TI Low Power RF

Designer’s Guide to LPRF
# TI Low-Power RF Technology Solutions

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Define
RF Design Requirements

Considerations when starting an RF design:

• How many members/nodes will participate the wireless network?
• What is the required range between the devices?
• Is there a special need for low power consumption?
• Are there common standards that have to be met?
Define
Network Topology

Star network with multiple nodes:
• Host device with hub function
• simple end devices

Point to Point:
• one way or two way communication
• simple protocol using SimpliciTI or TIMAC
Define

Network Topology: **ZigBee** Mesh

- **ZigBee Coordinator**
  - Starts the Network
  - Routes packets
  - Manages security
  - Associates Routers and End Devices
  - Example: Heating Central

- **ZigBee Router**
  - Routes packets
  - Associates Routers and End Devices
  - Example: Light

- **ZigBee End Device**
  - Sleeps most of the time
  - Can be battery powered
  - Does not route
  - Example: Light switch

- Devices are pre-programmed for their network function
- Coordinator can be removed
## Define

### Network Topology

<table>
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<tr>
<th>Topology</th>
<th>Any Radio HW + Proprietary SW</th>
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<th>802.15.4 TIMAC</th>
<th>RF4CE</th>
<th>ZigBee</th>
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<tr>
<td>Any Topology</td>
<td>Point to Point</td>
<td>Star Network</td>
<td>Star Network</td>
<td>Star Network</td>
<td>Mesh</td>
</tr>
<tr>
<td></td>
<td>Star Network</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Code Size</td>
<td>variable</td>
<td>&lt; 8 KByte</td>
<td>&lt;32 KByte</td>
<td>&lt;64 KByte</td>
<td>&gt;64 KByte</td>
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<tr>
<td>Complexity</td>
<td>variable</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Define

Range and Data rate: Range propagation

• How far can TX and RX be apart from each other?
• Friis’ transmission equation for free space propagation:

\[ P_r = P_t + G_t + G_r + 20 \log \left( \frac{\lambda}{4\pi} \right) - 20 \log d \quad \text{or} \quad P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2} \]

\[ d = \frac{\lambda}{4\pi} \sqrt{\frac{P_t G_t G_r}{P_r}} \]

– \( P_t \) is the transmitted power, \( P_r \) is the received power
– \( G_t \) is the transmitter, \( G_r \) is the receiver antenna gain
– \( d \) is the distance between transmitter and receiver, or the range
– Lambda is the wavelength \( \lambda = \frac{c}{f} = \frac{\text{Speed of light}}{\text{Frequency}} \)
Define

Range and Data rate: “Real life”

Compared to the estimated range we should get in theory here are some “real life” rules and experiences on RF range:

- 120 dB link budget at 433 MHz gives approximately 2000 meters (TI rule of thumb)

- Based on the empirical results above and Friis’ equation estimates on real range can be made

- Rule of Thumb:
  - 6 dB improvement ~ twice the distance
  - Double the frequency ~ half the range (433 MHz longer range than 868 MHz)
Define
Range and Data rate: Important factors

- Antenna (gain, sensitivity to body effects etc.)
- Sensitivity: Lowest input power with acceptable link quality (typically 1% PER)
- Channel Selectivity: How well a chip works in an environment with interference
- Output power
- Environment (Line of sight, obstructions, reflections, multi-path fading)
Define
Range and Data rate: Estimated LOS

Test Example:
CC1101 with 0dBm output power, 250KBps, Johansson Balun, 915MHz, Dipole Antenna
Range: 290m

See also
Design Note:
Range Measurements in an Open Field Environment

Note: These examples should be taken as a rough estimation as the final design is highly dependent on the antenna, frequency, output power and other parameters.
Define Power Consumption

Low Power characteristics and features of TI’s RF devices:

- Low sleep current
- Minimum MCU activity
- RX/TX turn around time
- Adaptive output power using RSSI
- Fast crystal start-up time
- Fast PLL calibration (and settling)
- Carrier sense recognition
- Low RX peak current
- Minimum duty cycle
- Wake on radio (new devices)
Define

