D | 3.90 | 4.00 | 4.10 |
| E | 3.90 | 4.00 | 4.10 |
| D2 | 2.60 | 2.70 | 2.80 |
| E2 | 2.60 | 2.70 | 2.80 |
| e | 0.40 BSC | | |
| L | 0.31 | 0.32 | 0.33 |
| K | 0.33 REF | | |
| R | 0.075 | — | 0.125 |
| aaa | 0.10 | | |
| bbb | 0.07 | | |
| ccc | 0.10 | | |
| ddd | 0.05 | | |
| eee | 0.08 | | |
| fff | 0.10 | | |

Note:

1. All dimensions shown are in millimeters (mm) unless otherwise noted.
2. Dimensioning and Tolerancing per ANSI Y14.5M-1994.
3. This drawing conforms to the JEDEC Solid State Outline MO-220, Variation VKKD-4.
4. Recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components.

8.2 TQFN32 PCB Land Pattern

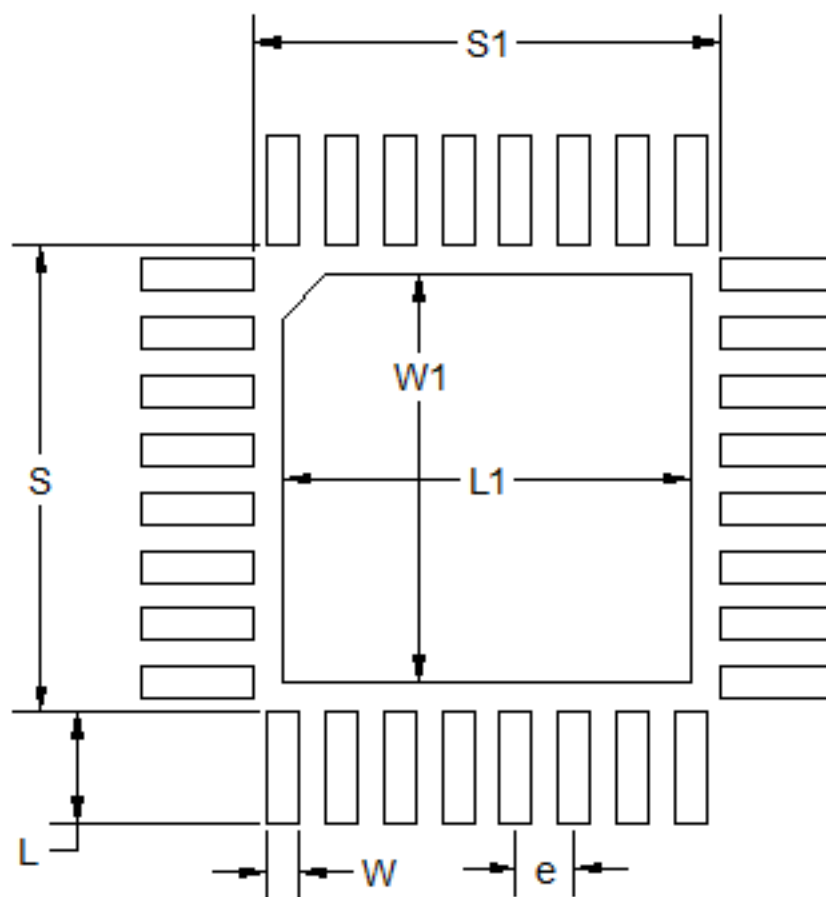


Figure 8.2. TQFN32 PCB Land Pattern Drawing

Table 8.2. TQFN32 PCB Land Pattern Dimensions

| Dimension | Typ |
|-----------|------|
| L | 0.76 |
| W | 0.22 |
| e | 0.40 |
| S | 3.21 |
| S1 | 3.21 |
| L1 | 2.80 |
| W1 | 2.80 |

Note:

1. All dimensions shown are in millimeters (mm) unless otherwise noted.
2. This Land Pattern Design is based on the IPC-7351 guidelines.
3. All metal pads are to be non-solder mask defined (NSMD). Clearance between the solder mask and the metal pad is to be 60 μm minimum, all the way around the pad.
4. A stainless steel, laser-cut and electro-polished stencil with trapezoidal walls should be used to assure good solder paste release.
5. The stencil thickness should be 0.101 mm (4 mils).
6. The ratio of stencil aperture to land pad size can be 1:1 for all perimeter pads.
7. A 2x2 array of 1.10 mm x 1.10 mm openings on a 1.30 mm pitch can be used for the center ground pad.
8. A No-Clean, Type-3 solder paste is recommended.
9. The recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components.
10. **Above notes and stencil design are shared as recommendations only. A customer or user may find it necessary to use different parameters and fine tune their SMT process as required for their application and tooling.**

