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*

San Diego
- Software R&D
- Application Support
- Marketing

Dallas
- IC R&D
- Test & Product Engineering
- Application Support
- Marketing

Oslo
- IC & FW R&D
- Test & Product Engineering
- Application Support
- Marketing

Bangalore
- IC R&D

Development Activity
Regional Support Center
LPRF Automotive Solutions

Overview
CC2541-Q1 Automotive Wireless MCU

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

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

http://www.ti.com/product/cc2541-q1
CC2640R2F-Q1 Automotive Wireless MCU

**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

**Example Applications**

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

**http://www.ti.com/product/cc2640r2f-q1**
## CC2640R2F-Q1 & CC2541-Q1 Feature Summary

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

BLE-enabled smartphones

BLE + LF

BLE + LF + UHF

UHF + LF
Multifunction BCM with Gateway (Example)

- Bluetooth low energy (BLE)
  - Wireless MCU / Network Processor
  - CC2640R2-Q1 or CC2541-Q1

- MCU
  - UHF Transceiver
  - LF Transceiver
  - BLE WMCU/WNP

- Output Functions
  - Ignition Relay
  - Exterior Lighting
  - Interior Lighting
  - Door Lock/Unlock
  - Window / Sunroof
  - Heater / Defroster
  - Wiper / Washer
  - ESCM
  - Fuel Pump
  - BYS
  - Horn / Alarm

- Switch Inputs
  - ignition Key Lighting
  - Door
  - Radio Anti-Theft
  - AC / Heater
  - Parking Brake
  - Wiper / Washer
  - Sensors

- CAN Bus LIN Bus
- CAN Networks
- LIN Networks
- Ethernet Network
- FlexRay Network
- MOST Network

- Tracking LDO
- Off-Board Sensor

- Front End Protection
- DC/DC LDO
- WDT
- CAN
- LIN
- Ethernet Interface
- FlexRay Interface
- MOST Interface

- SPI
- SPI / GPIO
- SPI / GPIO
- SPI / GPIO
- SPI / GPIO

- Texas Instruments
BLE + LF Car Access System Block Diagram

Similar architecture for CC2541-Q1
## CC2640R2F-Q1 Benefits

<table>
<thead>
<tr>
<th>TI Automotive Qualification</th>
<th>Low Power, Longest Range</th>
<th>Platform Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Wettable flanks package for enhanced production line inspection</td>
<td>• Longest range (RX sensitivity and TX power) with superior 101dB link budget</td>
<td>• Multi-core SoC with separate application and radio domain enabling flexibility for innovation</td>
</tr>
<tr>
<td>• AEC-Q100 qualification and TI high quality automotive flow</td>
<td>• Lowest active and sleep power consumption for increased battery life</td>
<td>• Bluetooth 5 qualified</td>
</tr>
<tr>
<td>• Grade 2 temperature range (-40C to 105C) for increased reliability</td>
<td>• ~6 mA Radio peaks</td>
<td>• Safe launch with TI Quality alignment</td>
</tr>
<tr>
<td>• Safe launch with TI Quality alignment</td>
<td>• 1 µA Sleep</td>
<td>• Multi-core SoC with separate application and radio domain enabling flexibility for innovation</td>
</tr>
<tr>
<td></td>
<td>• 65 µA/MHz ARM Cortex M3</td>
<td>• Bluetooth 5 qualified</td>
</tr>
<tr>
<td></td>
<td>• &lt;10 µA avg. Current @ 1s Cl</td>
<td></td>
</tr>
</tbody>
</table>
CC2640R2F-Q1 **Platform Flexibility**

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

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

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

**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
<table>
<thead>
<tr>
<th>Item</th>
<th>AEC-Q100 Requirement</th>
<th>CC2640R2F-Q1 TI Qual</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEC-Q100 Defined Tests</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>▪ Accelerated Environment Stress Tests (THB, UHST, TC, PTC, HSTL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ Accelerated Lifetime Simulation Tests (HTOL, ELFR, EDR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ Package Assembly Integrity Tests (WBS, WBP, SD, PD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ Electrical Verification (HBM, CDM, LU, ED)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS-16949 certified (TI is TS-16949 compliant)</td>
<td>no</td>
<td>✓</td>
</tr>
<tr>
<td><em>TS 16949 defines the quality management system requirements for the design and development, production and, when relevant, installation and service of automotive-related products.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ Special automotive process with increased inspection and screening</td>
<td>no</td>
<td>✓</td>
</tr>
<tr>
<td>▪ Statistical process control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>→ <strong>Tighter performance parameter control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>→ <strong>Increased device quality</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automotive dedicated package with wettable flanks</td>
<td>no</td>
<td>✓</td>
</tr>
<tr>
<td>Tri-temp device test (-40C/ambient/+105 C)</td>
<td>no</td>
<td>✓</td>
</tr>
<tr>
<td><em>All parts are production tested at minimum, ambient and maximum operational temperatures for increased reliability.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended documentation and support (PPAP)</td>
<td>no</td>
<td>✓</td>
</tr>
</tbody>
</table>
## CC2640R2F-Q1 vs. CC2640R2F

