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BLE-202

Bringing Bluetooth 6.0 Channel Sounding to Market: Precision Ranging for Secure & Smart Applications

Gansu Natarajan

Senior Product Manager

Agenda

01 Technology Overview

02 Channel Sounding Applications

03 Silicon Labs Offerings

04 Algorithm Performance Data

05 Developer Tools

06 Q&A

Why Bluetooth® Channel Sounding?

THE CHALLENGE:

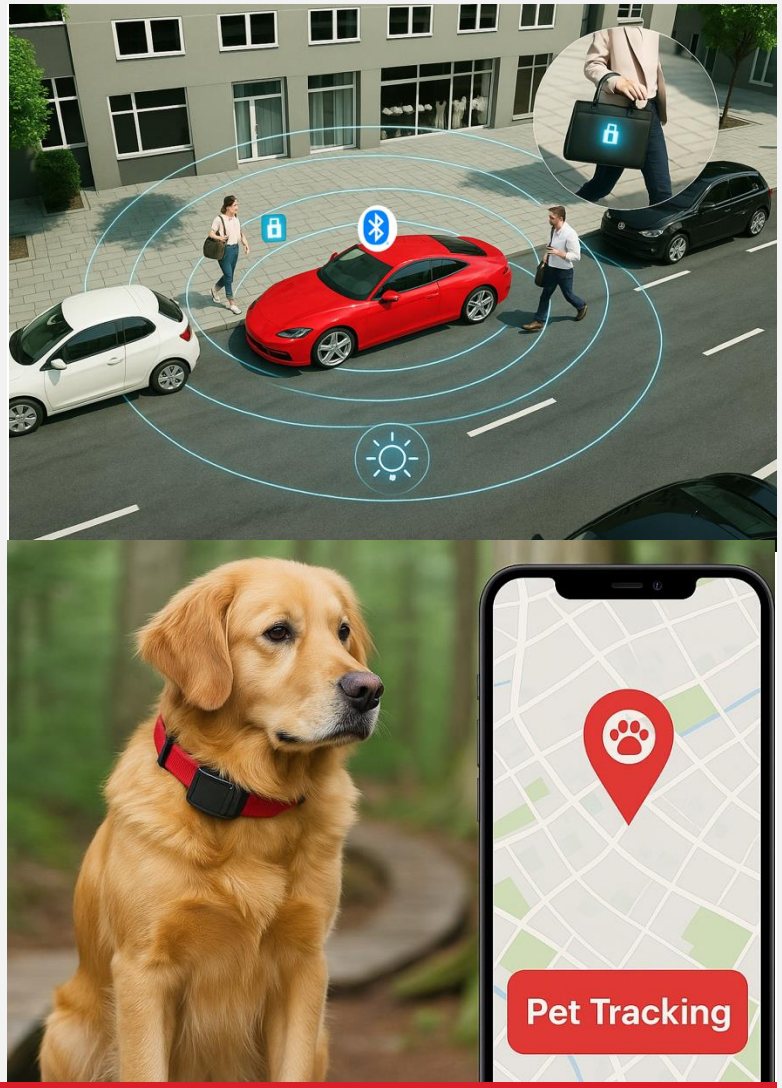
IOT applications need 'spatial' awareness to be more secure, reliable, and responsive

- Earlier Bluetooth LE versions lack native support for precise ranging
- RSSI-based ranging is noisy and unreliable in real-world use
- Direction Finding needs complex antennas, adding cost & complexity
- UWB is accurate but often too costly, and bulky for IoT

THE OPPORTUNITY:

Channel Sounding for Bluetooth

- Standardized approach for accurate, secure ranging in Bluetooth 6.0
- Enables sub-meter accuracy with robust performance, even in NLOS
- Works with single or dual antenna setups - flexible for different form factors
- More cost efficient than UWB; requires minimal external components



Built on existing Bluetooth infrastructure, simplifying adoption and ecosystem integration