8.3 TQFN32 Package Marking

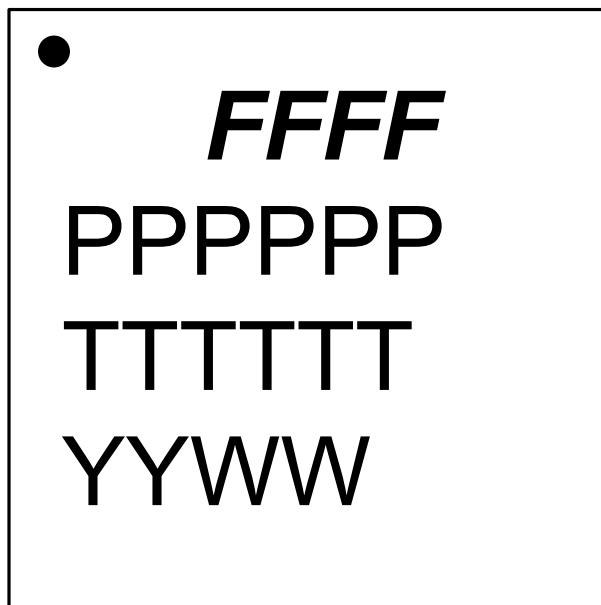


Figure 8.3. TQFN32 Package Marking

The package marking consists of:

- FFFF – The product family codes.
 1. Family Code (B | M | F)
 2. G (Gecko)
 3. Series (2)
 4. Device Configuration (1, 2, 3, ...)
- P P P P P P – The product option codes.
 - 1-2. MCU Feature Codes
 - 3-4. Radio Feature Codes
 - 5. Flash (J = 1024k | I = 768k | H = 512k | W= 352k | G = 256k | F = 128k)
 - 6. Temperature grade (G = -40 to 85 °C | I = -40 to 125 °C)
- T T T T T T – A trace or manufacturing code. The first letter is the device revision.
- Y Y – The last 2 digits of the assembly year.
- W W – The 2-digit workweek when the device was assembled.

