TI *Live!* INDIA AUTOMOTIVE SEMINAR

JÜRGEN AUSTEN

BLUETOOTH® LOW ENERGY CONNECTIVITY SOLUTIONS FOR AUTOMOTIVE APPLICATIONS

Agenda

- *Bluetooth*® Low Energy in automotive - market trends
- TI Bluetooth LE product overview
  - Hardware
  - Software
- Application use-cases
  - Bluetooth LE cluster for 2W
  - Car access
  - Infotainment
  - TPMS
  - Smart helmet
- Dual-mode Bluetooth

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  - Smart helmet
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3

TI Connectivity

★ Development activity

☆ Regional support center

- >20 years connectivity experience
- Shipped more than 2Bu RF devices
- >5000 customers
- Focus on Automotive and Industrial

TI Connectivity | Enabling low power wireless for >20yrs

Sub-1GHz
M-Bus wireless
Wi SUN
mioty
TI-15.4 Stack

2.4GHz
zigbee
TI-15.4 Stack
Wi Fi
Bluetooth
Thread

5GHz
Wi Fi

SimpleLink SDK

TI LaunchPad™

Development Kits

Low power radio for unlicensed bands

- Robust radios
- Up to 10km range
- Up to 100Mbps
- Up to 10yrs battery life

Driving innovation

- BLE 5.x
- WiFi IoT
- Localization
- Crystal free (BAW)
- Cable replacement

Software Scalability

- Quick time to market
- Highest flexibility
- SW reuse
- Easy switching within SimpleLink family

Hardware Scalability

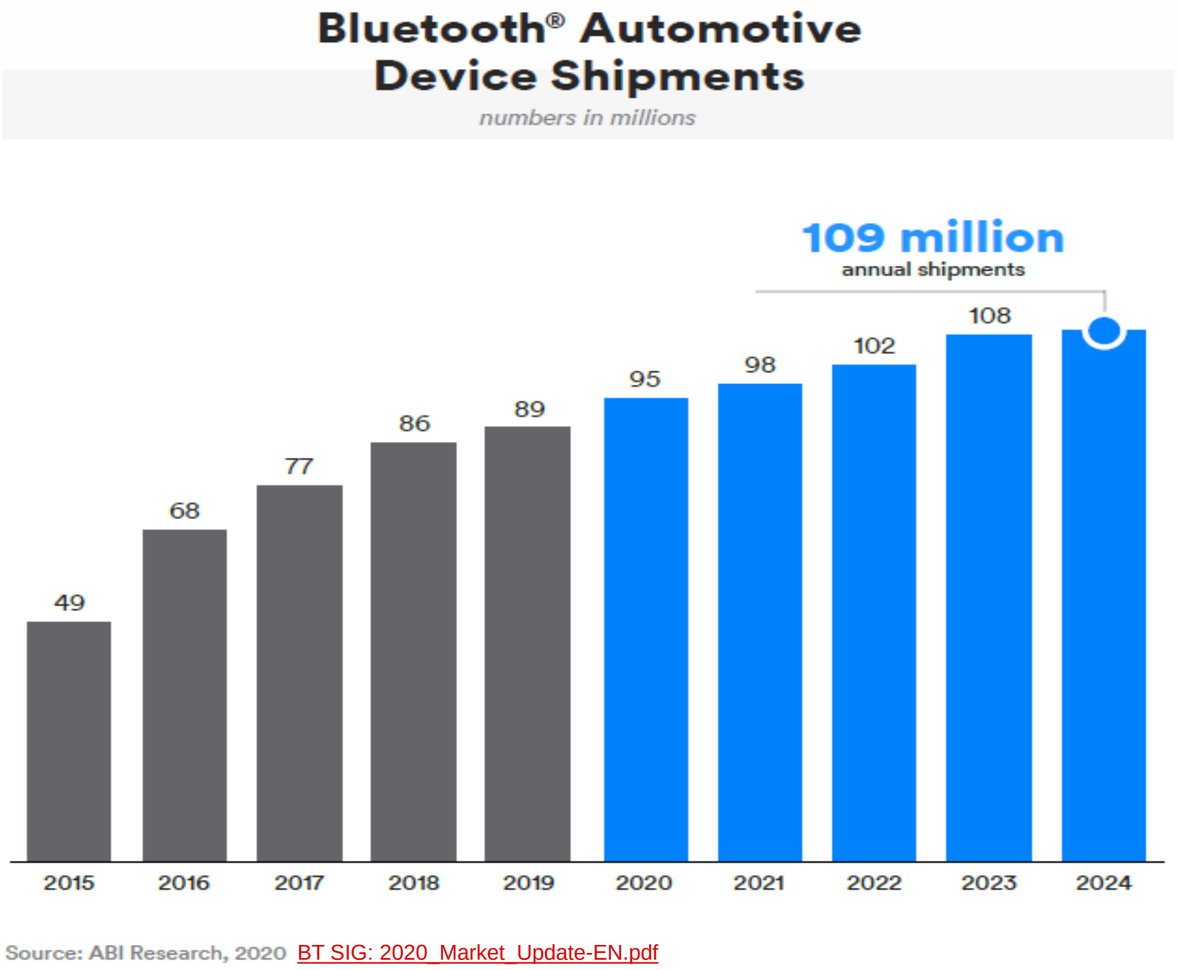
- From transceivers to wireless MCU and modules
- Scalability on RF, computation and memory

Complete development environment

- Code composer
- SysConfig
- Smart RF Studio
- SL Academy
- …

Bluetooth Low Energy | Automotive Market Trends

Bluetooth® technology creates connections between the car and driver that support new levels of safety, security, and access while enhancing the in-car experience. Thanks to lower power consumption, enhanced performance, and improved reliability, Bluetooth technology is the automotive standard for both in and out of the car – including keyless entry systems and in-car infotainment.



