Presentation Will Begin Shortly

4:00

BLUETOOTH

FEB 29TH	Small Bluetooth Devices - How to Minimize Size without Compromising Performance and Reliability
APR 4TH	Bluetooth LE Application Development Journey
MAY 9TH	Unboxing Silicon Labs' Latest Bluetooth SoC for Energy Harvesting
JUN 13TH	Explore Bluetooth Channel Sounding

Welcome

Small Bluetooth Devices:
How to Minimize Size without Compromising Performance and Reliability

Introduction

Matt Maupin

- Matt Maupin is a Senior Marketing Manager at Silicon Labs where he leads a Marketing team for IoT wireless hardware and software. Matt joined Silicon Labs in 2012 and has been in the semiconductor industry for over 20 years, defining and launching wireless ICs and modules, including Wi-Fi®, Bluetooth®, Zigbee, Z-Wave and proprietary solutions.

Brian Blum

- Brian Blum is a Senior Marketing Manager at Silicon Labs focused on the Portable Medical market segment. Brian has worked in the semiconductor industry in design, development, and marketing for over 18 years in a variety of technical roles. Brian has a deep technical background in the domain of embedded hardwre, software and wireless protocols.

Pasi Rahikkala

- Pasi Rahikkala is a Senior Systems Engineer at Silicon Labs with 18 years working experience with radio modules, antennas and regulatory certifications. He holds antenna patents for Silicon Labs modules and has been developing antennas and simulations methods for systems such as AoA (Angle of Arrival) and HADM (High Accuracy Distance Measurement).

Agenda

01 Why Miniaturize

02 Challenges of Miniaturization

03 How to Miniaturize

04 Case Studies

05 Silicon Labs Small Bluetooth Solutions

06 Summary and Q&A

Why Miniaturize Wireless Devices

Wireless miniaturization is being driven across industries

- **Medical, consumer, commercial and industrial**
- **May be a small form factor device, or just space constrained**

Bluetooth is ideal for miniaturization

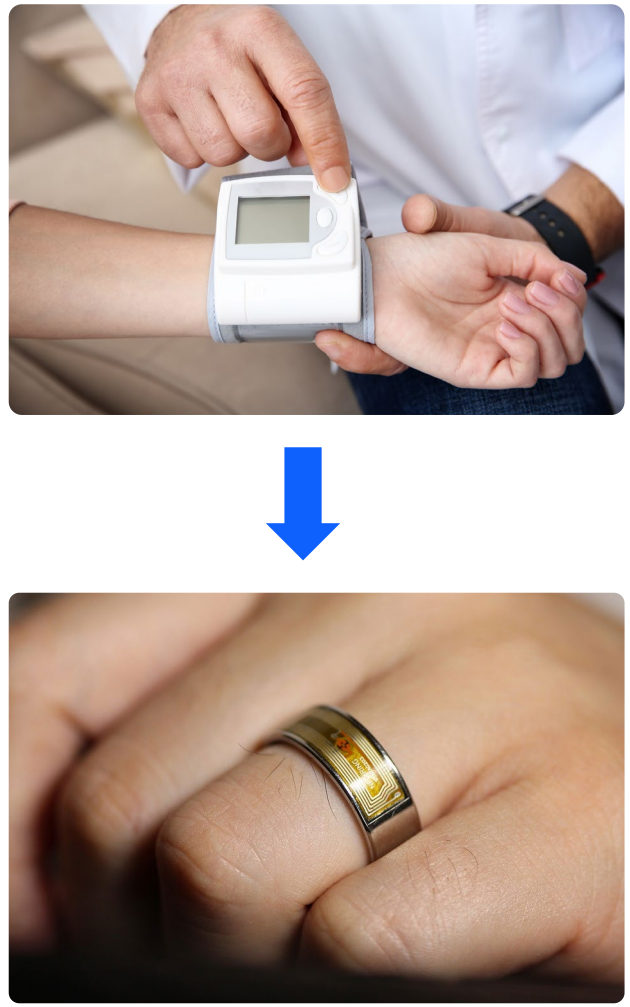
- **Low power consumption**
- **Connection to mobile phone**

Drivers

1. **Consumer Appeal**
   - Buyers prefer small and sleek designs
2. **Enables New Connected Applications**
   - Watches, rings, CGM, trackers, sensors, circuit breakers
3. **New Revenue Opportunities**
   - Enables new use cases and ability to differentiate
4. **Increased Usability**
   - Ergonomic, convenient, and discrete