Bluetooth® Ranging

Category	Bluetooth® RSSI	Bluetooth® Direction Finding	Bluetooth® Channel Sounding	UWB
Method	RSSI	AoA/AoD	PBR/RTT	ToF/AoA
Measurement Type	Distance Only	Direction + Distance	Distance Only	Direction + Distance
Ranging Accuracy	1-5 m	1-5 m	< 0.5m – PBR 1-5 m – RTT	~10–30 cm
Connection Mode	Connection-oriented or Connectionless	Connection-oriented or Connectionless	Connection-oriented only	Connection- oriented or Connectionless
Measurement Latency	20 ms (typical)	20 ms (typical)	100 ms (typical, PBR)	1 ms (typical)
Reliability	Very sensitive to multi-path and interference	Very sensitive to multi-path and interference	Sensitive to multi-path and interferences	Strong immunity to multi-path and interference
Security	Not secure, prone to relay attacks	Not secure, prone to relay attacks	Secure, several security features as countermeasure for relay attacks	Very Secure
Scalability	1000's of tags	1000's of tags	~10 tags	1000's of tags
Smartphone Support	Yes	No	TBC[1]	Yes
Device Cost	$	$	$	$$

1. Android 16 already supports Channel Sounding Ranging API. Google Pixel 10 officially supports Channel Sounding.

Bluetooth® Channel Sounding Overview

- **Measure distance between two devices using**
  - Phase-based Ranging (PBR)
  - Round Trip Time (RTT)
- **RTT and PBR operates across 2.4 GHz band**
  - Standard specifies up to 72 channels
  - Random channel hopping pattern
- **Connection-Oriented 2-way ranging with two roles**
  - Initiator: device that wishes to initiate ranging from itself to another device
  - Reflector: device responding to initiator
- **Supports up to 4 antenna paths between devices**
  - 8 possible antenna combinations
- **Multiple security features included in the standard**
- **Can be combined with Angle of Arrival / Departure (AoA/AoD)**
  - Enables position estimation with single locator/tag pair

Additional Resources

- **Webpage** – Learn more about Silicon Labs offerings and demos
- **Tech Talk** – Explore Bluetooth Channel Sounding
- **Workswith 2024** - Enable Accurate Distance Estimation Using Channel Sounding
- **Blog:** Learn more about Antenna Switching with Silicon Labs Channel Sounding
- **API Spec**: Getting Started with Silicon Labs Bluetooth Channel Sounding

Bluetooth® Channel Sounding - Target Markets & Use Cases

PROXIMITY AWARENESS

Door locks

Keyless entry

Building access systems

Geofencing - security alerts

LOCALIZATION

Indoor asset management - hospitals, warehouses

Pet tracking

Item finding - wallet, keys

AUTOMAPPING

Solar Trackers

Luminaires, Access Points

Accurate Mapping for Battery Storage

BG24: Optimized for Battery Powered, Channel Sounding-enabled IoT Devices

Bluetooth® Proprietary

- **5x5 QFN40 (26 GPIO), AEC-Q100**
- **6x6 QFN48 (32 GPIO), AEC-Q100**
- **3.1x3.0 WLCSP42**

DIFFERENTIATED FEATURES

- **Ultra small form-factor**
  - 3.1 x 3.0 WLCSP package
- **+20 dBm output power**
  - Eliminates need for external power amplify
- **AI/ML accelerator**
  - Accelerates inferencing while reducing power consumption
- **Secure Vault High**
  - Protects data and device from local and remote attacks
- **20-bit ADC**
  - 16-bit ENOB for advance sensing
- **Improved Coexistence**
  - Ideal for gateways and hubs
- **PLFRCO**
  - Eliminates need for 32 KHz xtal
- **Lowest Power RF**
  - Increases battery life
  - 1.3 µA EM2 (16kB RAM retention)

DEVICE SPECIFICATIONS

- **Wide Operating Range**
  - 1.71 to 3.8 volts
  - +125ºC operating temperature
- **High Performance Radio**
  - Up to +19.5 dBm TX
  - -97.6 dBm RX @ BLE 1 Mbps
- **Efficient ARM® Cortex®-M33**
  - Up to 78 MHz
  - 1536kB Flash, 256kB RAM
- **Low Power**
  - 49.1 µA/MHz (CoreMark)
  - 5.0 mA TX @ 0 dBm
  - 5.1 mA RX (802.15.4)
  - 4.4 mA RX (BLE 1 Mbps)
  - 1.3 µA EM2 sleep
- **Multiple protocol support**
  - Bluetooth 6.0 (1M/2M/LR), Bluetooth mesh, Proprietary 2.4 GHz

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BG24L: Channel Sounding Optimized, High-Performance & Low-Cost AI/ML Wireless SoC

Bluetooth®

- **5x5 QFN40 (26 GPIO)**

DIFFERENTIATED FEATURES

- **AI/ML accelerator**
  - Accelerates inferencing while reducing power consumption
- **Secure Vault Mid**
  - Protects data and device from local and remote attacks
- **16-bit ADC**
  - Up to 14-bit ENOB for better analog sensing
- **PLFRCO**
  - Eliminates need for 32 KHz XTAL and lowers overall system cost
- **Lowest Power RF**
  - Increases battery life
  - 1.3 µA EM2 (16kB RAM retention)