Power Consumption: Application Scenarios

High duty cycle applications:
• Active radio current consumption
• RX/TX and Calibration

Low duty cycle applications:
• MCU sleep current
• Regulator quiescent current
• Average radio current consumption

Long Packet Length
Radio power dominating

Short Packet Length
Calibration power dominating

Low duty-cycle transmission
Sleep power dominating
Define

Power Consumption: Low-Power Essentials

- Use the lowest possible duty cycle
  - Send data only when needed, do not send more data than necessary
  - Use the highest data rate you can (trade-off vs. range)
  - Watch out for protocol-related overhead

- Use the lowest possible voltage
  - RF chips have reduced current draw at lower voltages
  - Low voltage degrades RF performance
  - Above not a problem if on-chip regulator

- Use a switch-mode regulator with low quiescent current to maximize battery lifetime
Define
Power Consumption: Example

The Challenge of Powering a LPRF System

CC2500 Typicals:
Vcc Range: 1.8V to 3.6V
WOR Sleep Current: 900nA
Idle Current: 1.5mA
FSTXon Current: 7.4mA
Rx Current: 15mA @ 2.4kB/s
Tx Current: 21mA @ 0dB

MSP430F2274 Typicals:
Vcc Range: 1.8V to 3.6V
Sleep Current: 0.1uA @ 3V
32kOsc Current: 0.9uA @ 3V
CPU off Current: 90uA @ 3V
Active Current: 390uA @ 3V
Define
Power Consumption

Typical Power Profile of a LPRF System

- External Oscillator Settling: ~350us
  - 7.4mA x 809us = 1.67 uA Hr

- Frequency Synthesizer Calibration: ~809us
  - 15mA x 7.5us = 31.3 uA Hr

- Receive or Transmit: ~0.1us
  - 1.5mA x 0.1us = 0.04 pA Hr

- Radio In Idle: ~990ms
  - 1uA x 990ms = 0.275 pA Hr

- Radio In Sleep: ~7.5ms
  - 7.4mA x 809us = 1.67 uA Hr

Typical Power Profile of a LPRF System
Select
Choose the right RF solution

How to choose the perfect RF solution:
• Does the application need to associate with an existing system?
• What kind of software protocols fit the application best?
• Are there regulations to be considered?
• How much time/resources are available to get the product to market?
Select Proprietary or Standard

TI LPRF offers several low power RF solutions by providing the required Hardware and Software.

As a result there is no need to promote any specific low power RF protocol as the solution for all applications.

However, it is important to make the customer choose the best fitting protocol for the targeted application in order to get optimal performance and meet expectations.
## Select Proprietary or Standard

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<td>TI MAC</td>
<td>Design Freedom</td>
<td>CC2530, CC2530ZNP</td>
<td>2.4 GHz</td>
</tr>
<tr>
<td><em>Z-Stack + Simple API</em></td>
<td>Design Freedom</td>
<td>TI MAC</td>
<td>Design Freedom</td>
<td>CC2530, CC2430 MSP430+CC2520</td>
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<td><em>Remo TI</em></td>
<td>Design Freedom</td>
<td>TI MAC</td>
<td>Design Freedom</td>
<td>CC111x, CC251x MSP430+CC1101 or CC2500</td>
<td>2.4 GHz Sub 1 GHz</td>
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<td><em>IEEE 802.15.4</em></td>
<td>Design Freedom</td>
<td>TI MAC</td>
<td>SimpliciTI</td>
<td>all LPRF devices</td>
<td>2.4 GHz Sub 1 GHz</td>
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<td>Design Freedom</td>
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</table>
Select Proprietary or Standard: ZigBee

“The ZigBee Alliance is an association of companies working together to enable reliable, cost-effective, low-power, wirelessly networked monitoring and control products based on an open global standard”
Source: ZigBee Alliance homepage

Promoters of the ZigBee alliance are:
Select
Proprietary or Standard: ZigBee

Security & Alarm
Smoke detectors sound alarm if a fire occurs. Lights toggle at the same time.

Motion Detector
Communicates wirelessly with central alarm.

Door Control
Lock/unlock entrance door using a wireless key. When the door locks, lights can automatically be turned off.