The Challenges of Miniaturizing Wireless Devices

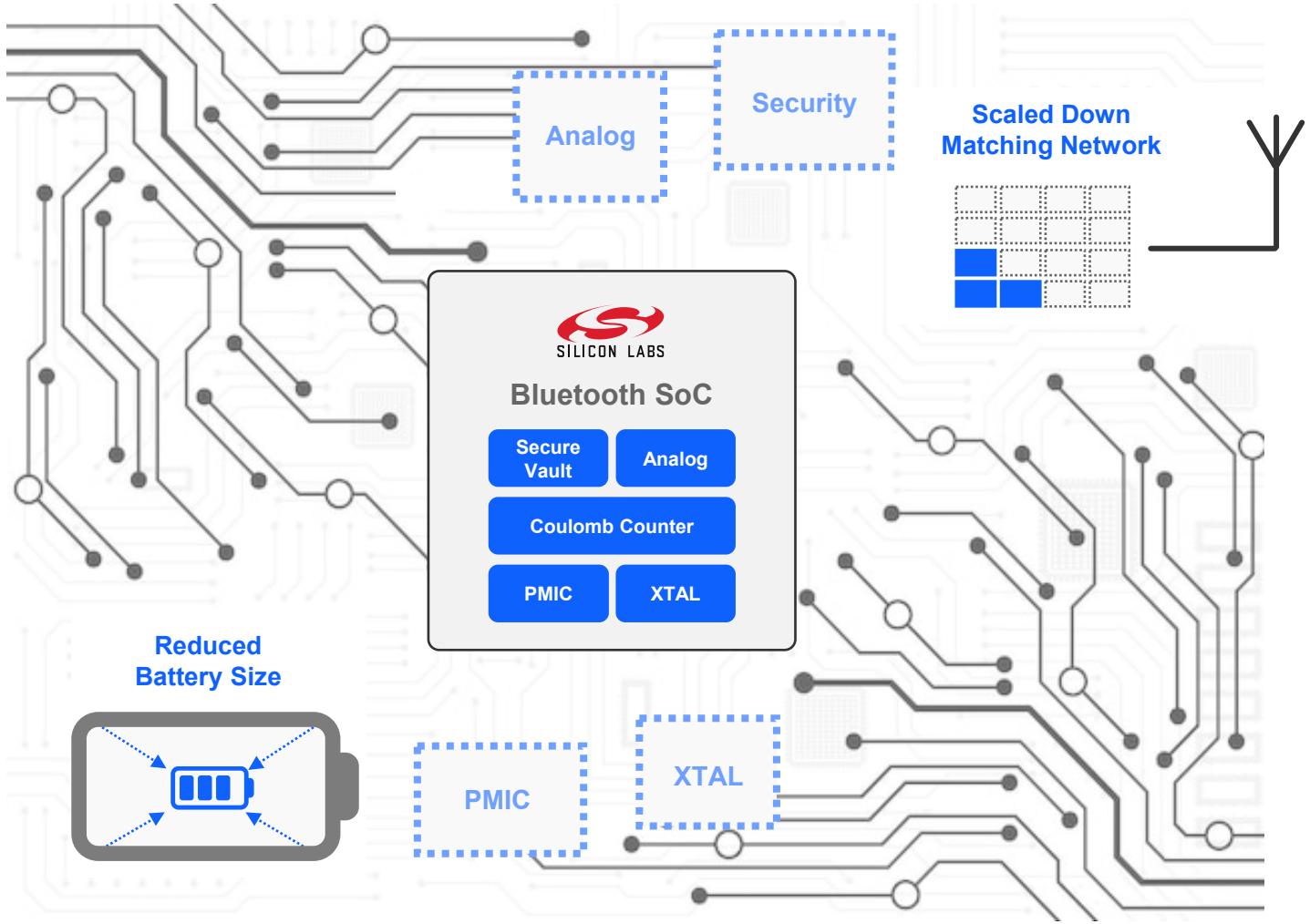
- **Design complexity**
  - Layout, interference and thermal issues
- **Battery life**
  - Smaller batteries provide lower capacity and voltage
- **Product features**
  - Additional features increase area
- **RF performance and regulatory compliance**
  - Smaller designs impact RF performance
- **Cost**
  - Increased MFG and components cost



How to Miniaturize

Reducing Device Size Through SoC Integration

- **Wireless communication**
  - High performance wireless
  - Simplified RF matching network
- **Power management**
  - Integrated DC-DC
- **Security**
  - Eliminates need for external security chip
- **Low-frequency RC oscillator**
  - Eliminates external 32KHz XTAL
- **Analog peripherals – ADC/DAC**
  - Eliminates external analog components
- **Low active and sleep currents**
  - Enables smaller capacity batteries