DEVICE SPECIFICATIONS

- **Wide Operating Range**
  - 1.71 to 3.8 volts
  - +125ºC operating temperature
- **High Performance Radio**
  - Up to +10 dBm TX
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- **Efficient ARM® Cortex®-M33**
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  - 49.1 µA/MHz (CoreMark)
  - 5.0 mA TX @ 0 dBm
  - 5.1 mA RX (802.15.4)
  - 4.4 mA RX (BLE 1 Mbps)
  - 1.3 µA EM2 (16kB RAM retention)
- **Supports Bluetooth 6.0**
  - Channel Sounding optimized BLE SoC
  - Single-connection two-way ranging
  - Ideal Solution for Channel Sounding tags
- **Multiple protocol support**
  - Bluetooth 6.0 (1M/2M/LR), Bluetooth mesh, Proprietary 2.4 GHz

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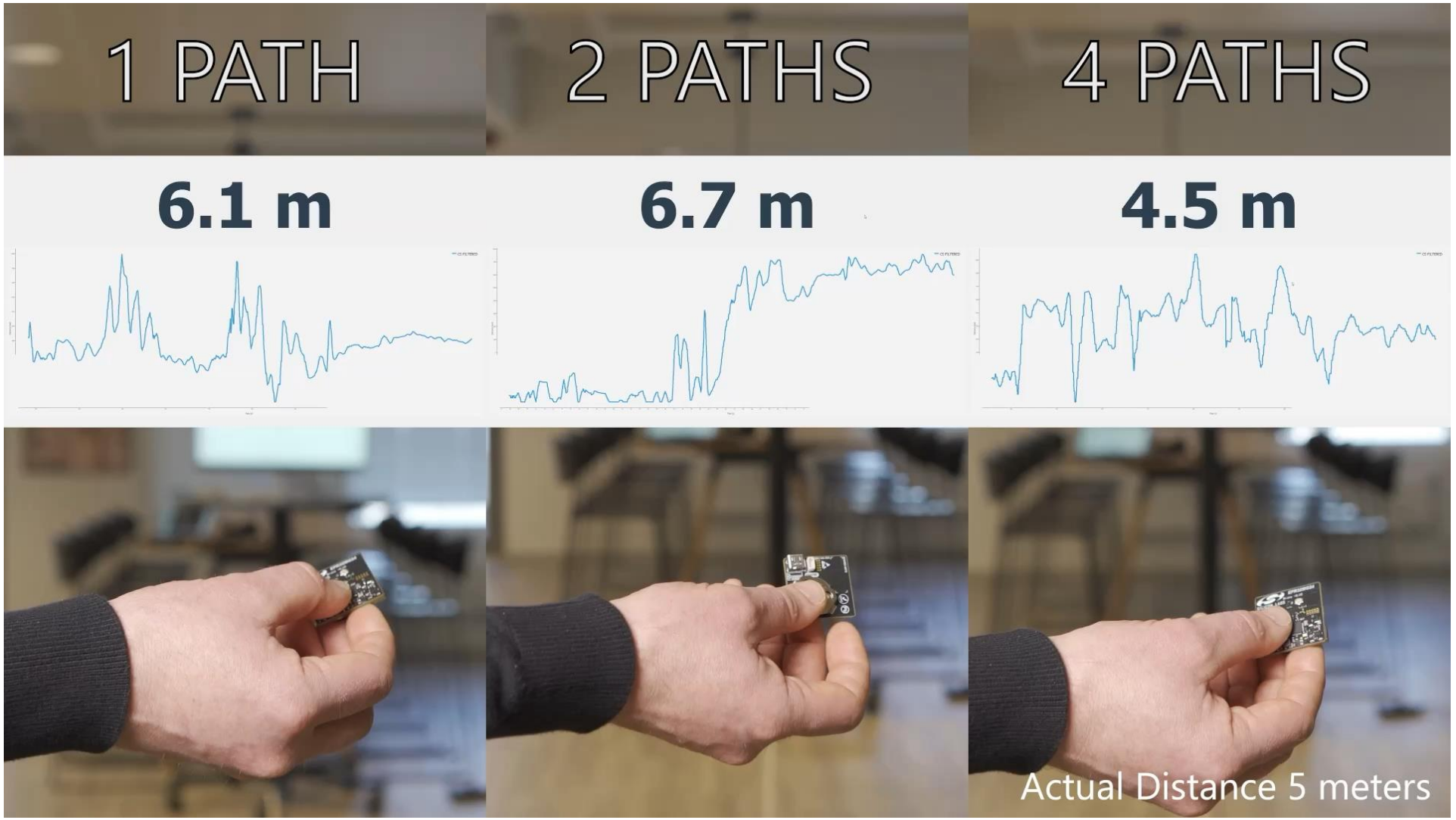
Bluetooth® Channel Sounding Dual Antenna Development Kit