Window Control
Blinds can be controlled by simple battery-operated devices using a remote control.

Radiator & Temperature
Radiator and temperature sensors maintain ideal temperature, saving power and money.

Environmental Monitoring
Monitors temperature, humidity and pressure. Waters lawn according to exact requirements, saving water usage and costs.

Monitoring & Control
Monitor and control the network over the internet.

Lighting Control
Lighting schemes can be used to easily control all lights in a room.

Remote Control
The remote control enables the user to control all devices in the home. The network will forward messages to nodes that are not within direct range of the remote control.

Automatic Notification
The system can be set up to automatically contact the owner if problems occur.
Select Proprietary or Standard: RF4CE

- Founding Members
  - SONY
  - PHILIPS
  - Panasonic
  - SAMSUNG

- Invited Contributors
  - Texas Instruments
  - Freescale
  - OKI

The RF4CE industry consortium has been formed to develop a new protocol that will further the adoption of radio frequency remote controls for audio visual devices.

The consortium will create a standardized specification for radio frequency-based remote controls that deliver richer communication, increased reliability and more flexible use.

Visit [www.rf4ce.org](http://www.rf4ce.org) for more information on the RF4CE consortium
Visit [www.ti.com/rf4ce](http://www.ti.com/rf4ce) for more information on TI’s RF4CE solution
Select Protocol Software

- **Z-Stack** - ZigBee Protocol Stack from TI
  - Mesh networking
  - Golden Unit certification for ZigBee-2006, ZigBee-2007 and ZigBee PRO
  - Supports multiple platforms including the CC2530ZNP, CC2530 and CC2520+MSP430 platforms
  - ZigBee 2007/PRO available on MSP430 platform

- **TIMAC**
  - A standardized wireless protocol for battery-powered and/or mains powered nodes
  - Suitable for applications with low data-rate requirements
  - Support for IEEE 802.15.4-2003/2006

- **SimpliciTI** Network Protocol – RF Made Easy
  - A simple low-power RF network protocol aimed at small RF networks
  - Typical for networks with battery operated devices that require long battery life, low data rate and low duty cycle

- **RemoTI** Remote control
  - RF4CE is built on the well-tested, reliable software, the TIMAC, which is based on the IEEE 802.15.4 protocol stack and runs in millions of devices worldwide

All software solutions can be downloaded free from TI web
Select Protocol Software: ZigBee™ Z-Stack

Key Benefits:
- Self healing (Mesh networks)
- Low node cost
- Easy to deploy (low installation cost)

• Application
• ZigBee™ Stack
  - Network functionality
• IEEE 802.15.4
  - Physical layer/Radio
  - Standardized point to point link
• ZigBee™ devices from TI
  - CC2480 (network processor)
  - CC243x System on Chip
  - CC253x System on Chip

- Supports large networks (hundreds of nodes)
- Intended for monitoring & control applications
- Standardized protocol (interoperability)
Select
Protocol Software: SimpliciTI

- Low Power: a TI proprietary low-power RF network protocol
- Low Cost: uses < 8K FLASH, 1K RAM depending on configuration
- Flexible: simple star w/ extendor and/or p2p communication
- Simple: Utilizes a very basic core API
- Low Power: Supports sleeping devices

Supported LPRF devices:
- MSP430+CC1101/CC2500/CC2520,
- CC1110/CC1111,
- CC2510/CC2511,
- CC2430, CC2530

Diagram:
- Application
  - Ping: Port 0x01
  - Link: Port 0x02
  - Join: Port 0x03
  - Freq: Port 0x05
- Network
  - NWK
- Data Link/PHY
  - MRFI
    - Minimal RF interface
Select Protocol Software: RemoTI

The RemoTI protocol:
- Based on IEEE 802.15.4
- Includes a thin NWK layer
- Command Set Interface

RemoTI (RF4CE) Standard Includes:
- Frequency agility for multi-channel operation to avoid interference
- A mechanism for secure transactions
- A power save mechanism for power efficient implementations
- A simple and intuitive pairing mechanism
Select
Regulations: ISM/SRD frequency bands
Select
Regulations: 2.4 GHz ISM band