<table>
<thead>
<tr>
<th>Item</th>
<th>Automotive CC2640R2F-Q1</th>
<th>Commercial CC2640R2F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality System</td>
<td>TS 16949</td>
<td>ISO 9001</td>
</tr>
<tr>
<td>Qualification</td>
<td>AEC-Q100</td>
<td>JEDEC</td>
</tr>
<tr>
<td>Temperature Range</td>
<td>-40 C to +105 C</td>
<td>-40 C to +85 C</td>
</tr>
<tr>
<td>Automotive qualified Fabs/AT-sites</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Special automotive process with increased inspection and screening (tighter performance parameter control)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Package</td>
<td>Automotive grade package with wettable flanks</td>
<td>Standard QFN package</td>
</tr>
<tr>
<td>Test coverage</td>
<td>Improved test coverage compared to CC2640R2F</td>
<td>Good</td>
</tr>
<tr>
<td>PCN period for significant changes</td>
<td>180 days</td>
<td>90 days</td>
</tr>
<tr>
<td>PPAP</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Customer Return</td>
<td>Automotive Flow (8D)</td>
<td>Commercial</td>
</tr>
</tbody>
</table>
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)
- Cortex M3
- Automotive qualified
- AEC-Q100
- 7x7 QFN Wettable Flanks

CC2541 (BT4.0)
- World’s first Integrated Flash
- Automotive qualified
- BLE SoC

CC2540 (BT4.0)
- High output power +4dBm
- Up to 256KB Flash
- USB interface

CC2540T (BT4.0)
- World’s only 125C graded BLE solution

CC2541-Q1 (BT4.0)
- World’s first Integrated Flash
- System cost optimized

SimpleLink MCU Platform

2017
2018
2019
**CC2640R2F-Q1 Re-Purposed Industrial CC2640R2F**

- 256kB flash equivalent BLE SoC
  - ~100 kB Free Flash for Application
  - ~80+ kB BLE Stack + Drivers + RTOS
  - ~150 kB 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

**TI CC2640R2F-Q1**
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

Hardware

- CC2640R2F-Q1 Samples
  - Feb 10
- CC2640R2F-Q1 RTM
  - Sept. 15
- BLE3.0.1 SDK CC2640R2F-Q1 Support
- BLE3.1 SDK CC2640R2F-Q1 Support
- BLE5 SDK CC2640R2F-Q1 Support

Software

- 2017
- 2018
Getting Started

CC2640RF2-Q1 Development
Get started right now

Use CC2640R2F for development, visit dev.ti.com

CC2640R2 Lauchpad $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
Evaluation Tools

BTool
Run and test all possible Bluetooth low energy functionality controlled from the PC tool.

BLE Device Monitor
Provides an intuitive and graphical way to explore Bluetooth low energy Services and Characteristics.

SmartRF™ Protocol Packet Sniffer
Capture Bluetooth low energy communication live with full overview.

SmartRF™ Flash Programmer
Program devices and Read/write IEEE addresses
Bluetooth low energy **Support Collateral**

- **TI Cloud Tools** ([dev.ti.com](dev.ti.com))
  - Resource Explorer with SDK, SLA, Documentation
  - CCS Cloud
  - And more

- **E2E Support Community** ([www.ti.com/ble-forum](www.ti.com/ble-forum))
  - Support by TI Software and Hardware experts

- **GitHub SW Repository** ([github.com/ti-simplelink](github.com/ti-simplelink))
  - Additional SW examples to the SDK

- **BLE Wiki** ([www.ti.com/ble-wiki](www.ti.com/ble-wiki))
  - Additional design resources