

Bluetooth low energy Wireless MCU for Automotive Applications

SimpleLink™ CC2640R2F-Q1
SimpleLink™ CC2541-Q1

Low Power RF
4Q17



Agenda

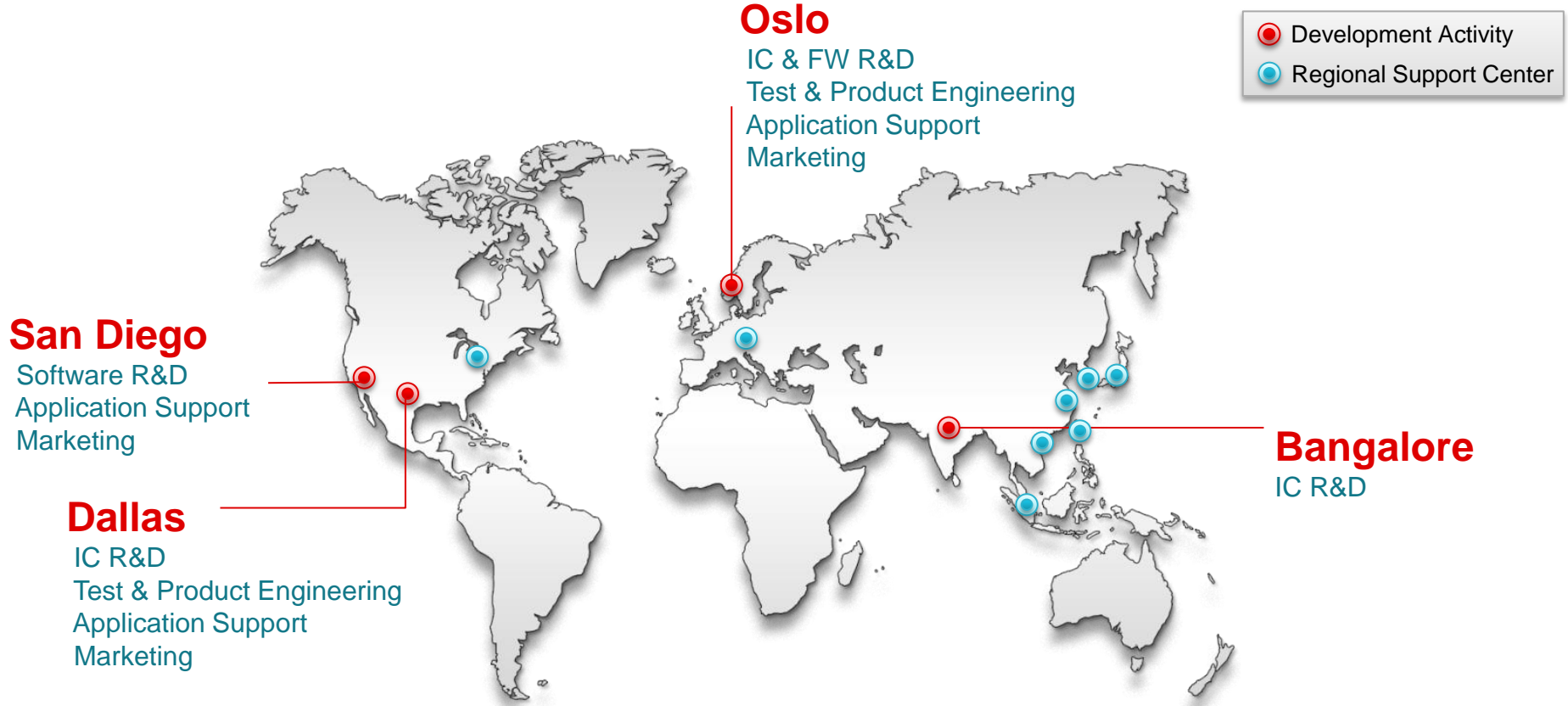
- **Why BLE for Automotive?**
- **LPRF Automotive Introduction**
- **LPRF Automotive Solutions**
- **SimpleLink™ CC2640R2F-Q1 Wireless MCU**
- **Getting Started with Development**

Why BLE for Automotive Applications?



- Interoperability with smartphones and wearables
- Global deployment in 2.4 GHz ISM band
- Low power for long battery life, and low footprint on car module
- Enables a cost effective solution for many emerging application

Introduction *LPRF Automotive*



LPRF Automotive Solutions

Overview

CC2541-Q1 Automotive Wireless MCU

IN PRODUCTION

Features and Benefits

- AEC-Q100 automotive qualified
- **Wireless MCU**— BLE radio, MCU and embedded flash. First automotive BLE SoC with in-system programmable flash
- **Grade 2 Temperature Rating (-40°C to +105°C)**
- **<20 mA peak current / 500 nA sleep current** – Long battery lifetime. Low average current allows for operation when the vehicle is not running
- **94 dB link budget** – Long Range and reliable data exchange

Software and Tools

- Royalty free BLE-STACK
- SmartRF™ Studio and SmartRF™ Flash Programmer
- iOS and Android sample apps
- Extensive library of SW examples and sample code