9. QFN40 Package Specifications

9.1 QFN40 Package Dimensions

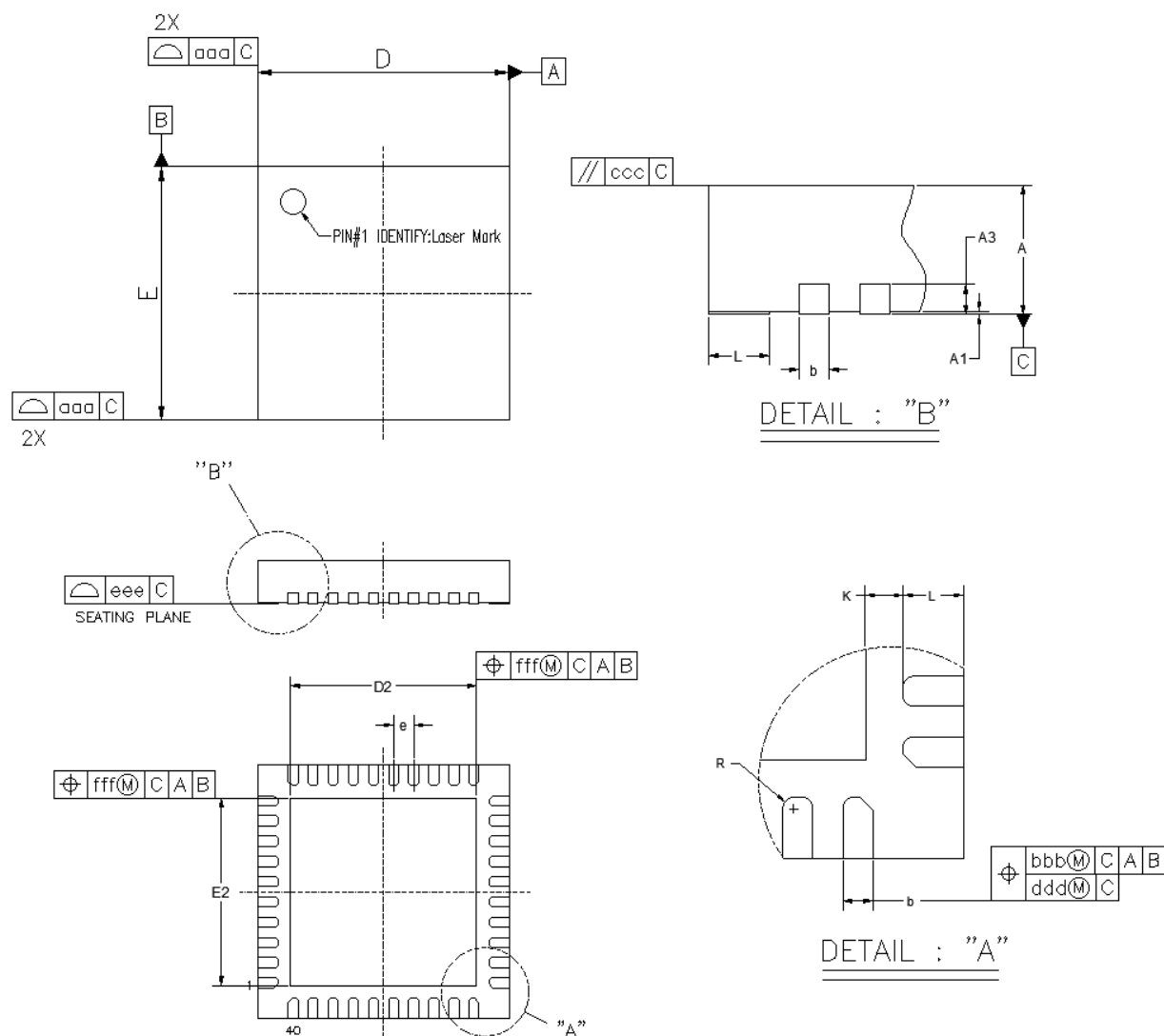


Figure 9.1. QFN40 Package Drawing

Table 9.1. QFN40 Package Dimensions

| Dimension | Min | Typ | Max |
|-----------|----------|------|------|
| A | 0.80 | 0.85 | 0.90 |
| A1 | 0.00 | 0.02 | 0.05 |
| A3 | 0.20 REF | | |
| b | 0.15 | 0.20 | 0.25 |
| D | 4.90 | 5.00 | 5.10 |
| E | 4.90 | 5.00 | 5.10 |
| D2 | 3.55 | 3.70 | 3.85 |
| E2 | 3.55 | 3.70 | 3.85 |
| e | 0.40 BSC | | |
| L | 0.30 | 0.40 | 0.50 |
| K | 0.20 | — | — |
| R | 0.075 | — | — |
| aaa | 0.10 | | |
| bbb | 0.07 | | |
| ccc | 0.10 | | |
| ddd | 0.05 | | |
| eee | 0.08 | | |
| fff | 0.10 | | |

Note:

1. All dimensions shown are in millimeters (mm) unless otherwise noted.
2. Dimensioning and Tolerancing per ANSI Y14.5M-1994.
3. This drawing conforms to the JEDEC Solid State Outline MO-220, Variation VKKD-4.
4. Recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components.

9.2 QFN40 PCB Land Pattern

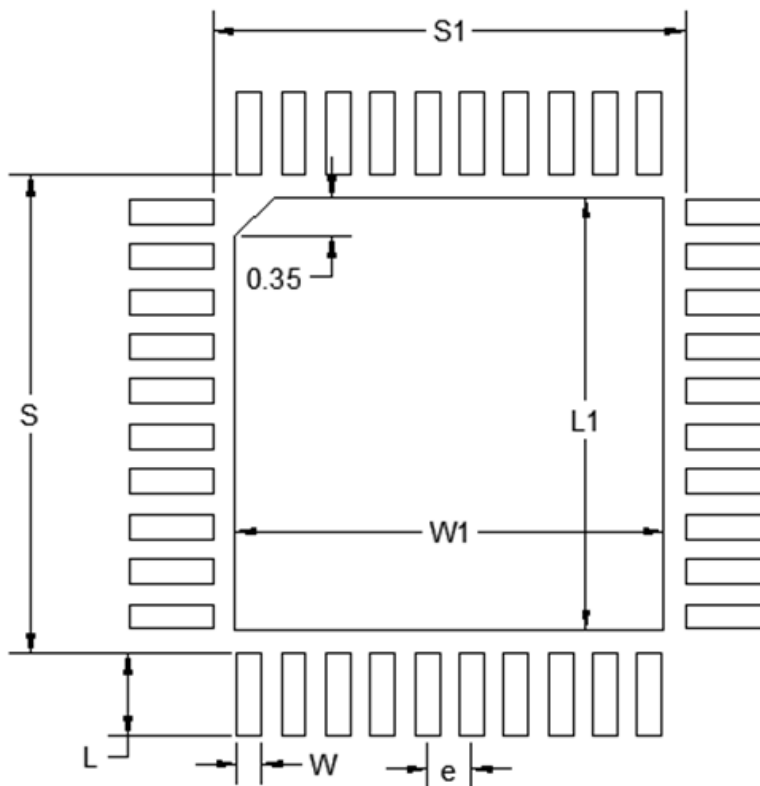


Figure 9.2. QFN40 PCB Land Pattern Drawing

Table 9.2. QFN40 PCB Land Pattern Dimensions

| Dimension | Typ |
|-----------|------|
| S1 | 4.25 |
| S | 4.25 |
| L1 | 3.85 |
| W1 | 3.85 |
| e | 0.40 |
| W | 0.22 |
| L | 0.74 |