- **xG24 Channel Sounding Development Kit**
  - Available since March 2025
  - Development Kit with two PCB antennas
    - Antenna diversity offers increased robustness and accuracy
  - Intra-event antenna switching for optimal non-line of sight performance
  - Includes IMU sensor to detect movement & wake-up the tag
  - Small form factor
    - Ideal for size-constrained applications like key fobs
  - AEC-Q100 Compliant
  - SoC/NCP Sample Apps
    - Initiator and Reflector examples supported
  - Ranging Library
    - Process IQ samples, post-filtering, and compute distance using configurable algorithm

Antenna Diversity – What does it bring?



Silicon Labs Channel Sounding Algorithm

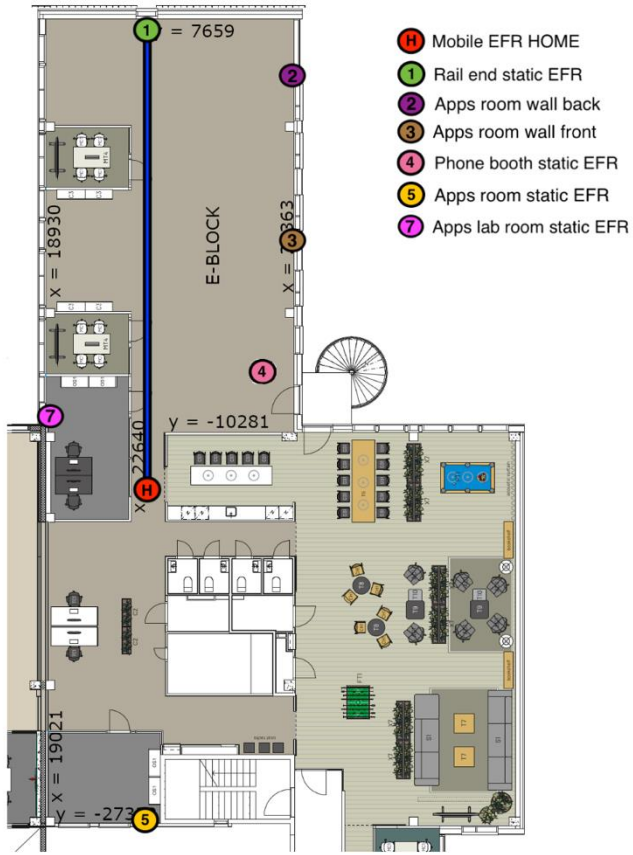
Algorithm Features

- Supports Multiple Channel Sounding Ranging Modes
  - PBR, RTT, PBR with RTT as sub mode
- Antenna Switching
  - Built-in support for antenna diversity
  - Supports 1, 2 and 4 antenna paths
- Supported Algorithm modes
  - Static mode – Delivers the highest accuracy with high measurement latency; optimized for ranging between stationary devices
  - Real Time Basic – Provides high accuracy with increased computational and measurement latency; supports tracking at speeds up to 1 m/s
  - Real Time Fast – Balances moderate accuracy and range with low latency; supports tracking at speeds up to 2.1 m/s, additionally produces velocity metric
- Configurable Channel Selection (72, 37, or 20 Channels)
  - Selectable based on accuracy needs and power constraints

Key Benefits

- Licensing cost free
  - Eliminates third-party royalties, simplifying BOM cost structure
- Optimized HW-SW Co-Design
  - Tight coupling between silicon & firmware ensures seamless performance & efficiency
- Single-Vendor Lifecycle Support
  - Unified hardware & software ownership streamlines debugging, validation, and updates

Algorithm Performance Test Setup



Node Pairs	Distance (in m)	Obstacles
H & 1	20	Line-of-Sight
H & 4	7.9	Walls, Kitchen
1 & 4	14.84	Cubicles, Luminaires
1 & 5	33.9	Walls, Glass door