Hardware Development Kits



CC2541 Mini Development Kit



CC2541 Development Kit

<http://www.ti.com/product/cc2541-q1>

CC2541-Q1		Temperatures: -40 °C to 105 °C	
Bluetooth Smart (BLE) SimpleLink Wireless MCU	Memory	Power & Clocking	
	256kB flash 8kB RAM	32MHz XOSC 32.768 kHz XOSC 16 MHz RCOSC 32kHz RCOSC Low Power Modes POR and BOD	
Protocol	Interfaces	Timers	
Bluetooth Smart (BLE)	ADC Comparator 23 GPIO I2C	16 bit timer 8 bit timers (2) Sleep timer Watchdog timer	
System Modules	Radio	Packages	
8051 CPU DMA IO Controller IRQ Control Debug Interface	2.4 GHz GFSK	QFN 6x6 40 pin	
	Data Protection		
	AES Security Module		

Example Applications

- Car Access (RKE, PKE, PEPS)
- Car sharing
- Piloted parking
- Cable replacement and remote control
- Proximity sensing
- Interior lighting control
- Wireless On-Board Diagnostics
- Power seats with memory



CC2640R2F-Q1 Automotive Wireless MCU

IN PRODUCTION

Features and Benefits

- **AEC-Q100 automotive qualified**
- **Most integrated wireless MCU** – Design versatility and single-chip SoC
- **Lowest power consumption** - ~6mA radio RX/TX and low sleep current for increased battery life
- **Longest range** – 102 dB link budget for increased range and reliability
- **Grade 2 Temperature Rating (-40°C to +105°C)** – Use in areas where elevated temperatures are common
- **Wettable flanks package** – Enables faster and lower cost production line inspection

Software and Tools

- **Software Development Kit, including royalty free Stack**
- **BT v4.2 support with qualified Adopted Profiles (BLE 3.x)**
- **SmartRF Studio & TI iOS/Android Multitool**
- **Sensor Controller Studio**

Hardware Development Kits



CC2650 SensorTag



CC2640R2F LaunchPad

<http://www.ti.com/product/cc2640r2f-q1>

CC2640R2F-Q1

Temperature Grade 2: -40°C to 105°C

AEC-Q100 SimpleLink™ Wireless MCU	Memory 128 kB Flash 8 kB Cache 20+2+8 kB SRAM ROM	Power & Clocking Up to 48 MHz Internal DC-DC
Protocol Bluetooth® Low Energy	Comms Peripherals 2× SSI (SPI, μW, TI) UART I²C I²S Low-Power SPI 32-Ch μDMA	Timers 4× 16-Bit Timers RTC
Radio 2.4 GHz	System Modules ARM® Cortex®-M3 Radio Core ULP Sensor Controller	Analog 12-Bit ADC, 200 ks/s 2 Analog Comparators Programmable Current Source Temp. & Battery Monitor
	Interfaces 31 GPIOs Capacitive Sensing	Package 7×7 QFN48 Automotive Dedicated Wettable Flanks

Example Applications

- **Car Access (RKE, PKE, PEPS)**
- **Car sharing**
- **Piloted parking**
- **Cable replacement and remote control**
- **Proximity sensing**
- **Interior lighting control**
- **Wireless On-Board Diagnostics**
- **Power seats with memory**



CC2640R2F-Q1 & CC2541-Q1 *Feature Summary*

Parameter	CC2640R2F-Q1	CC2541-Q1
Temperature range	-40°C to 105°C (grade 2)	-40°C to 105°C (grade 2)
Bluetooth Specification	Bluetooth v4.2 + v5.0	Bluetooth v4.0
SW Upgradeable for Future BLE Spec Updates	Yes	No
Supply Voltage Range	1.8 – 3.8 V	2.0 – 3.6 V
Current Consumption @ best RX sensitivity	6.2 mA	18.3 mA
Current Consumption @ 0 dBm TX output power	6.9 mA	18.6 mA
Operating System	Yes, TI-RTOS	No, Task Scheduler
On-chip DC-DC	Yes	No
Shutdown current	150 nA	500 nA
Standby current with memory retention	1 µA	1 µA
MCU	32-bit ARM Cortex-M3 (48 MHz)	8-bit 8051 (32 MHz)
Embedded Flash / RAM	128 KB + 8 KB cache / 20 KB + On Chip ROM	256 KB / 8 KB
Output Power	+5 dBm	0 dBm
Receiver Sensitivity	-97 dBm	-94 dBm
RF Link Budget	102 dB	94 dB
Package	Automotive Grade RGZ QFN48-7x7 w/ 0.5 mm pitch	RHA QFN40-6x6 w/ 0.5 mm pitch
Wettable Flanks on QFN	Yes	No
Simultaneous Connections	Up to 8 (Multi-Role)	Up to 3 (Central to Peripheral)
#GPIOs	31	23
Development Environment	TI Code Composer Studio, IAR	IAR
Availability	Available now 15 September 2017	Available now (released April 2014)