Note:

1. All dimensions shown are in millimeters (mm) unless otherwise noted.
2. This Land Pattern Design is based on the IPC-7351 guidelines.
3. A stainless steel, laser-cut and electro-polished stencil with trapezoidal walls should be used to assure good solder paste release.
4. The stencil thickness should be 0.101 mm (4 mils).
5. The ratio of stencil aperture to land pad size can be 1:1 for all perimeter pads.
6. A 3x3 array of 0.90 mm square openings on a 1.20 mm pitch can be used for the center ground pad.
7. A No-Clean, Type-3 solder paste is recommended.
8. The recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components.
9. **Above notes and stencil design are shared as recommendations only. A customer or user may find it necessary to use different parameters and fine tune their SMT process as required for their application and tooling.**

9.3 QFN40 Package Marking

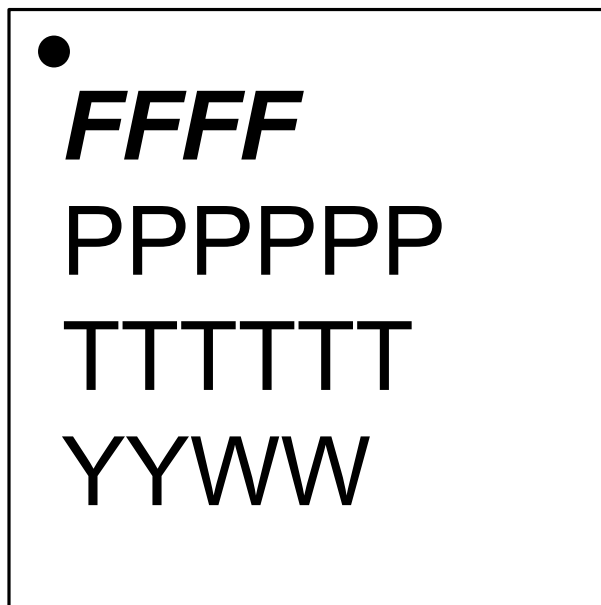


Figure 9.3. QFN40 Package Marking

The package marking consists of:

- FFFF – The product family codes.
 1. Family Code (B | M | F)
 2. G (Gecko)
 3. Series (2)
 4. Device Configuration (1, 2, 3, ...)
- P P P P P P – The product option codes.
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 - 6. Temperature grade (G = -40 to 85 °C | I = -40 to 125 °C)
- T T T T T T – A trace or manufacturing code. The first letter is the device revision.
- Y Y – The last 2 digits of the assembly year.
- W W – The 2-digit workweek when the device was assembled.

10. Revision History

Revision 0.5

February, 2020

- [1. Feature List](#): Updated list slightly to highlight different features.
- Expanded [3.7 Security Features](#) section and corrected security details.
- Added [3.9.2 Voltage Scaling](#) section.
- [4.1 Electrical Characteristics](#):
 - Additional characterization results and test limits added where available.
 - Removed thermistor driver specification table until full software support becomes available.
- Updated [5.2 RF Matching Networks](#) section with recommended match values.
- Updated [9.3 QFN40 Package Marking](#) with mark details.

Revision 0.4

December, 2019

- [4.1 Electrical Characteristics](#):
 - Added detailed lifetime information to DC-DC specifications section.
 - Additional characterization results and preliminary test limits added where available.
- Added DC-DC efficiency plots and updated supply current plots to [4.20 Typical Performance Curves](#).

Revision 0.3

October, 2019

- In the front page block diagram, updated the lowest energy mode for LETIMER.
- Updated [3.5.2 Low Energy Timer \(LETIMER\)](#) lowest energy mode.
- [1. Feature List](#) updated with additional modulation formats, protocol stack, and security details.
- [2. Ordering Information](#):
 - OPN numbering changes for security grade differentiator.
 - Supported protocol stack details updated.
- [4.1 Electrical Characteristics](#):
 - Additional characterization results and preliminary test limits added where available.
 - Corrected maximum clock speed details in General Operating Conditions Table.
 - Removed specification lines with 3 dBm output power conditions from RF transmit tables.
 - Removed DECOUPLE BOD table.
 - Added timing diagrams and specifications for PDM and USART SPI.
- Added [4.20 Typical Performance Curves](#).

Revision 0.2

July, 2019

- [2. Ordering Information](#): Updated part number to revision C, added several new variants.
- [4.1 Electrical Characteristics](#): Added early silicon characterization data to several tables, and refined specification conditions.
- [4.1 Electrical Characteristics](#): Added flash electrical characteristics table.
- Minor wording edits for System Overview sections.

Revision 0.1

April, 2019

Initial release.

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