Source: ABI Research, 2020 BT SIG: 2020_Market_Update-EN.pdf

Transition from BT Classic for mobile phone connection towards BLE
BLE Bluetooth **Low Energy** enables new use cases for automotive applications

Connected Car | TI automotive end equipments

Car Access (Key fobs)

Transition from LF and UHF towards ***Bluetooth LE based systems***

Phone as a Key

Bluetooth LE defined as standard for all phone as a key systems

Wireless BMS

(*Battery Management System*)

Lowest system cost BMS
Highest system availability
Weight savings

Infotainment

Bluetooth LE based mobile phone and helmet connection

TPMS

Transition from LF and UHF towards ***Bluetooth LE based systems***

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Connectivity | Most Reliable Low Power Wireless 2.4 Portfolio

Memory scalability

Bluetooth LE 5 & Proprietary
Bluetooth LE 5, Mesh, Direction Finding

CC2652R7
704kB, 144kB
7x7
Bluetooth and multiprotocol w/ on-chip OTA
M4F

CC2642R
352kB, 80kB
7x7
Bluetooth 5.1, Mesh, RTLS
M4F

CC2640R2F
128kB, 20kB
4x4, 5x5, 7x7, WCSP
Network attached & low power sensing
M3

CC2640R2L
128kB, 20kB
5x5, 7x7
Network attached & non-sensing application
M3

Bluetooth LE 5 & Proprietary
AUTOMOTIVE

CC2642R-Q1
352kB, 80kB
7x7
Bluetooth 5.1, Mesh, RTLS
M4F

CC2640R2F-Q1
128kB, 20kB
4x4, 5x5, 7x7, WCSP
Network attached & low power sensing
M3

2.4 GHz Multiprotocol

CC2652R7
704kB, 144kB
7x7
CHIP, Multiprotocol with on-chip OTA
M4F

CC2652RB (BAW)
352kB, 80kB
7x7
Single protocol, system provisioning
M4F

CC2652R (P)
352kB, 80kB
7x7
Single protocol, system provisioning
M4F

Bluetooth LE 5 & Proprietary
System in Package (SIP)

CC2652RSIP
352kB, 80kB
7x7
M4F

Platform Highlights
- Lowest 1.0 µA standby current consumption
- Integrated PA up to +20dBm (+10dBm coin cell optimized)
- Pin-to-pin QFN compatibility and chip-scale package opts.

Key Features
- Bluetooth support
- Zigbee support
- Thread support
- Matter support
- Sensor Controller
- +20dBm Integrated PA
- BAW Resonator

NEW

Production

TI Bluetooth LE portfolio overview

Part number	Typical use case	Flash (kB)	RAM (kB)	BLE version	# of connections	BLE Long range	BLE Mesh	2Mbps PHY	Temp range	Low power sensor controller	Low power	Package options (same size = pin to pin)
CC2640R2L Lowest cost basic Bluetooth LE Lowest 1ku price in the market	- Bluetooth LE peripheral / end node - Beacon	128 + 147 (ROM)	28	5.1	4			YES	-40C to 85C		1.5uA Standby 100 nA shutdown +5dBm TX @ 9.1mA	5x5mm QFN (15 GPIO) 7x7mm QFN (31 GPIO)
CC2640R2F Lowest power basic Bluetooth LE for sensor applications Smallest size option	- Bluetooth LE peripheral / end node - Low power sensor - Beacon	128 + 147 (ROM)	28	5.1	4			YES	-40C to 85C	YES	1.1uA Standby 100 nA shutdown +5dBm TX @ 9.1mA	2.7x2.7mm WSCP (14GPIO) 4x4mm QFN (10 GPIO) 5x5mm QFN (15 GPIO) 7x7mm QFN (31 GPIO)
CC2651R/P Bluetooth LE with long range 20dBm TX power option Sampling Now, 4Q RTM	- Bluetooth LE peripheral/central - On chip OTA - Bluetooth Mesh friend node	352 + 40 (ROM)	40	5.2	16	YES	YES	YES	-40C to 105C		0.94uA Standby 150 nA shutdown +5dBm TX @ 9.6mA	5x5mm QFN (15 GPIO) 7x7mm QFN (31 GPIO)
CC2642R/52R/52P/52RB Full features Bluetooth LE for all applications 20dBm TX power option BAW option available (CC2652RB)	- Bluetooth LE peripheral/central - Bluetooth LE Multirole - On chip OTA - Full Bluetooth Mesh - Multiprotocol (BLE, ZB or Thread) - Real time locationing	352 + 256 (ROM)	88	5.2	32	YES	YES	YES	-40C to 105C	YES	0.94uA Standby 150 nA shutdown +5dBm TX @ 9.6mA	7x7mm QFN (31 GPIO)
CC2652R7/P7 More Flash memory for advanced features and applications 20dBm TX power option Sampling Now, 4Q RTM	- Bluetooth LE peripheral/central - Bluetooth LE Multirole - On chip OTA - Full Bluetooth Mesh - Multiprotocol (BLE, ZB and Thread) - Real time locationing	704 + 256 (ROM)	152	5.2	32	YES	YES	YES	-40C to 105C	YES	1.2uA Standby 150 nA shutdown +5dBm TX @ 9.6mA	7x7mm QFN (31 GPIO)

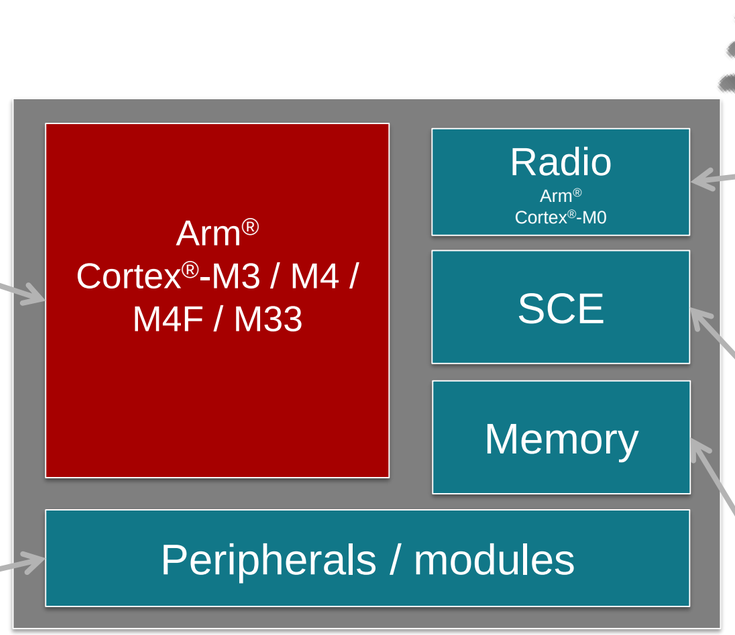
2.4 GHz Connectivity | Device architecture