End Equipment's for BLE

Target EE's for Bluetooth Low Energy in Automotive

Target End Equipment for BLE



Infotainment & Cluster

- Head Unit
- Telematics
- Media Interface
- Rear Seat Entertainment



BCM/Gateway

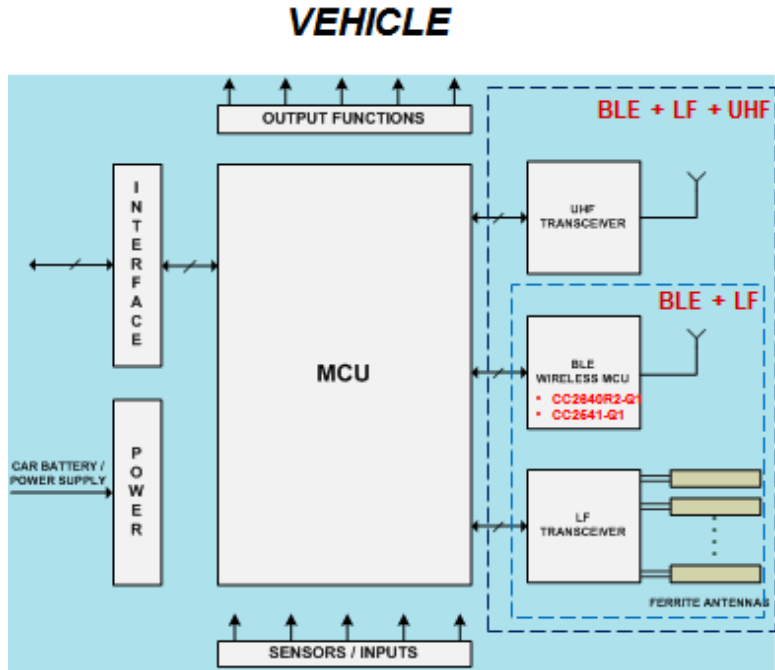
- Body Control Module (BCM)
- Junction Box
- Gateway