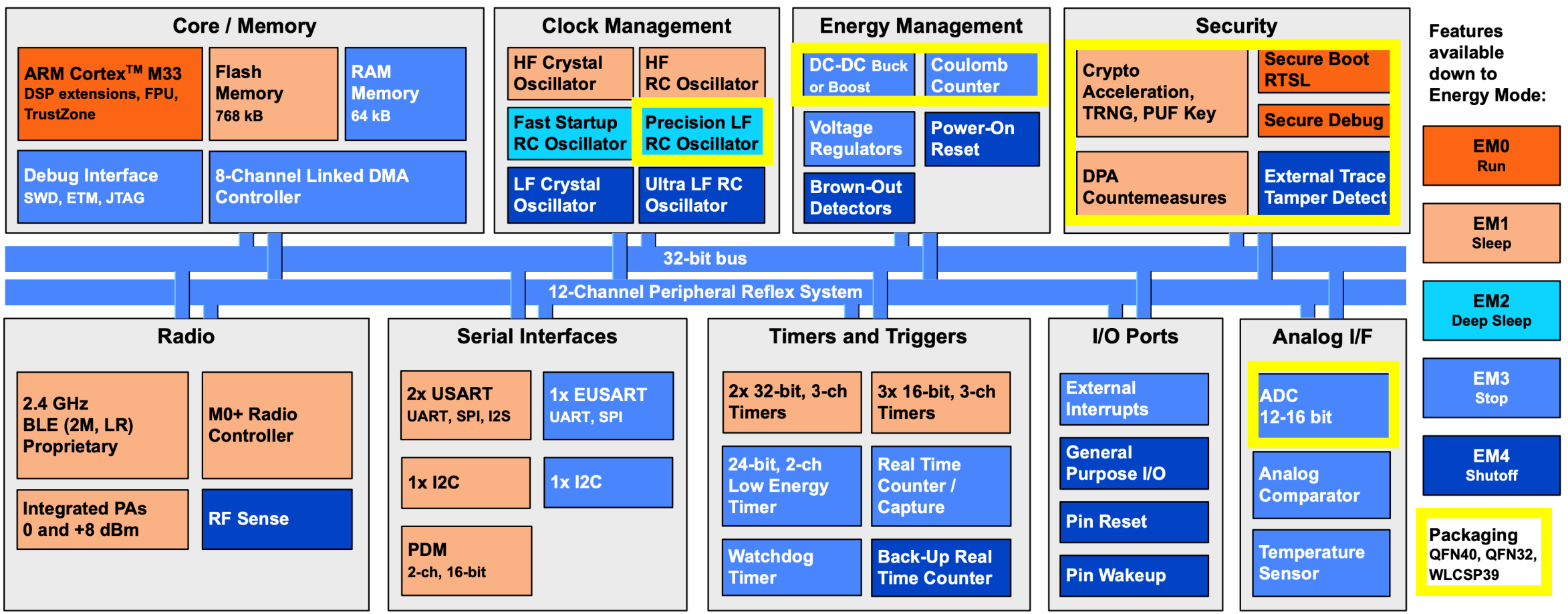


Choosing the Right Package for Your Application

Feature	QFN	TQFN	WLCSP	SiP
Size	BG22 (4 x 4 x 0.85mm)	BG22 (4 x 4 x 0.3mm)	BG27 (2.3 x 2.6 x 0.5mm)	BGM220S (6 x 6 x 1.1mm)
Thickness	Standard	Thinnest option	Thinner than standard QFN	Varies
I/O Count	Low to Moderate	Low to Moderate	Low to High	Moderate to High
Heat Dissipation	Good	Good	Depends on design	Good
Semiconductor Cost	Low	Low	Higher, due to processing costs	Higher, due to complexity
Product Manufacture Design Complexity	Normal	Normal	Higher due to more advanced routing	Higher due to more advanced routing
Assembly	Standard SMT techniques	Standard SMT techniques	Requires precision placement	Varies. May require precision placement
Time-To-Market	Normal	Normal	More than normal*	Fastest (RF Certified)

**Advanced Hardware Designs can extend Development time*

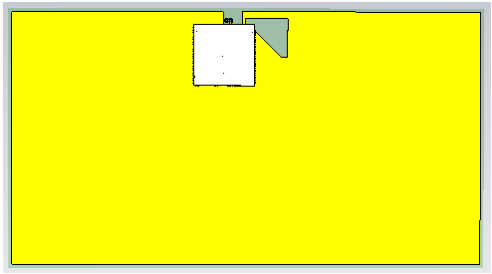
BG27 SoC Integration Block Diagram Example