Application MCU

- Application
- Profiles / services
- TI RTOS
- Peripheral drivers and libraries
- Royalty free protocol stacks

Peripherals / modules

- DC/DC converter
- Temp/battery monitor
- AES
- GPIO
- Timers
- UART / SPI
- I2C / I2S
- DMA



QFN package: 4x4 mm, 5x5 mm 7x7 mm
WCSP: 2.7x2.7 mm

Low power

- **Standby:** <1 uA (RTC and full RAM retention)
- **Shutdown:** 100 nA
- **RX / TX @ 0 dBm:** 5.9 mA / 6.1 mA

Radio

- Multi-band, multi-protocol
- Software configurable
- Power output:
  - +5 dBm / +20 dBm @ 2.4 GHz
- Strong Sensitivity:
  - 1-Mbps BLE: -97 dBm
  - 802.15.4: -100 dBm
- Industry's first completely crystal-less wireless MCU using **BAW** technology

Sensor controller engine

- ADC and comparators
- Digital sensor readings
- Capacitive sensing

Memory

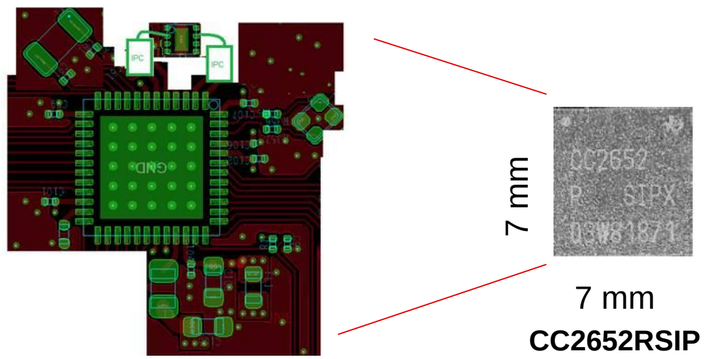
- **Flash:** 128 KB / 352 KB / 704 KB / 1 MB
- **RAM:** 28 KB / 40 KB / 88 KB / 152 KB / 296 KB (+ cache)
- **ROM:** 147 KB / 256 KB

CC2652RSIP solution

Pre-certified system-in-package wireless MCU to solve space constraint applications

BENEFITS:

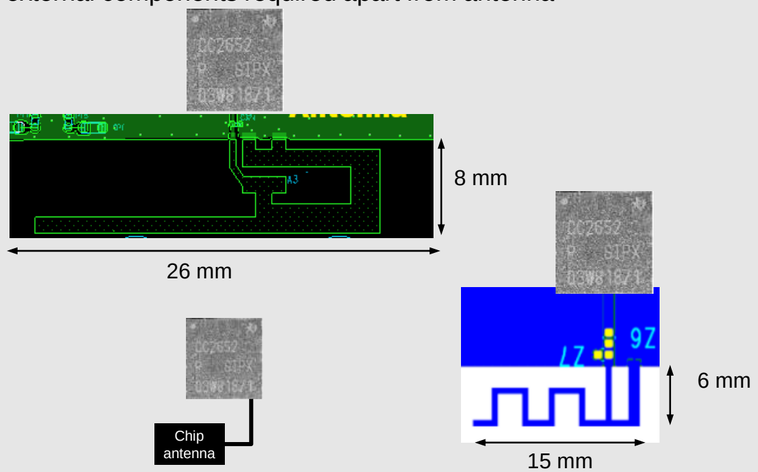
- **Reduce overall solution size by 70%**
- Enables **fast-time to market**
- **No external components required**
  - Integrated passives for all power management
  - Integrated 48 MHz and 32-kHz crystal
  - Integrated antenna matching circuits
- Industry leading 1-µA standby current (10+ years battery life on coin cell)
- 352-kB flash and up to 80-kB RAM
- Up to 32 GPIOs
- 105º C temperature range



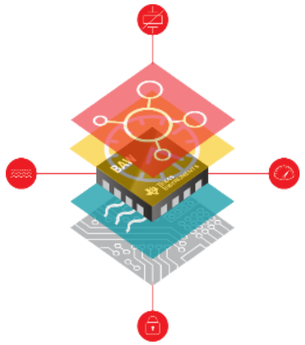
70% smaller footprint

Certified antenna reference designs

No external components required apart from antenna



CC2652RB | BAW resonation for crystal-less applications



- TI Bulk Acoustic Wave (BAW) resonator
- The industry's only crystal-less wireless MCU solution
- On-chip MEMS resonator that serves as a high-precision, low-jitter clocking reference
- BLE 5.2 qualified, supports Thread and Zigbee with multiprotocol functionality

CC2652RB wireless MCU:
BLE 5.2 qualified and support for Zigbee, Thread and Multiprotocol

Why TI?

Lower solution cost	• On-chip MEMS resonator that eliminates the need for external high frequency crystal • $0.05 to $0.10 lower cost than discrete solution with external crystal
Smaller, simpler solution	• 30% space savings with no high frequency crystal or routing
More stable solution in harsh environments resulting in fewer MCU timing errors and transmission issues	• Less PPM variance when tested against MIL-STD-883H for mechanical shock • Ability to actively compensate BAW resonator for greater stability over temperature variance and battery voltage
Simplified supply chain	• No need to source high frequency crystals

Key Applications


Power tools


Circuit breakers


Electricity meters


HVAC systems


Temp, humidity, pressure sensors

Resources / Getting started

Nick Smith 2018

1. Get the LaunchPad development kit
2. Download the SDK
3. Follow training / documentation

Getting Started With CC2652RB for Crystal-less BAW Operation

Minimizing Frequency Error Due to Soldering Process on CC2652RB Crystal-Less MCU

Exploring IoT wireless connectivity in mechanical shock and vibration environments

SimpleLink Crystal-Less Wireless MCU based on TI BAW technology

Running Bluetooth® Low Energy on CC2640 Without 32 kHz Crystal (Rev. C)

SimpleLink™ | Connectivity Bluetooth® LE Software

Bluetooth® LE 2Msym/s and Long Range PHY

- Bluetooth 5.1 PHYs for 2Msym/s and Long Range

Bluetooth® LE + Wi-Fi Coexistence

- 3-wire Co-ex interface (conformance to Broadcom Wi-Fi® standards), 1-wire SimpleLink™ Co-ex interface

Secure OAD – On-Chip, Off-Chip

- Authenticate an image using ECDSA before installing and executing

SysConfig GATT Builder

- Simplify creation and configuration of Bluetooth® LE Profiles

2.4 GHz | Wi-Fi + Bluetooth LE Coexistence

What is Coexistence?
Co-located Wi-Fi and *Bluetooth*® Low Energy radios manage their RF activity during 2.4-GHz frequency band access.