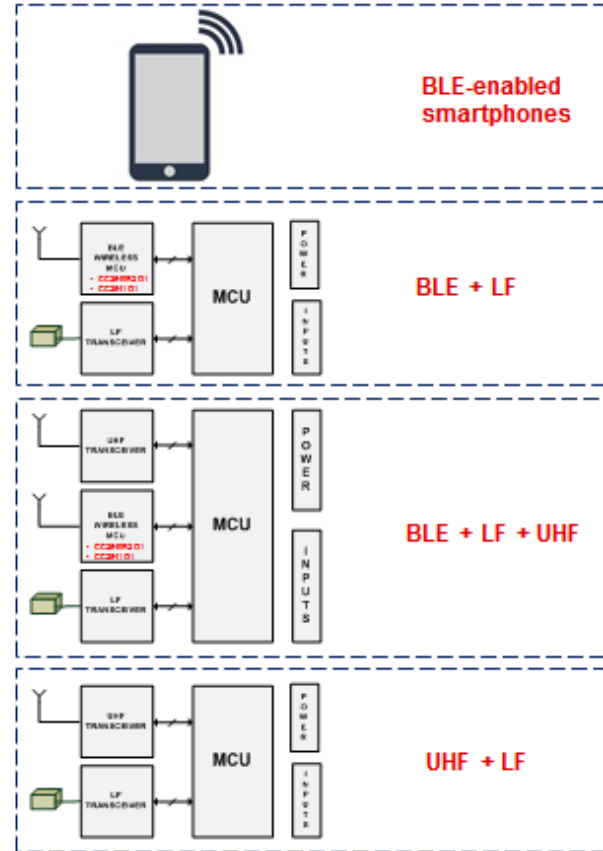
Security Systems

- Passive Entry Passive Start -PEPS
- Remote Keyless Entry- RKE
- Base Station

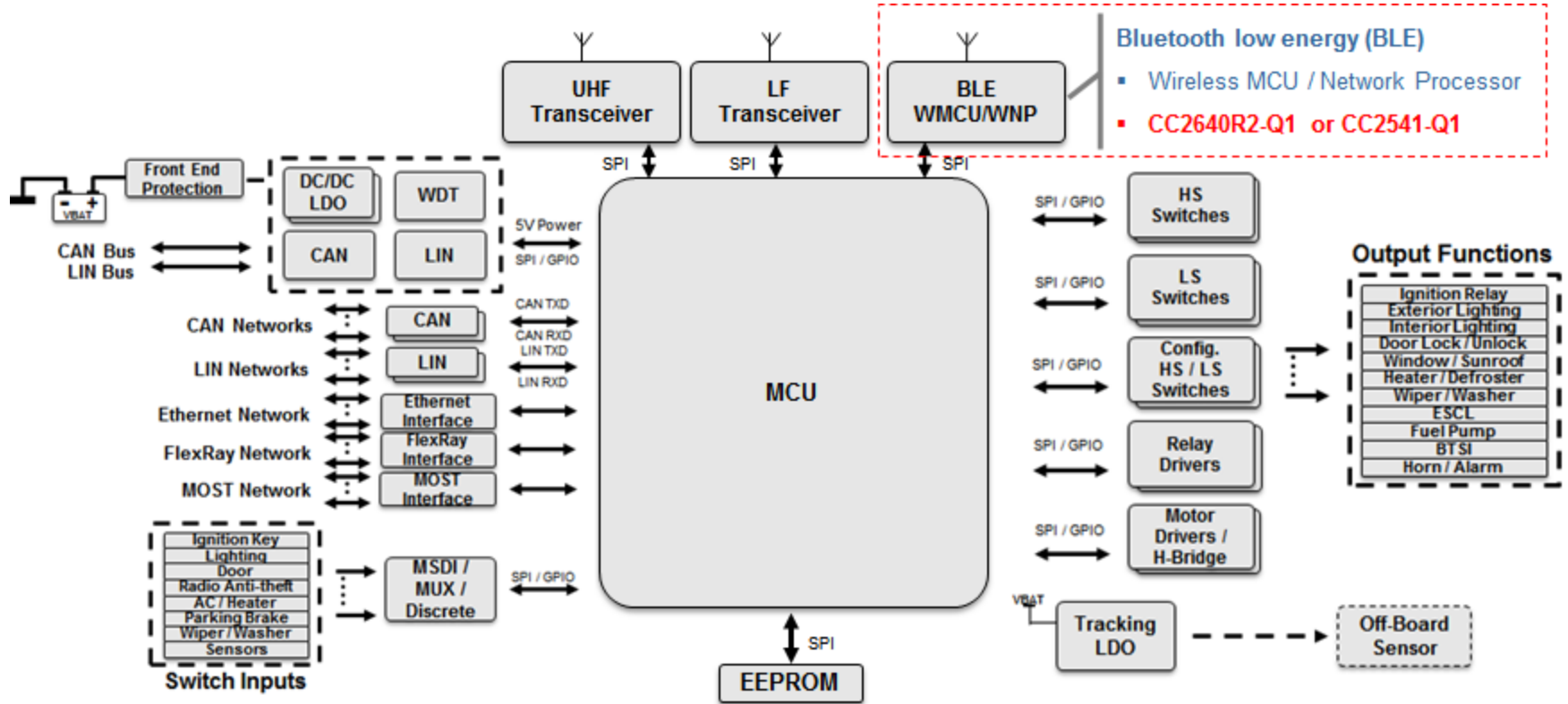
Generic Wireless Car Access



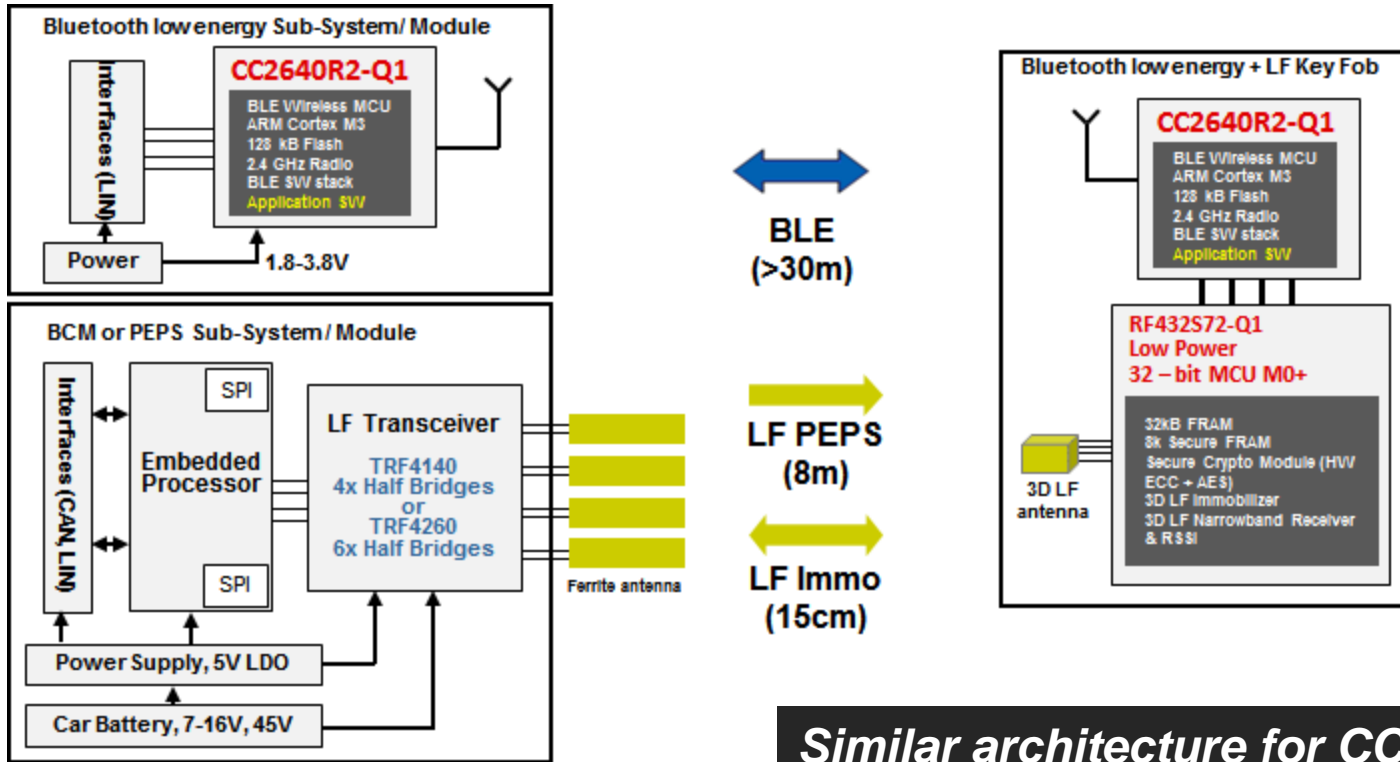
'Key Fob'