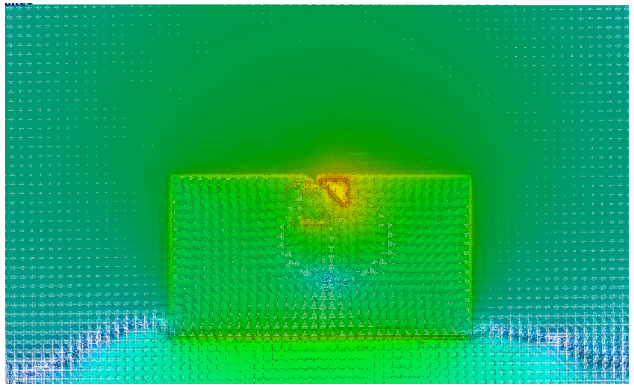


Antenna Design for Small Form Factor Devices

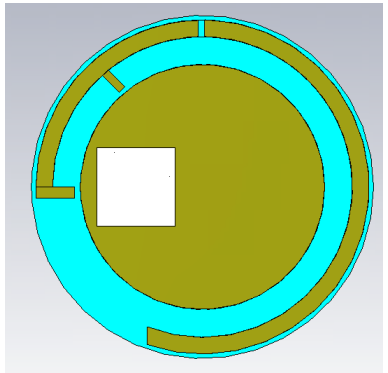
- **No one size fits all for antenna design**
  - No single antenna design will work optimally for all designs
- **The optimal selection of the antenna type depend on**
  - Physical size of the product
  - Range expectation
  - Technology (Wi-Fi, Bluetooth, etc.)
  - Mechanical constraints of the product
- **Most common antenna types for 2.4 GHz IoT are**
  - Ground radiating loop antennas
    - Ground radiating loop antennas are commonly used with modules
    - Due to their small size and immunity to loading with dielectric materials
  - Planar inverted-F antennas
  - Monopole / chip monopole antennas
- **The ground plane of the PCB is part of the antenna**
  - GND size/shape affects resonant frequency and radiation
  - Antenna can be designed into any size and shape board
- **The antenna can have significant impact to the link budget**
  - The antenna efficiencies typically vary between -1dB and -8dB
  - This means -2dB to -16dB variation in the link budget