1-wire coexistence scheme supported on SimpleLink devices

Key devices supported:

- CC2642R
- CC2652RX (P)

- CC3230/CC3235
- CC3130/CC3135

Key Features

Combo 2-Chip design	• Wi-Fi + BLE capability for both provisioning & peripheral role
Low power design for continuous connectivity	• Wi-Fi: 0.7uA DTIM 1 beacon receive profile • BLE: lowest power standby 0.94uA
Security features	• Wi-Fi: Personal & Enterprise-WPA3 support • BLE: AES-256, SHA2, ECC/RSA, TRNG
Ease of certification	• Regulatory certified reference design • FCC, ISED and CE

Key Applications

Thermostat | Electronic lock | Smoke / heat detector | Lighting | Appliances | Medical

Resources / Getting started

- CC3135, CC3235x SimpleLink™ Wi-Fi® Internet-on-a Chip™ Solution–BLE Coexistence
- Low-Power Internet Connectivity Over Wi-Fi (Rev. A)

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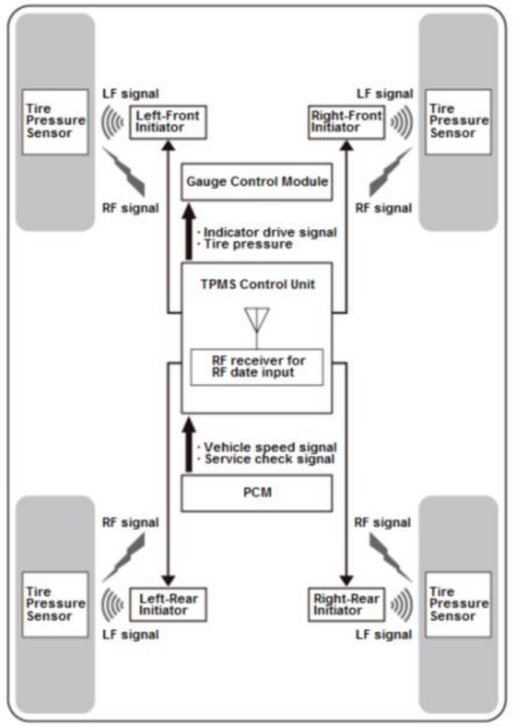
  - Smart helmet
- Dual-mode Bluetooth

TPMS | Today and future

Today



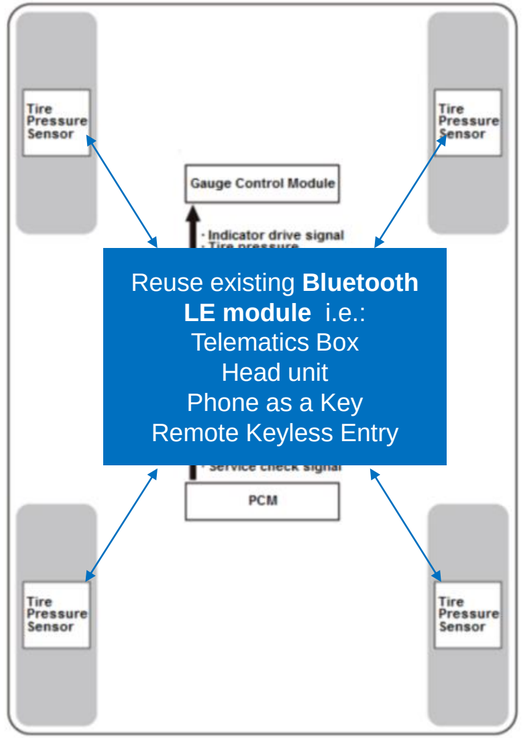
System cost saving:

- Re-use of existing vehicle infrastructure
- Weight reduction
- Remove LF system + cables + antennas
- Single solution for all countries (homologation)

Advanced feature offering:

- TPMS mobile phone apps

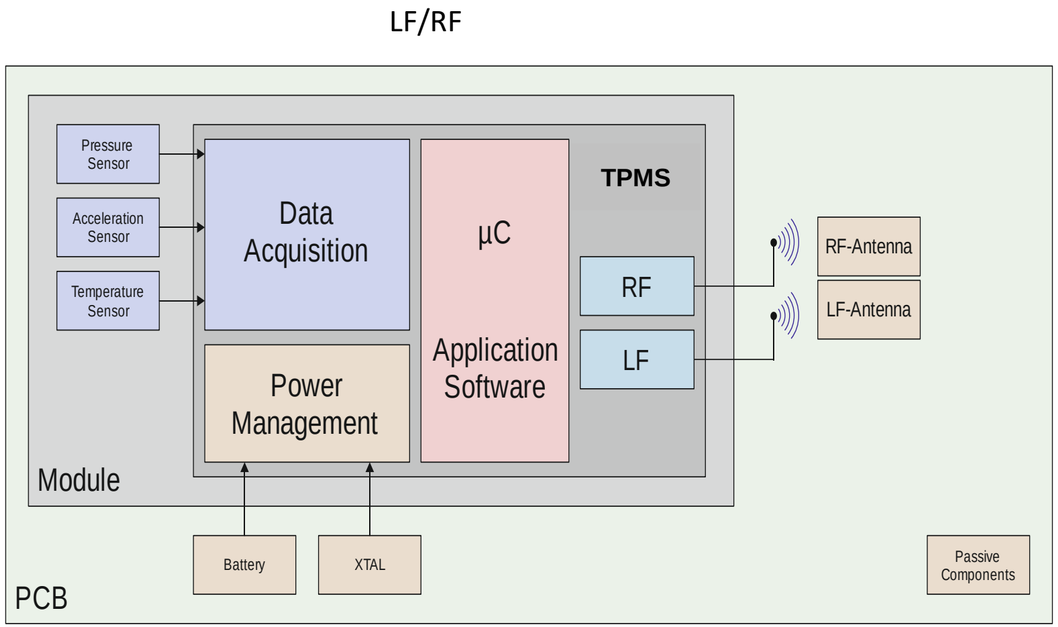
Future



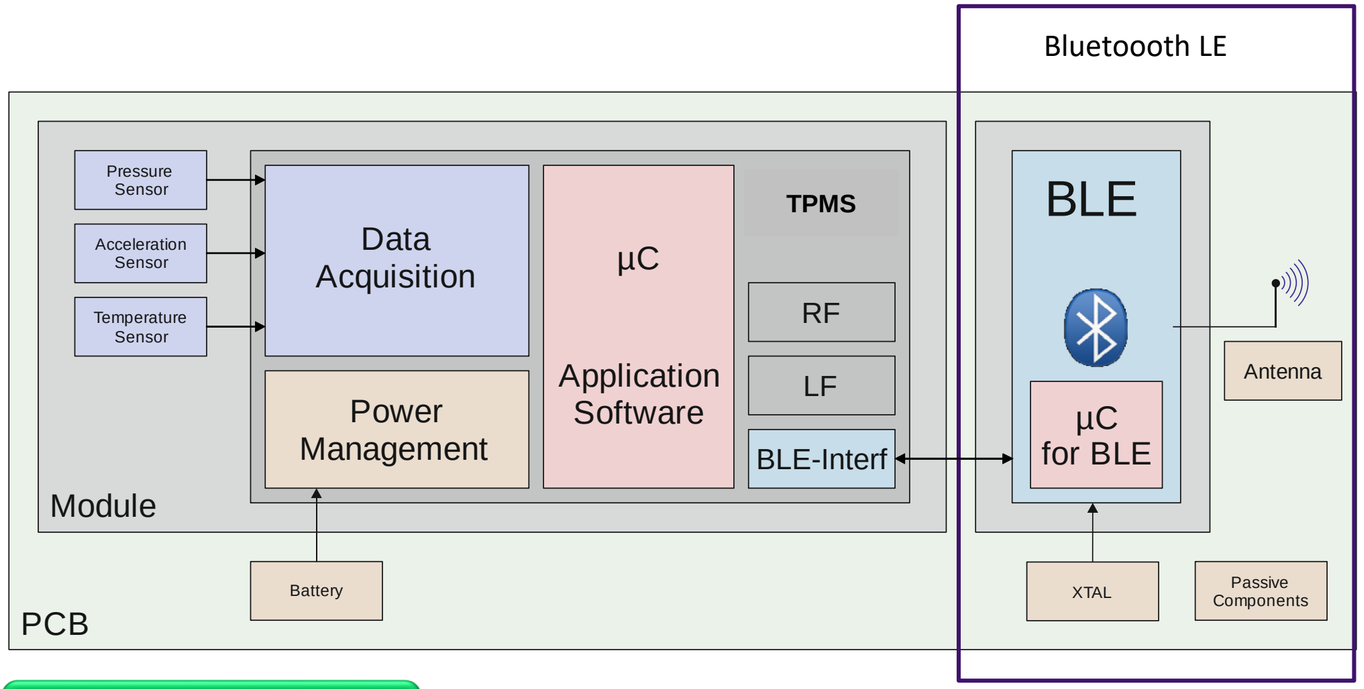
Vehicle	4-8 Sensors	Vehicle	4-8 Sensors
4x LF Transmitter	1x LF Wake Receive	4x L…itter	
1x UHF receiver	1x UHF Transmitter	1x …iver	1x BLE SoC

TPMS | Sensor block diagram

Today



Future



TI benefits

- Shutdown mode not preferred due to periodic transmissions
- Lowest standby current is most important for battery lifetime
- TI BLE products offer lowest standby current in the market

Car access | System block diagram

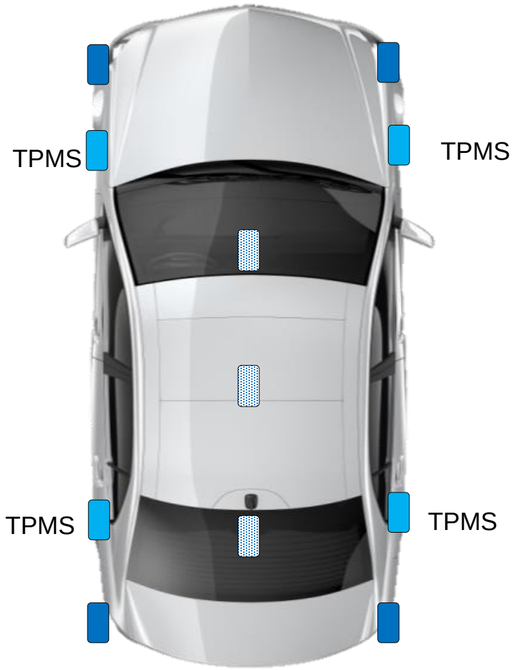
Phone as a key (up to 8)

Bluetooth LE Master

Vehicle nodes

Bluetooth LE peripheral for phones
Bluetooth LE peripheral or proprietary for key fob
Bluetooth LE central (SCAN) for TPMS

Bluetooth LE nodes
Bluetooth LE TPMS



SimpleLink™ Bluetooth® Low Energy
Texas Instruments

Key fob (up to 4)

Bluetooth LE central (SCAN) for vehicle

TPMS (4x)

Bluetooth LE broadcaster
Bluetooth LE connected

TI Benefits

- Software configurable radio enabling newest Bluetooth LE features
- Support up to 32 simultaneous connections
- Proven technology supporting different connection roles (Central, Peripheral, Multirole/Multimode) with multiple OEMs
- Best in class Rx sensitivity
- Ultra-low power
- Continuous quarterly Interoperability testing on flagship phones