Multifunction BCM with Gateway (Example)



BLE + LF Car Access System Block Diagram



Similar architecture for CC2541-Q1

CC2640R2F-Q1

Overview, Roadmap, Schedule and Development Path

CC2640R2F-Q1 *Benefits*



TI Automotive Qualification

- **Wettable flanks package** for enhanced production line inspection
- **AEC-Q100** qualification and TI **high quality** automotive flow
- **Grade 2** temperature range (-40C to 105C) for increase reliability
- **Safe launch** with TI Quality alignment



Low Power, Longest Range

- **Longest range** (RX sensitivity and TX power) with superior 101dB link budget
- Lowest active and sleep power consumption for increased battery life
 - **~6 mA** Radio peaks
 - **1 uA** Sleep
 - **65 μ A/MHz** ARM Cortex M3
 - **<10 uA** avg. Current @ 1s CI

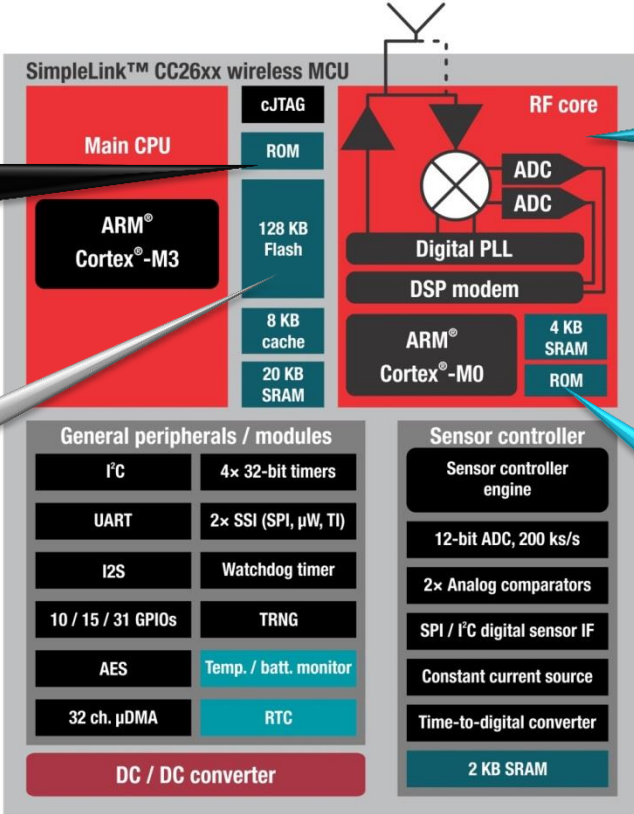


Platform Flexibility

- Multi-core SoC with separate application and radio domain enabling **flexibility for innovation**
- **Bluetooth 5** qualified

CC2640R2F-Q1 Platform Flexibility

Bluetooth LE v4.2
Patchable M3 ROM Supports
Host & Controller including
v4.2 Privacy, Security &
Higher Throughput.



Increased Range
Bluetooth 5.0 PHY
validated with range of
~1km line-of-sight
outdoors

Embedded Flash
80+ kB Flash available for
customer applications & future
Bluetooth LE standard
revisions.

Updatable Radio
Patchable M0 ROM supports
lower-level radio changes as
special standard requirements
change & other locationing
features are needed.

TI and AEC-Q100

- AEC Q100 is an industry standard specification developed by major *automotive* manufacturers and suppliers that details a set of stress tests, defines the minimum stress test driven qualification requirements, and references test conditions for the qualification of integrated circuits.

TI is actively participating in the AEC-Q100 standard process.