- **NLOS performance indoors**
  - Setup in office space with nodes on the ceiling
  - Nodes face various obstacles: walls, kitchen, office cubicles
  - Utilizes antenna diversity and intra-event antenna switching
  - Dual-antenna solution ensures robust accuracy

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Algorithm Performance Data[1]

Algorithm Mode	LOS 90th Pct. Absolute Error (in m)	LOS 95th Pct. Absolute Error (in m)	NLOS 90th Pct. Absolute Error (in m)	NLOS 95th Pct. Absolute Error (in m)	Computation time (in ms)	Tracking moving object – max speed (in m/s)
STATIC_HIGH_ACCURACY	0.5	0.6	1.7	2.7	20000[2]	0
REAL_TIME_BASIC	0.5	0.6	1.9	4.2	188	<1.0
REAL_TIME_FAST	0.4	0.5	4.0	5.3	20	<=2.1

1. CS mode – PBR, CS channels – 72, number of antenna paths – 4
2. ~100 CS Procedures used to produce single distance estimate

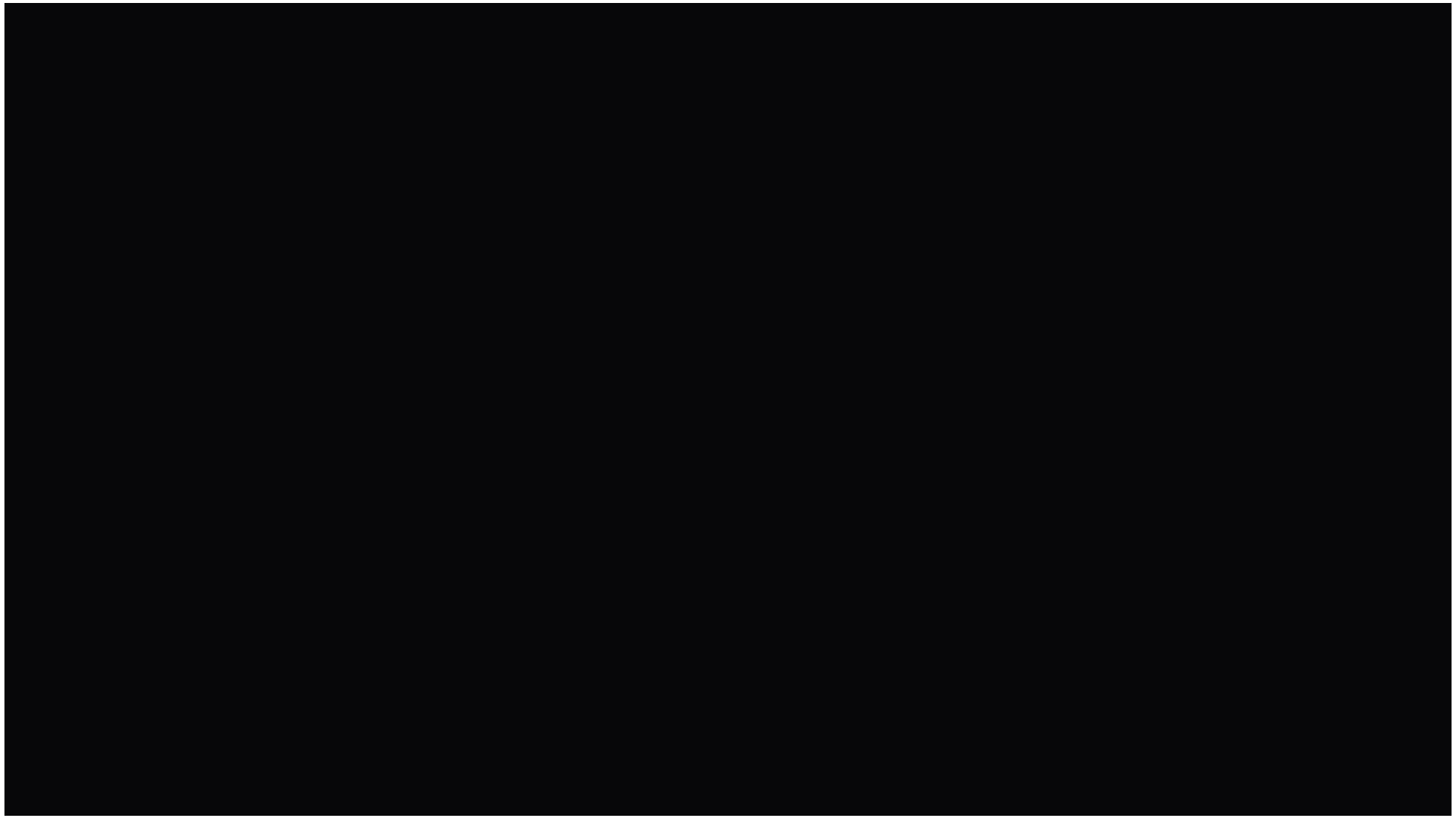
Fit For Purpose Algorithm Modes

Energy Consumption Profile – Reflector

Reference Board	Number of Antenna Paths (NAP)	Number of Channels	Mean Current Consumption (mA)	Mean Energy Consumption (nAh)
BRD2606A	4	72	~2.2	~191.0
		37	~1.2	~111.0
		20	~0.9	~75.4
	2	72	~1.7	~146.0
		37	~1.0	~91.0
		20	~0.8	~65.0
	1	72	~1.5	~122.8
		37	~1.0	~79.0