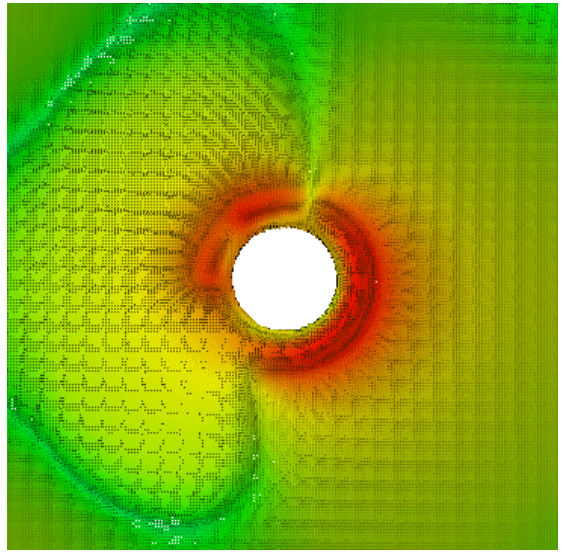
Ground Radiating Loop Antenna





Planar Inverted-F Antenna



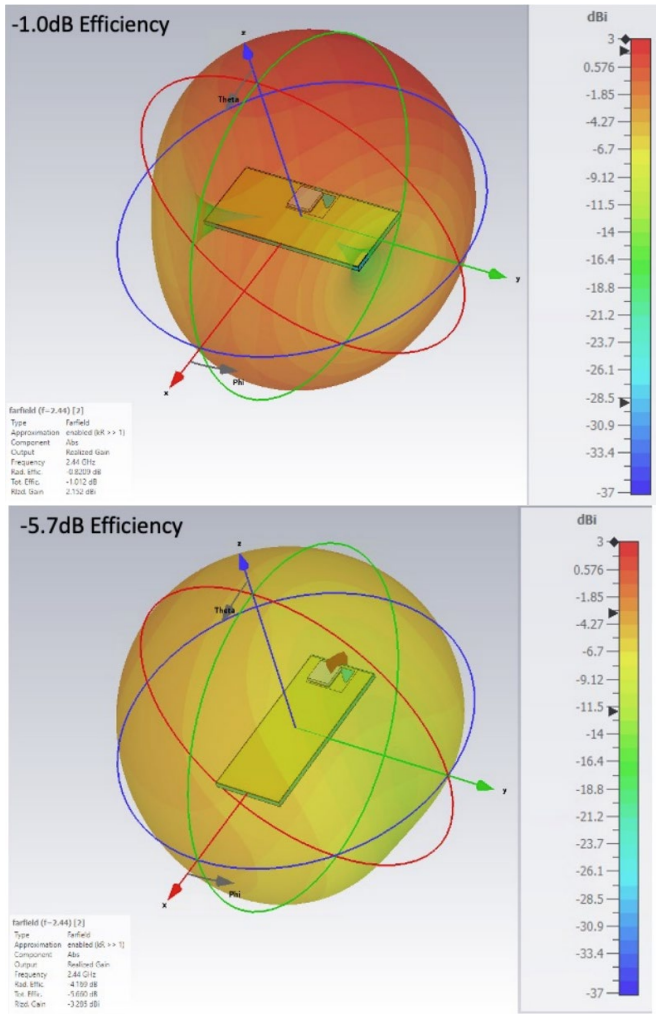


Silicon Labs Bluetooth Modules with Integrated Antennas

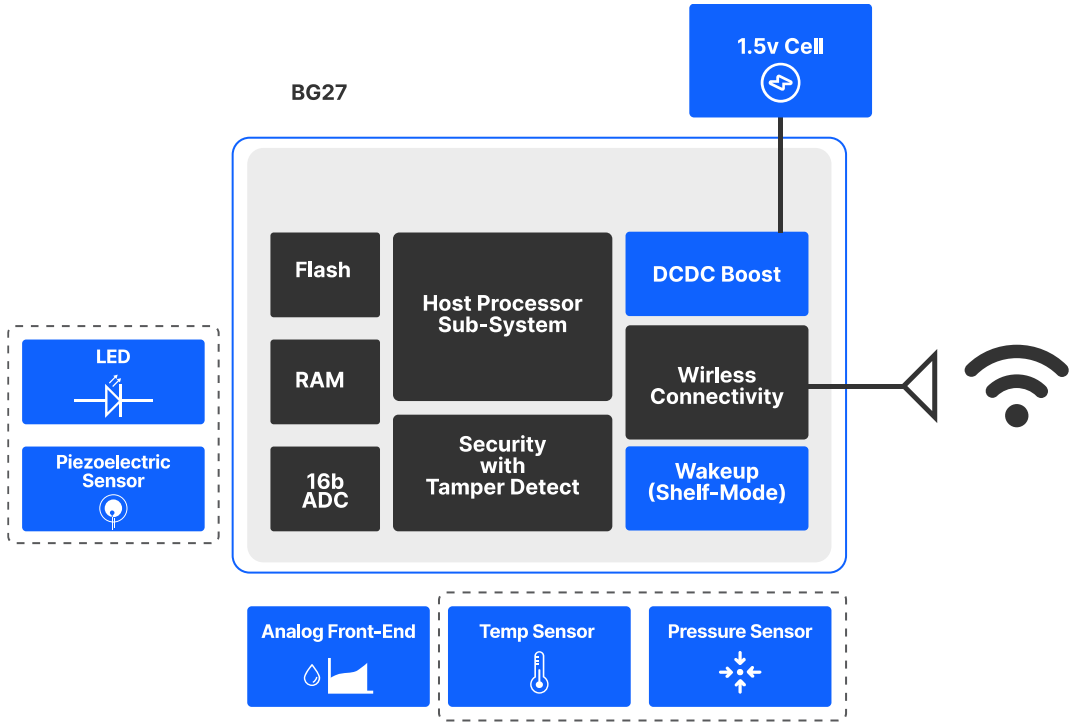
- **SiP Antenna Design Benefits**
  - Saves PCB space and design time
  - Pre-certified for various wireless standards and regions
    - Reduces time and cost of regulatory compliance and certification
  - Matched and tuned for the module's RF and PCB layout
    - Eliminates the need for external matching components and manual tuning
  - Optimized for performance and efficiency
    - Provides reliable wireless connectivity and low power consumption

- **Placement of module is still important**
  - Same size board can have 10 dB difference in the link budget

- **A custom antenna design is possible**
  - Connect the antenna to the RF pad of the module
  - Will need to certify the new antenna