- TI has in-house expertise and equipment to perform stress tests (AEC-Q100 and beyond)
Advantages: Reliability, flexibility and quick turn-around time

TI CC2640R2F-Q1 Auto Qual beyond AEC-Q100

Item	AEC-Q100 Requirement	CC2640R2F-Q1 TI Qual
AEC-Q100 Defined Tests <ul style="list-style-type: none"> ▪ Accelerated Environment Stress Tests (THB, UHST, TC, PTC, HSTL) ▪ Accelerated Lifetime Simulation Tests (HTOL, ELFR, EDR) ▪ Package Assembly Integrity Tests (WBS, WBP, SD, PD) ▪ Electrical Verification (HBM, CDM, LU, ED) 	✓	✓
TS-16949 certified (TI is TS-16949 compliant) <i>TS 16949 defines the quality management system requirements for the design and development, production and, when relevant, installation and service of automotive-related products.</i>	no	✓
<ul style="list-style-type: none"> ▪ Special automotive process with increased inspection and screening ▪ Statistical process control <ul style="list-style-type: none"> → Tighter performance parameter control → Increased device quality 	no	✓
Automotive dedicated package with wettable flanks	no	✓
Tri-temp device test (-40C/ambient/+105 C) <i>All parts are production tested at minimum, ambient and maximum operational temperatures for increased reliability.</i>	no	✓
Extended documentation and support (PPAP)	no	✓

CC2640R2F-Q1 vs. CC2640R2F

Item	Automotive CC2640R2F-Q1	Commercial CC2640R2F
Quality System	TS 16949	ISO 9001
Qualification	AEC-Q100	JEDEC
Temperature Range	-40 C to +105 C	-40 C to +85 C
Automotive qualified Fabs/AT-sites Special automotive process with increased inspection and screening (tighter performance parameter control)	Yes	No
Package	Automotive grade package with wettable flanks	Standard QFN package
Test coverage	Improved test coverage compared to CC2640R2F	Good
PCN period for significant changes	180 days	90 days
PPAP	Yes	No
Customer Return	Automotive Flow (8D)	Commercial