		20	~0.7	~58.0

Antenna Diversity Increases Total Energy Per Measurement

Algorithm Performance

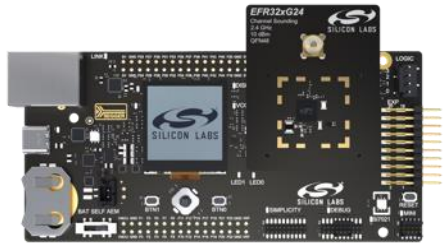


Visualizer Tool

Visualizer Tool displays real-time CS data

- CS configuration
  - Channel map selection
  - Antenna path configuration
  - Algorithm mode selection
- CS data visualization
  - RSSI based distance for comparison
  - Raw distance estimate and likeliness
  - Filtered distance estimate
  - IQ data visualization
- Interfaces with CS enabled EVKs

Silicon Labs Bluetooth ® Channel Sounding Offering



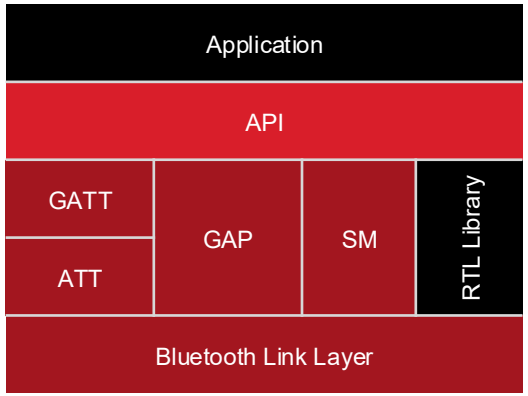
ICS & DEVELOPMENT KITS

Channel Sounding Supported by **B/MG24**

Kits:

xG24-RB4198A single antenna kit

xG24-DK2606A dual antenna kit

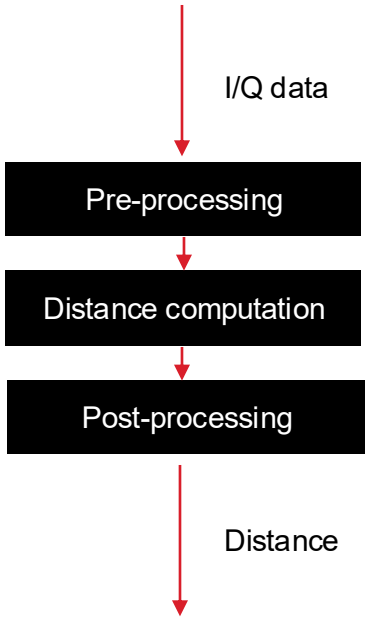


BLUETOOTH 6.0 STACK

In-house developed stack, supported and maintained stack

Bluetooth 6.0 qualified

PBR & RTT Modes



RTL LIBRARY

Computes distance from raw I/Q data

Developed and supported by Silicon Labs

New features added based on market needs

No 3rd party license fees

SIMPLICITY STUDIO

SDK & TOOLS

Initiator & Reflector examples

Real-time visualization tool for Bluetooth Channel Sounding

Energy Profiler etc.