Example System Solution for Miniature Portable Medical Device

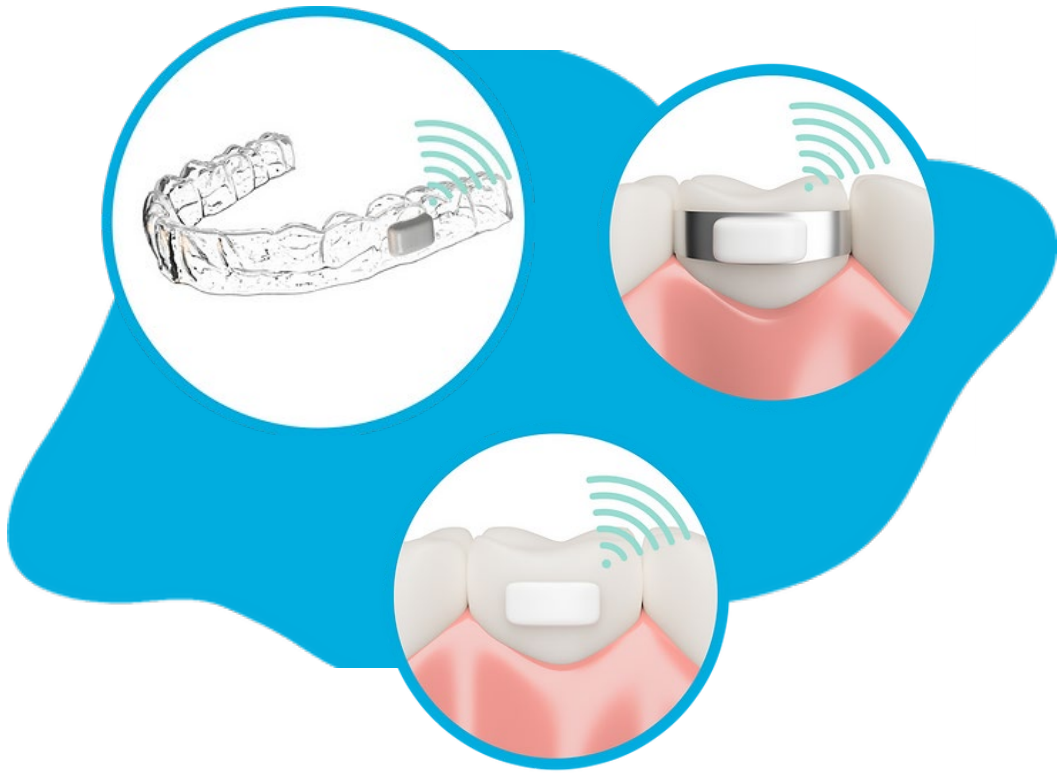


- **BG27**
  - Integrated application MCU + Bluetooth / 802.15. SoC
  - Memory for application and Bluetooth connectivity
  - Analog peripherals and interface to AFE (Analog Front-End)
  - 0.8-1.7V supply for optimized battery selection (button cell)
  - Secure Vault Mid – Secure Key Management, Anti-Tamper, more.
  - 16-bit ADC, GPIO, Serial interfaces, ACMP
  - Coulomb counter for accurate battery level tracking
  - Tiny 2.3 x 2.6 mm WL-CSP package
  - Shelf Mode draws <20 nA for stocking and transport

Questions

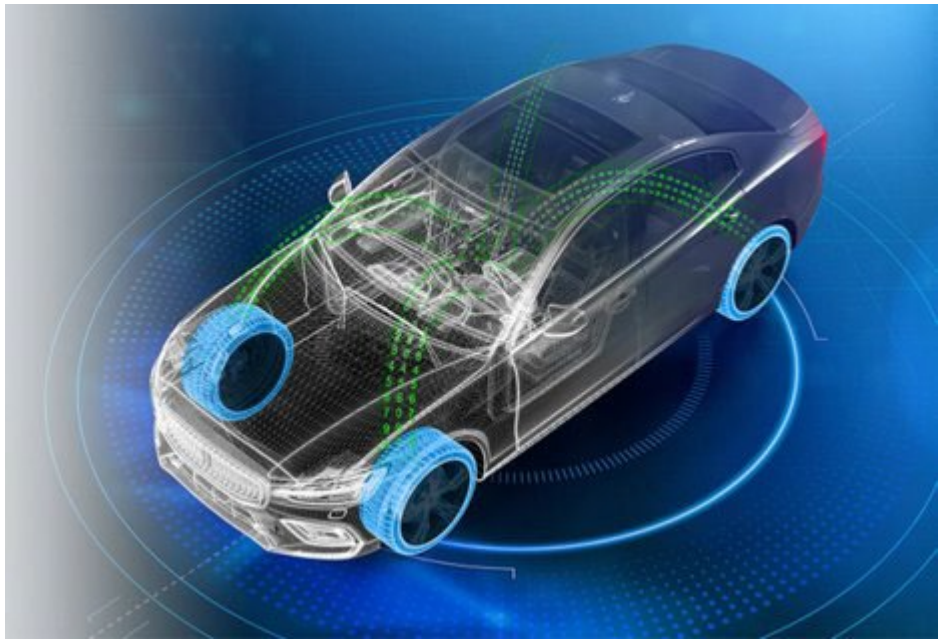
Case Studies

Lura Health Sensor for Salivary Diagnostics



- **Application and Use Case**
  - Smallest wearable medical device to date
  - The first device to continuously measures pH to help fight against tooth decay and erosion.
  - Future – possibility to measure electrolytes, glucose, and other Biologics
- **Product**
  - EFR32BG27
  - Bluetooth protocol
- **Key Features**
  - Small form factor (BG27 CSP package)
    - Lura Health device is less than 4x7mm
  - DC/DC Boost enabled tiny battery and low power
    - They needed months battery life
  - High level of security

Tire Pressure Monitoring



- **Application and Use Case**
  - Bluetooth LE Connected Tire Pressure Monitoring Sensor
  - Leveraged existing Bluetooth LE technology in vehicle
- **Products**
  - BG22
  - Bluetooth protocol
- **Key Features**
  - Low power consumption for longer batter life
    - OOK option to wake up device
  - Small package 4x4 package
  - +125ºC operating temperature