TI's Bluetooth low energy HW

CC2640 BT4.2 ★

Cortex M3
128KB Flash
20KB RAM
Ultra low power
4x4 / 5x5 / 7x7 QFN

CC2650MOD BT4.2

Pre-certified BLE module
Integrated antenna
Longest range at lowest power

CC2640R2F BT5 ★

Cortex M3
275KB NV Memory
Upto 28KB RAM
Ultra low power

2.7x2.7 WCSP
4x4 / 5x5 / 7x7 QFN

CC2640R2F-Q1 BT5 ★ Q1

Cortex M3
Automotive qualified
AEC-Q100
7x7 QFN Wettable Flanks

CC2540 BT4.0

High output power +4dBm
Up to 256KB Flash
USB interface

CC2541 BT4.0

Up to 256KB Flash
Flexible
System cost optimized

CC2541-Q1 BT4.0 Q1

World's first
Integrated Flash
Automotive qualified
BLE SoC

CC2540T BT4.0

World's only 125C graded
BLE solution

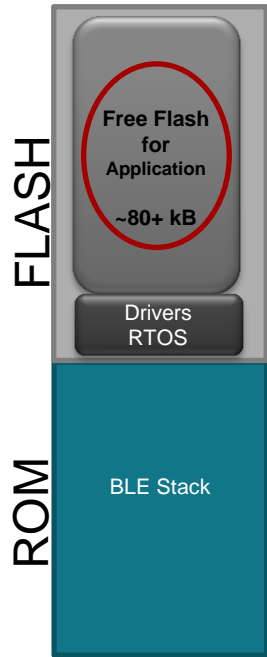
★ SimpleLink MCU Platform

2017

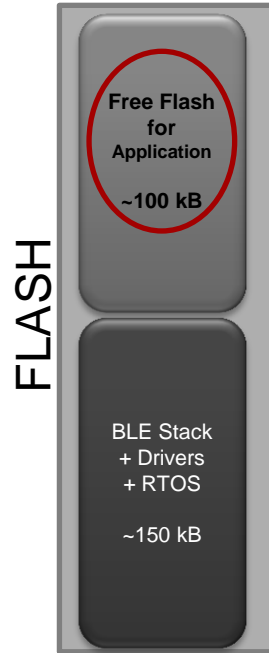
2018

2019

CC2640R2F-Q1 *Re-Purposed Industrial CC2640R2F*



TI CC2640R2F-Q1



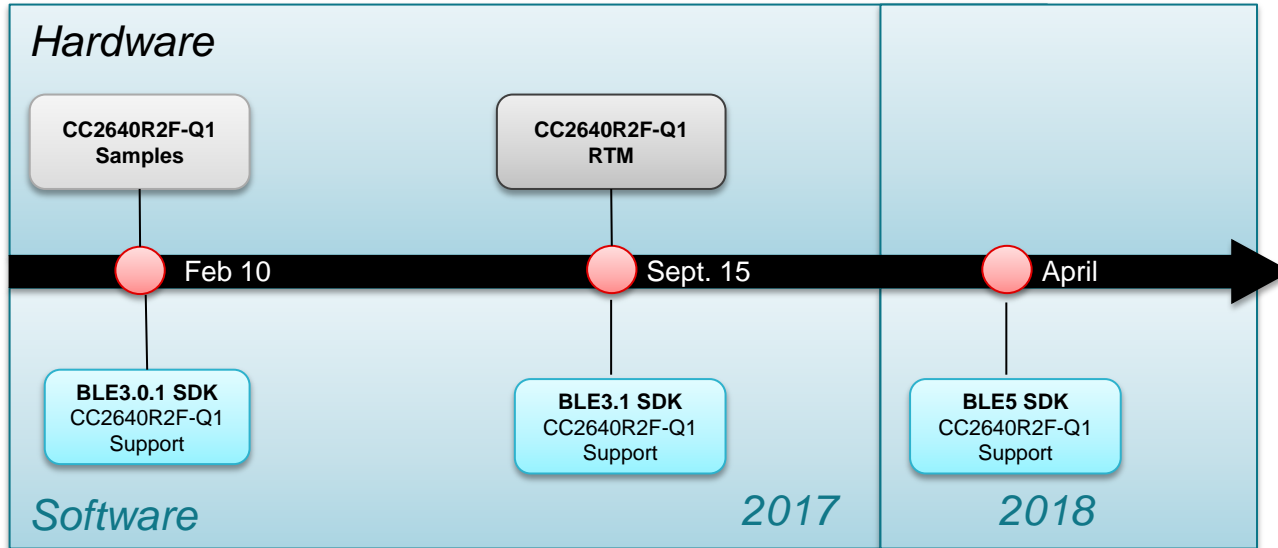
Comp BLE
(256k flash)

Start Development Today

- CC2640R2F-Q1 Sampling
- 256kB flash equivalent BLE SoC
 - 80+ kB free flash for application
- Bluetooth 4.2 support in the ROM
- Bluetooth LE stack upgradable via ROM patches

CC2640R2F-Q1 *Development Path*

- CC2640R2F silicon and software **available today**
- CC2640R2F-Q1 silicon sampling
- CC2640R2F to CC2640R2F-Q1 transition
 - Pin-out and package layout compatible
 - API Compatible; Application Migration Guide Included”



Getting Started

CC2640RF2-Q1 Development

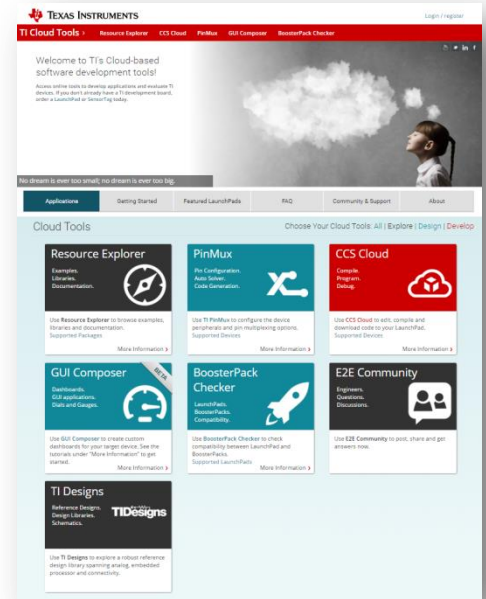
Get started right now

Use CC2640R2F for development, visit dev.ti.com



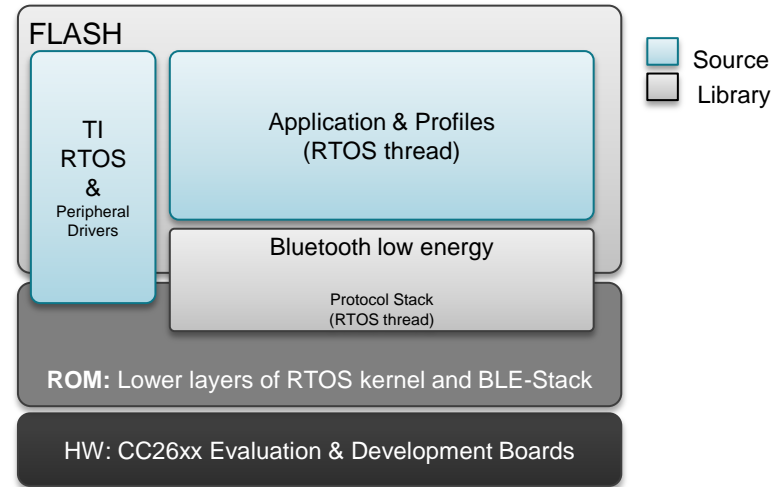
CC2640R2 LaunchPad \$29

- The **LaunchPad** features on-board emulation with the XDS-110 emulator, which means you can program and Debug without any additional tools
- Plenty of **software examples** to get started
- Comprehensive selection of add-on boards for flexible prototyping”
- Supported by accompanying iOS/Android apps



Software Platform

- BLE-Stack™ 3.0 *Available now*
- BT4.2 Support
 - LE Data Length Extension (2.5x Increased throughput)
 - LE Secure Connections (DH ECC)
 - LE Privacy 1.2