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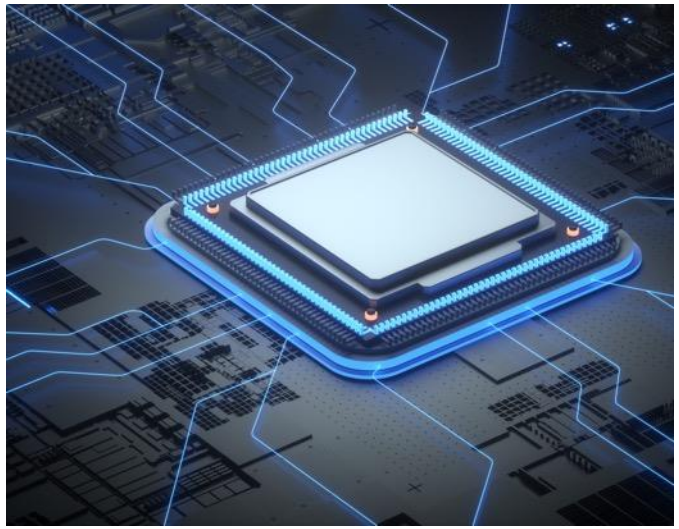
Learn More About Silicon Labs Channel Sounding



GETTING STARTED

Channel Sounding Kits Available at:

Visit site

Download Simplicity Studio here:

Visit site

FOR MORE INFORMATION

Channel Sounding:

Visit site

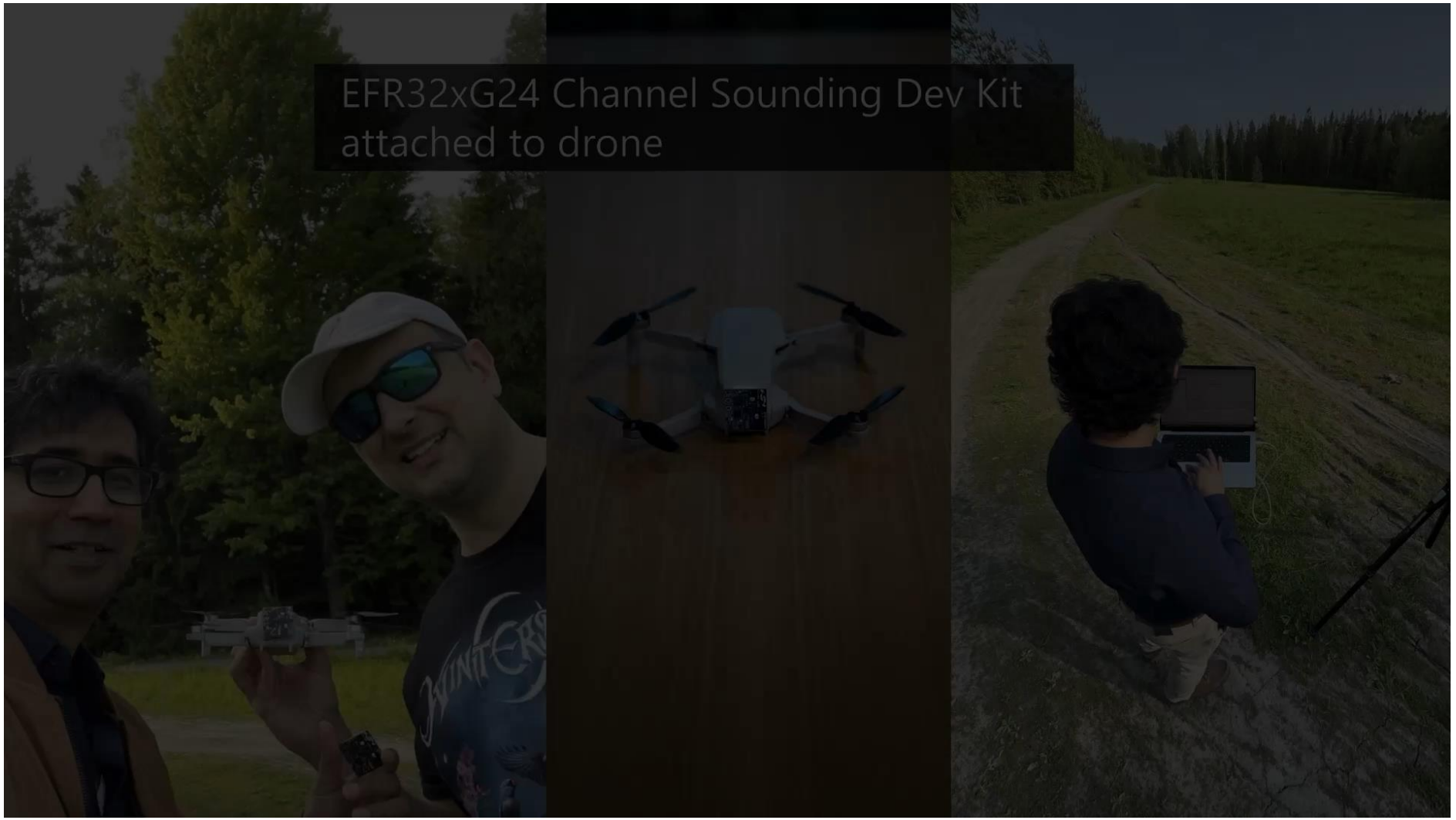
Explore Bringing Bluetooth 6.0 Channel Sounding to Market