Infotainment | System block diagram

Phone

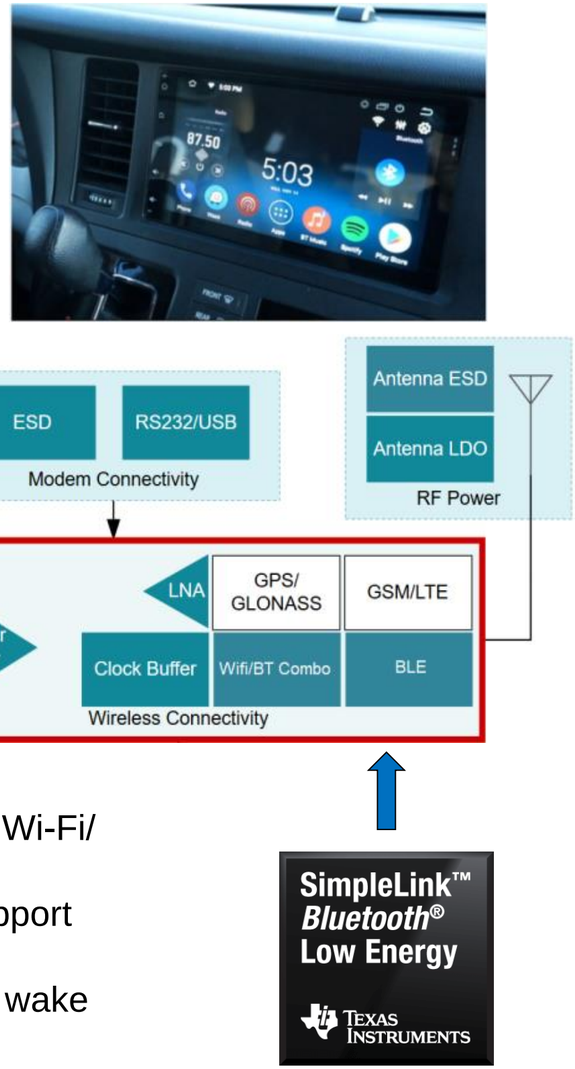
Bluetooth LE master

Vehicle Nodes

Bluetooth LE peripheral for low power wakeup

Application

- Head unit/telematics box
- Used as low power auxiliary wireless communication
- When entering ignition-OFF state head unit including combo Wi-Fi/ Bluetooth chip will shutdown to save power
- Standalone Bluetooth LE chip enters advertising mode to support low power wakeup
- Once smartphone is back in range the Bluetooth LE chip will wake up the head unit/telematics box for regular operation



TI benefits

- Software configurable radio enabling newest Bluetooth LE features (BLE 5.x Long Range)
- Ultra low power
- Faster go-to market by easily re-using TI SW/SDK
- Continuous quarterly Interoperability testing on flagship phones.
- Best in class Rx sensitivity
- 1 or 3 wire coexistence

2-wheeler cluster | System block diagram

Phone

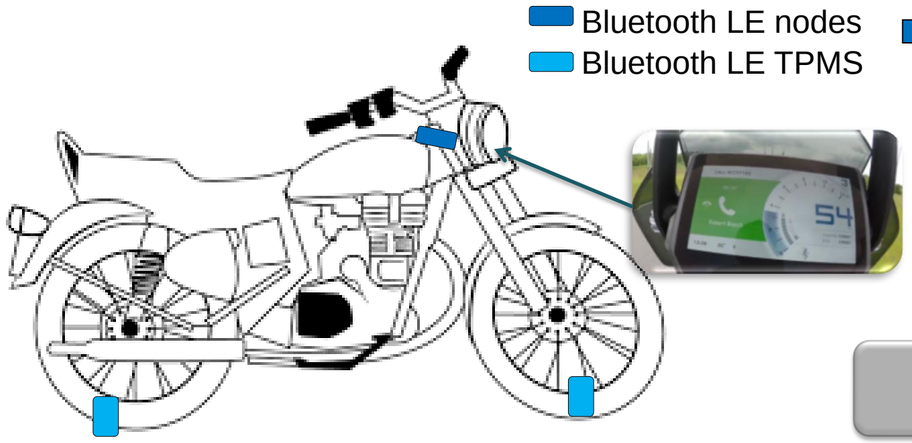
Bluetooth LE master

Vehicle nodes

Bluetooth LE peripheral for phones
Bluetooth LE central (SCAN) for TPMS

Application

- Connectivity cluster 2-wheeler
- Used as low power auxiliary wireless communication
- Scan/connect to mobile phones
- Indicate incoming calls to helmet
- Mirror GPS/navigation data from phone to cluster
- TPMS signaling to head unit, phone or helmet



SimpleLink™ Bluetooth® Low Energy
Texas Instruments

TPMS (2x)

Bluetooth LE broadcaster
Bluetooth LE connected

TI benefits

- Software configurable radio enabling newest Bluetooth LE features (BLE 5.x long range)
- Support up to 32 connections for different roles (central, peripheral, multirole/multimode)
- Continuous quarterly Interoperability testing on flagship phones.
- Best in class Rx sensitivity
- Ultra low power
- Faster go-to market by easily re-using TI SW/SDK

Smart helmet | Dual-mode Bluetooth

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CC2564C | product highlights

- TI's *Bluetooth*® CC2564C: Dual-mode Bluetooth 5.1 (compliant) controller for legacy and high throughput applications, including integrated audio capabilities
- CC2564C and the TI software stack provide a complete solution, including:
  - LE Secure connections: Bluetooth Low Energy security algorithm (ECDH) for key generation and new pairing procedure for key exchange
  - Link layer topology: Bluetooth Low Energy scatternet capabilities, managing connection in a dual mode topology allowing sensor network topology
  - QDID 177061: Controller subsystem