Getting Started *with CC2640 SW Development*

CCS Cloud + Project Zero

- No software needed. Only a Launchpad and a browser
- Click a button to flash device with Project Zero and follow instructions for your first iOS / Android interaction with BLE
- Import project to cloud editor and develop / build / debug, or:
- Download all needed project files in one archive file for CCS Desktop development
- Visit dev.ti.com

SimpleLink Academy

- Training modules integrated with CCS
- Explanations and theory
- Interactive quizzes
- Tasks with step by step instructions
- Learn about:
 - TI-RTOS concepts (Task, Semaphore etc)
 - BLE Services
 - Simple Network Processor
 - Sensor Controller Studio
 - BLE Security
 - Over the Air Download Bluetooth Developer Studio
- Visit www.ti.com/ble-wiki

BLE-Stack SDK + GitHub

- Example usage of adopted profiles included in the BLE SDK installer
 - Blood Pressure
 - HID Keyboard / Mouse
 - Heart Rate
 - Cycling / Running Sensor
 - Glucose Sensor / Collector
 - .. and more
 - Visit www.ti.com/ble-stack
- Advanced / specialized examples
 - Simple Network Processor
 - Log application events to UART
 - Simultaneous Master/Slave
 - Visit github.com/ti-simplelink

Simple

Advanced

Development Tools

SmartRF™ Tools

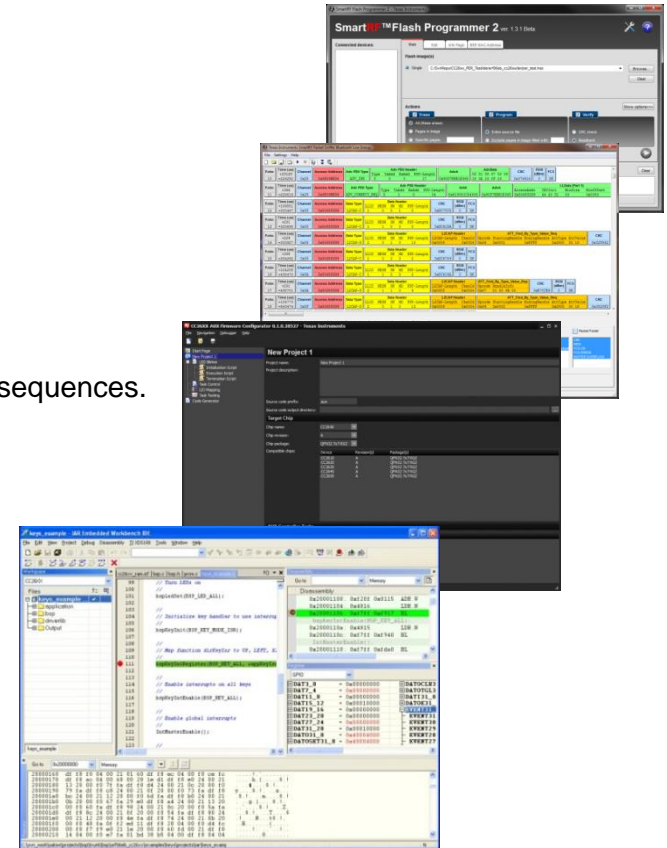
- SmartRF Studio
 - Radio performance evaluation, testing and configuration
- SmartRF Packet Sniffer
 - Capture over the air packets for RF link debugging and protocol analysis
- SmartRF Flash Programmer
 - Flash tool. Comes in command-line version for automated programming sequences.

Sensor Controller Studio

- Setup SCE tasks and code the behaviour script for them
- Generate driver source files for the CM3

Multiple software development tools supported

- IAR Embedded Workbench® for ARM
- Code Composer Studio



Bluetooth low energy Support Collateral

- TI Cloud Tools (dev.ti.com)
 - Resource Explorer with SDK, SLA, Documentation
 - CCS Cloud
 - And more
- E2E Support Community (www.ti.com/ble-forum)
 - Support by TI Software and Hardware experts
- GitHub SW Repository (github.com/ti-simplelink)
 - Additional SW examples to the SDK
- BLE Wiki (www.ti.com/ble-wiki)
 - Additional design resources

The collage displays various TI support resources:

- Cloud Tools:** A grid of tool cards including Resource Explorer, PinMux, CCS Cloud, Gallery, GUI Composer, UniFlash, BoosterPack Checker, E2E Community, and TI Designs.
- E2E Community Forum:** A screenshot of the TI E2E Community forum showing a search for "Bluetooth low energy" and a list of threads such as "Excel sheet to estimate CC2640R2F, CC2640, CC2650, CC254x with Android 6.016" and "CC2640R2F/CC2640/CC2650 Getting Started and FAQ [u: 2017 Mar 27]".
- GitHub Repository:** A screenshot of the TI SimpleLink GitHub repository showing a table of files and folders, including "Getting Started", "Product Information", "Tools and IDEs", and "Support".



本資料僅供參考，使用本資料需遵守TI的使用條款，詳情請參考www.ti.com.tw