Silicon Labs Small Bluetooth Solutions

BG22

BG24

BG27

BG22 and BGM220: Lowest Power for Battery Powered End Devices

SOCS AND MODULES

BG22 SoC

BGM220S SiP Module

BGM220P PCB Module

SOC DEVICE SPECIFICATIONS

High Sensitivity 2.4 GHz Radio
- -98.9 dBm RX @ BLE 1 Mbps

Efficient ARM® Cortex®-M33
- Up to 76.8 MHz
- 512kB Flash, 32kB RAM

Low Power
- 27 µA/MHz
- 4.1 mA TX @ 0 dBm
- 3.6 mA RX (BLE 1 Mbps)
- 3.9 mA RX (802.15.4)
- 1.4 µA EM2 sleeps (32 kB retained)

Multiple protocol support
- Bluetooth 5.3 (1M/2M/LR)
- Bluetooth mesh LPN
- Direction Finding
- Proprietary 2.4 GHz

SoCs and Modules
- 5x5 QFN40 (26 GPIO) +125ºC
- 4x4 QFN32 (18 GPIO) +125ºC
- 4x4 TQFN32 (18 GPIO) +85ºC
- 6x6 SiP Module (25 GPIO) +105ºC
- 12.9x15.0 PCB Module (25 GPIO) +105ºC

DIFFERENTIATED FEATURES

- **Lowest Power RF**
  - Increases battery life
- **RFSense with OOK mode**
  - Ultra-low power receive mode
- **PLFRCO**
  - Eliminates need for 32 KHz xtal
- **16-bit ADC**
  - Up to 14-bit ENOB for better analog sensing

SEGMENTS AND APPLICATIONS

Smart Cities
- Livestock Management

Industrial
- Access Control
- Human Machine Interface
- Predictive Maintenance
- Asset Tracking

Commercial / Building
- Electronic Shelf Labels
- Clinical Medical
- Point of Sale
- Loss Prevention
- Indoor Real Time Location Services

Smart Home
- Appliances
- Locks
- Switches
- Sensors
- HVAC

Connected Health
- Portable Medical
- Smart Hospitals
- Smart Wearables

BG24 and BGM240: Ideal for Battery Powered IoT Mesh Devices

SOCS AND MODULES

BG24 SoC

BGM240S SiP Module

BGM240P PCB Module

SOC DEVICE SPECIFICATIONS

High Performance Radio
- Up to +19.5 dBm TX
- +4 dBm TX (CSP)
- -97.6 dBm RX @ BLE 1 Mbps

Efficient ARM® Cortex®-M33
- 78 MHz
- 1536kB Flash, 256kB RAM

Low Power
- 33.4 µA/MHz
- 5.0 mA TX @ 0 dBm
- 5.1 mA RX (802.15.4)
- 4.4 mA RX (BLE 1 Mbps)
- 1.41 µA EM2 sleep (32 kB retained)

Multiple protocol support
- Bluetooth 5.3 (1M/2M/LR)
- Bluetooth mesh
- Direction Finding
- Proprietary 2.4 GHz

SoCs and Modules
- 5x5 QFN40 (26 GPIO) +125ºC
- 6x6 QFN48 (32 GPIO) +125ºC
- 3.1x3.0 WLCSP42 (20 GPIO) +125ºC
- 7x7 SiP Module (32 GPIO) +105ºC
- 12.9x15.0 PCB Module (26 GPIO) +105ºC

DIFFERENTIATED FEATURES

+20 dBm output power
- Eliminates need for external power amplify

AI/ML accelerator
- Accelerates inferencing while reducing power consumption

Small form-factor
- 3.1x3.0mm WLCSP42 package

Secure Vault High
- Protects data and device from local and remote attacks

20-bit ADC
- 16-bit ENOB for advance sensing

PLFRCO
- Eliminates need for 32 KHz xtal

SEGMENTS AND APPLICATIONS

Smart Home
- HVAC
- Locks
- LED Lighting
- Switches
- Sensors
- Gateways, Hubs and Panels

Connected Health
- Portable Medical
- Clinical Medical

Industrial and Smart Buildings
- Access Control
- HVAC
- Predictive Maintenance
- Asset Tracking

Smart Cities
- EV Charging

Commercial
- Lighting
- Access Points
- Clinical Medical
- Indoor Real Time Location Services

BG27: Most Battery Versatile Series-2 SoC

SOCS AND MODULES

BG27 SoC

SOC DEVICE SPECIFICATIONS

High Performance 2.4 GHz Radio
- Up to +8 dBm TX
- +4 dBm TX (CSP)
- -99.2 dBm RX @ BLE 1 Mbps

Efficient ARM® Cortex®-M33
- 76.8 MHz
- 768kB Flash, 64kB RAM

Ultra Low Power
- 4.1 mA TX @ 0 dBm
- 3.6 mA RX (BLE 1 Mbps)
- 1.43 µA EM2 sleeps (32 kB retained)

Multiple protocol support
- Bluetooth 5.3 (1M/2M/LR)
- Bluetooth mesh
- Direction Finding
- Proprietary 2.4 GHz