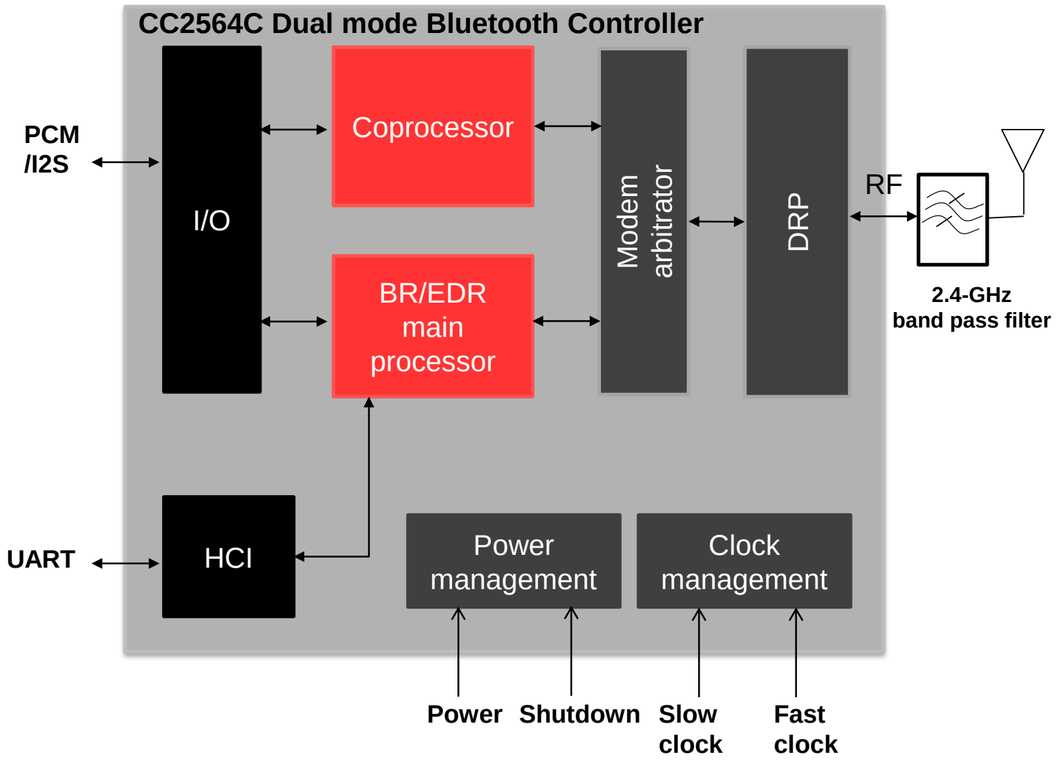
Dual-mode *Bluetooth*® | Hardware

Key Parameter

- **2.2 - 4.8 V** supply range
- **8 x 8** mm QFN
- **-40°C to +85°C** temp range
- **UART** host interface
  - 4-wire H4
  - 3-wire H5
- **PCM-I2S** voice/audio I/F
- A2DP internal SBC encoding/decoding is supported
- Bluetooth SIG 5.1 certified
- The evaluation board is FCC, IC and CE certified

Radio Performance

- **+12 dBm** transmit power (“Class 1.5”)
- **-95 dBm** receive sensitivity



Target applications

- Wireless audio
- Point of sale (ePOS)
- Medical devices
- Set-top boxes (STBs)
- Wearable devices
- Sensor hub, sensor gateway: home and factory automation
- Industrial: cable replacement
- Automotive aftermarket
- Sports and fitness devices

Wi-Fi | WL18xx and CC2564C: Controller subsystem qualification

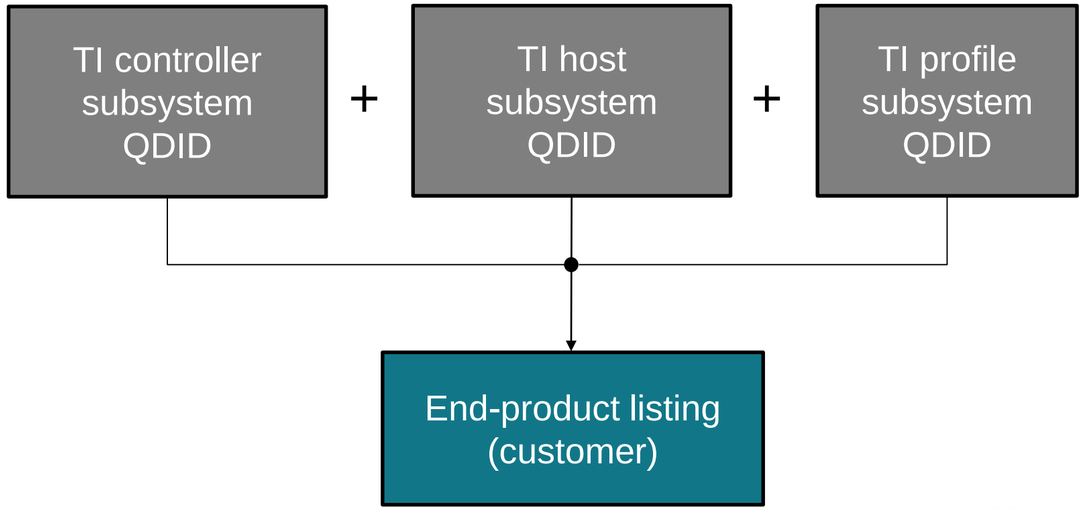
What is it?
Reclassification of dual mode Bluetooth transceiver solutions from component to controller subsystem in order to **simplify the certification process for customers**

Key benefits & features	
Design simplification	• Customers no longer need to register design as controller subsystem based on TI's component • Ensures longevity of Bluetooth designs (no need to worry about recertification every 3 years) • No additional RF testing • No need to address mandatory errata between our qualification and customer certification
Recommendations	• Customers must follow TI's guidelines and/or ensure they meet the RF-PHY performance • Customers should look at the ICS of the certification listing to understand what features are supported • Product qualification is determined using least common denominator of the Component/Controller Subsystem and Host Subsystem qualifications

QDID listings:

- QDID 177062 – WL183x
- QDID 177061 – CC2564C, BL6450CQ
- QDID 177060 – WL18xxQ (v5.0)

Bluetooth qualification process:



Software stack | Overview

TI's Dual-mode *Bluetooth*® stack is based on Bluetopia

The device can be used on any host processor* with sufficient memory (256KB is the recommended minimum)

Several host platforms are provided and supported directly by TI

- MSP432
- STM32F4
- AM335x

The software stacks are royalty free with TI's CC256x or WiLink™ 8 devices

Third parties can be contacted for

- Custom MCU/MPU porting
- Optimization and development
- Application integration and custom support

*Host processor requires software stack compatible with TI's BT controllers

Software stack

Bluetooth® software stack	
Bluetooth BR/EDR and Bluetooth low energy profiles	• BR/EDR – A2DP, AVRCP, GAP, HSP, HFP, HID, MAP, PBAP, SPP • Bluetooth LE – ANS, BAS, CSCS, DIS, FMP, GAPS, GATT, HTS, HRS, HIDS, HID over GATT, IAS, LLS, PASS, PXP, TPS
Tool chains supported	• IAR Systems® and Code Composer Studio™ IDE
OS	• No OS, FreeRTOS, Linux
MCU/MPU supported	• MSP432™ microcontrollers • Sitara™ (Linux) • STM32 support (No OS/FreeRTOS)
Product info	Selection Guide: SWRU523 Product page: https://www.ti.com/product/CC2564C#software-development