Visit site

CALL TO ACTION

For any questions about SiLabs offerings, please contact our Sales team.

Bluetooth® Channel Sounding – Lift Off



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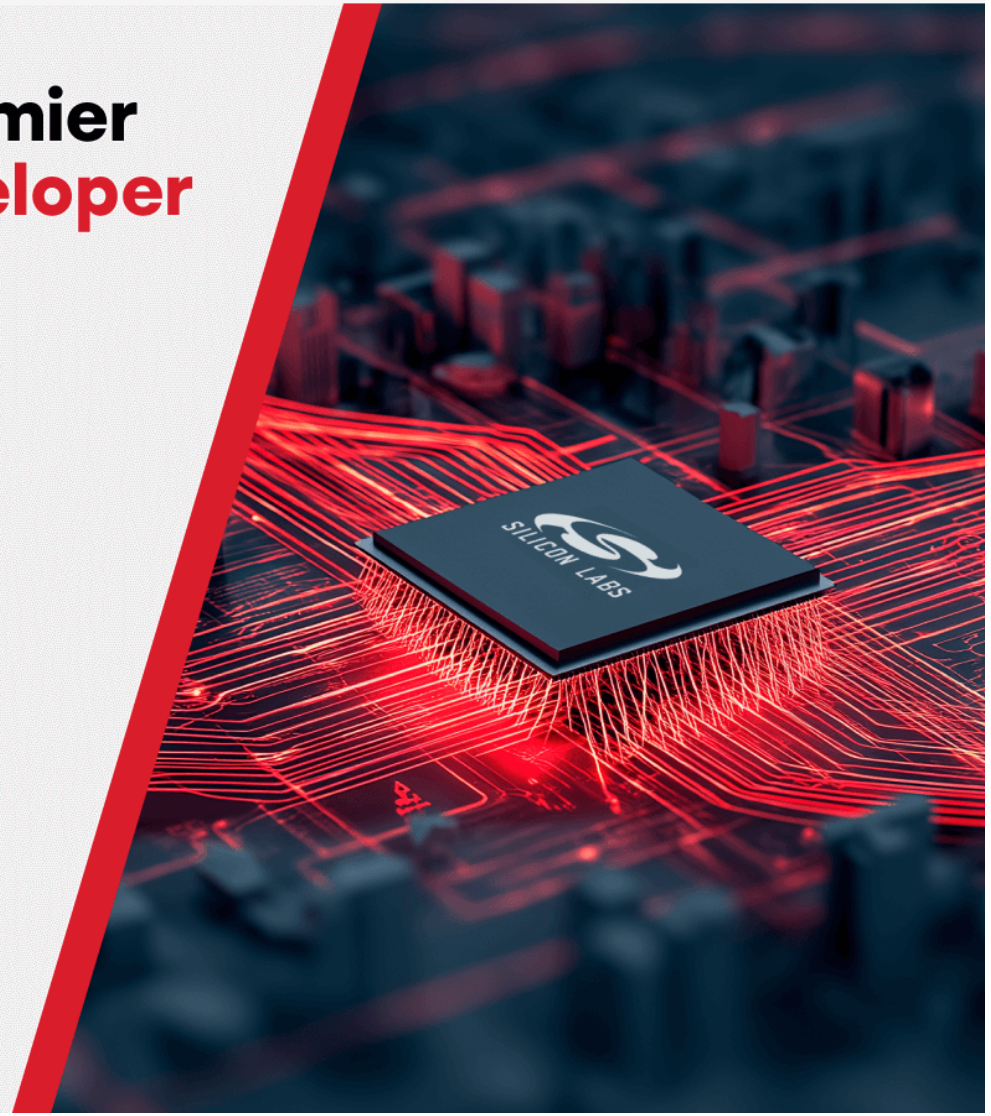

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