Package
- 2.3x2.6 WLCSP (19 GPIO) +85ºC
- 5x5 QFN40 (26 GPIO) +125ºC
- 4x4 QFN32 (18 GPIO) +125ºC

DIFFERENTIATED FEATURES

Flexible battery support
- DCDC Buck/Boost
- Supports 0.8 to 1.7 volts
- Supports 1.7 to 3.6 volts

Enhanced security
- Secure Vault™ Mid
- Tamper detect
- Secure Key Management w/PUF

Battery management
- Coulomb counter

Wake-up pin (BOOST_EN)
- allows the device to be off (<20 nA) for long-term storage
- Up to 10 years of shelf storage

PLFRCO
- Eliminates need for 32 KHz xtal

Small form-factor
- 2.3 x 2.6mm WLCSP39 package

SEGMENTS AND APPLICATIONS

Medical and Health and Fitness
- Portable Medical
- Clinical Medical
- Wearables

Smart Home
- Appliances
- Door Locks
- Sensors
- Switches
- HVAC
- LED Lighting

Industrial & Commercial
- Access Control
- HMI
- HVAC
- Smart Buildings
- Asset Tracking
- Indoor RTLS
- Point of Sale
- Commercial Lighting
- Predictive Maintenance

Choosing the Right Package for Your Application

	QFN			TQFN	WLCSP		SiP	
	BG22	BG24	BG27	BG22	BG24	BG27	BGM220S	BGM240S
Device Type	IC	IC	IC	IC	IC	IC	Module	Module
Dimensions (mm)	4 x 4 x 0.85	5 x 5 x 0.85	4 x 4 x 0.85	4 x 4 x 0.30	3.1 x 3.0 x 0.4	2.29 x 2.62 x 0.5	6 x 6 x 1.1	7 x 7 x 1.18
Max Flash	512 kB	1536 kB	768 kB	512 kB	1536 kB	768 kB	512 kB	1536 kB
Max RAM	32 kB	256 kB	64 kB	32 kB	256 kB	64 kB	32 kB	256 kB
Max Output Power	+6 dBm	+19.5 dBm	+8 dBm	+6 dBm	+4 dBm	+4 dBm	+6 dBm	+10 dBm
RX Sensitivity (Bluetooth LE 1 Mbps)	-98.9 dBm	-97.6 dBm	-99.2 dBm	-98.9 dBm	-98.1 dBm	-99.6 dBm	-98.6 dBm	-97.0 dBm
TX Current (0 dBm transmitting packet)	4.3 mA	5.0 mA	4.3 mA	4.3 mA	4.9 mA	4.1mA	4.6 mA	4.6 mA
RX Current (1 Mbps receiving packet)	3.8 mA	4.7 mA	3.8 mA	3.8 mA	4.5 mA	3.8 mA	4.2 mA	5.1 mA
Sleep Current (EM2 32 kB retained)	1.40 µA	1.41 µA	1.43 µA	1.40 µA	1.41 µA	1.43 µA	1.40 µA	1.41 µA
Shutoff Current (EM4, wake on pin)	0.17 µA	0.25 µA	0.18 µA	0.17 µA	0.25 µA	0.18 µA	0.17 µA	0.31 µA
AI/ML Accelerator		✓			✓			
Analog to Digital Converter	16-bit	20-bit	16-bit	16-bit	16-bit	16-bit	16-bit	16-bit
Digital to Analog Converter (VDAC)		✓			✓			✓
Analog Comparator (ACMP)		✓	✓		✓	✓		✓
PLFRCO (500 ppm LFRCO)	✓	✓	✓	✓	✓	✓	✓	✓
Coulomb Counter			✓			✓		
Operating Voltage	1.71 to 3.8 V	1.71 to 3.8 V	0.8 to 1.7 V 1.8 to 3.8 V	1.71 to 3.8 V	1.71 to 3.8 V	0.8 to 1.7 V 1.8 to 3.8 V	1.8 to 3.8 V	1.8 to 3.8 V
Security	Secure Vault Mid	Secure Vault High	Secure Vault Mid	Secure Vault Mid	Secure Vault High	Secure Vault Mid	Secure Vault Mid	Secure Vault High
Security Certifications	SESIP L3 with DTSec PP	PSA L3, SESIP L3 w/ PSA, MCU, MPU profile	*SESIP L3 with DTSec PP	SESIP L3 with DTSec PP	PSA L3, SESIP L3 w/ PSA, MCU, MPU profile	*SESIP L3 with DTSec PP	SESIP L3 with DTSec PP	PSA L3, SESIP L3 w/ PSA, MCU, MPU profile

*Certification by similarity (BG22 subsystem)

Summary

- Product miniaturization is a system level approach
- SoC integration, low component count, battery type and antenna design are all key considerations
- Antenna design is critical for small form factor
- Silicon Labs provides a variety of solutions and reference designs to help with your design

Q&A

Thank you

tech talks

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