Software features

- **LE Secure connections:** Bluetooth Low Energy security algorithm (ECDH) for key generation and new pairing procedure for key exchange
- **Link Layer topology:** Bluetooth Low Energy scatternet capabilities, managing connection in a dual-mode topology allowing sensor network topology
- Enhanced audio time synchronization supporting multi-speaker functionality
- PCM NBS/WBS enhancements
- **IoT:** internet access infrastructure (Bluetooth 4.1 L2CAP dedicated channels)
- Enhanced Voice HFP 1.6 (CSA2 spec commands)
- AFH (adaptive Frequency Hopping) enhancements
- **Security:** Bluetooth Core Errata 10734 and 11838 support

Reusable Bluetooth controller (5.1 compliant) & host stack certification

QDID 177060: Controller Subsystem (WL18xxQ)

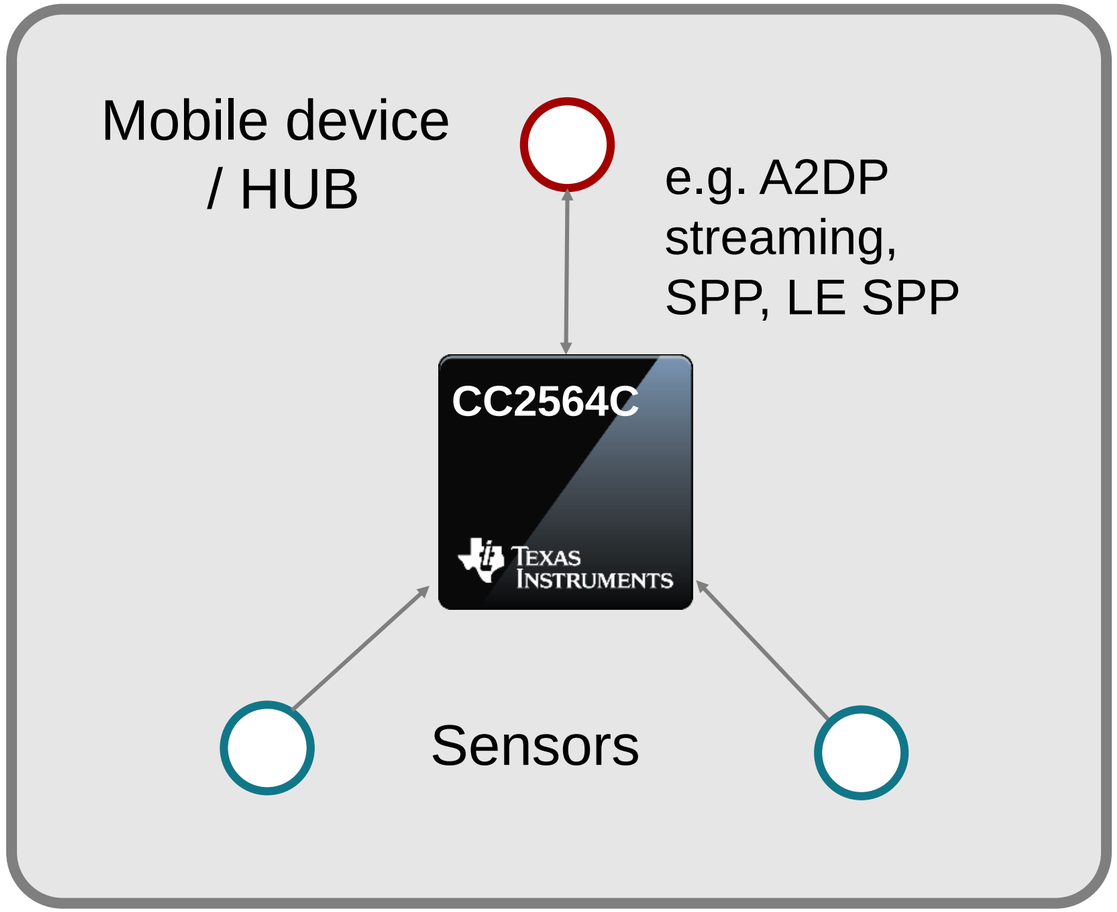
QDID 177061: Controller Subsystem (CC2564C)

QDID 177062: Controller Subsystem (WL183x)

QDID 172096: 5.1 Profile Subsystem

QDID 172097: 5.1 Host Subsystem

Dual mode/link layer topology



Dual-mode topology: Enables a dual-mode device to act as a *Bluetooth*® smart ready hub and Bluetooth Low Energy peripheral at the same time. The device can then communicate with Bluetooth Low Energy peripherals on one side and another Bluetooth smart ready hub device on the other side.

Link layer topology: Manages the connections between the devices used in a dual-mode topology implementation.

Source: Bluetooth SIG

Pick the right part – Key Bluetooth/Bluetooth LE dual mode options

Part number	Typical use case	BT HCI spec supported (controller certification)	TI Bluetooth Stack spec supported (host subsystem)	BT profile support	OS	Automotive Temp	Certified TI module available	Optional BLE features supported
CC2564MODA (Based on CC2564B)	**Headsets, hubs, point-of-sale systems** BT Audio and legacy profile applications. Dual mode BT classic (BR/EDR) + BLE	4.1	4.2	See QDID172096, QDID69886	RTOS Linux		yes	
CC2564C	**Best for headsets, hubs, point-of-sale systems that require BT classic + BLE** Best for future-proofing - BT SIG certification	5.1	4.2 5.1 coming 4Q21		RTOS Linux			
BL6450CQ	**Automotive dual-mode BT infotainment applications, such as head units**	5.1	4.2 5.1 coming 4Q21		RTOS Linux	yes		
WL1831MOD (part of the Wi-Fi family)	Wi-Fi + BT/BLE on one chip Seamless Wi-Fi and BT/BLE coexistence.	5.1	4.2 5.1 coming 4Q21		Linux		yes	
CC2642R (part of the 2.4GHz family)	BLE only Peripherals, central roles BLE mesh, Long range and high bandwidth	5.2	5.2	No BT classic support	RTOS			LE coded PHYs (Long Range) LE 2-Mbit PHY (High speed)

Thank you!

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