The 2400–2483.5 MHz band is available for license-free operation in most countries

- **2.4 GHz Pros**
  - Same solution for all markets without SW/HW alterations
  - Large bandwidth available, allows many separate channels and high datarates
  - 100% duty cycle is possible
  - More compact antenna solution than below 1 GHz

- **2.4 GHz Cons**
  - Shorter range than a sub 1 GHz solution (with the same current consumption)
  - Many possible interferers are present in the band
Select

Regulations: Sub 1GHz ISM bands

The ISM bands under 1 GHz are not world-wide. Limitations vary a lot from region to region and getting a full overview is not an easy task

• Sub 1GHz Pros
  – Better range than 2.4 GHz with the same output power and current consumption
  – Lower frequencies have better penetration through concrete and steel (buildings and office environments) compared to 2.4 GHz

• Sub 1GHz Cons
  – No worldwide solution possible. Since different bands are used in different regions a custom solution has to be designed for each area
  – Duty cycle restrictions in some regions
Select

Regulations: Sub 1GHz ISM bands

902-928 MHz is the main frequency band in the US

- The 260-470 MHz range is also available, but with more limitations

The 902-928 MHz band is covered by FCC CFR 47, part 15

Sharing of the bandwidth is done in the same way as for 2.4 GHz:

- *Higher output power is allowed if you spread your transmitted power and don’t occupy one channel all the time* FCC CFR 47 part 15.247 covers wideband modulation

- Frequency Hopping Spread Spectrum (FHSS) with ≥50 channels are allowed up to 1 W, FHSS with 25-49 channels up to 0.25 W

- Direct Sequence Spread Spectrum (DSSS) and other digital modulation formats with bandwidth above 500 kHz are allowed up to 1W

FCC CFR 47 part 15.249

- "Single channel systems” can only transmit with ~0.75 mW output power
Select

Regulations: Unlicensed ISM/SRD bands

USA/Canada:
- 260 – 470 MHz (FCC Part 15.231; 15.205)
- 902 – 928 MHz (FCC Part 15.247; 15.249)
- 2400 – 2483.5 MHz (FCC Part 15.247; 15.249)

Europe:
- 433.050 – 434.790 MHz (ETSI EN 300 220)
- 863.0 – 870.0 MHz (ETSI EN 300 220)
- 2400 – 2483.5 MHz (ETSI EN 300 440 or ETSI EN 300 328)

Japan:
- 315 MHz (Ultra low power applications)
- 426-430, 449, 469 MHz (ARIB STD-T67)
- 2400 – 2483.5 MHz (ARIB STD-T66)
- 2471 – 2497 MHz (ARIB RCR STD-33)

**ISM** = Industrial, Scientific and Medical  
**SRD** = Short Range Devices
Select
Make or Buy

Self development based on a chipset or buy a module?

![Graph showing costs per unit for Chip based and Module options with quantity on the x-axis and costs on the y-axis. The graph indicates that as the quantity increases, the cost per unit decreases for both options, with chip-based options generally being more expensive per unit.]
Select
Make or Buy

Benefits of a module based solution compared to a self development:

- Shortest time to market
- Focus on core competence
- 100% RF yield
- FCC/CE re-use
- Field proven technology: Temperature, antenna loads,...
Design
Build your Application

Design your application using TI technology:

• Low Power RF IC documentation
• Design notes supporting your RF Antenna design
• PCB reference designs help to accelerate your hardware layout
• Powerful and easy to use development tools
• Worldwide TI support organization
Design
LPRF Product Portfolio

**Sub 1 GHz**
- Narrowband
- Proprietary

**2.4 GHz**
- ZigBee/ RF4CE/ 15.4/ BLE
- Proprietary

### Software
- ZigBee
- RF4CE
- BLE
- Proprietary
- SimpliciTI
- TIMAC

### Protocol Processor
- CC1110
- CC1111
- CC430
- CC243x
- CC2480
- CC2540
- CC2590
- CC2591
- CC1070
- CC1020
- CC1100E
- CC2520
- CC2550
- CC2510
- CC2511
- CC2530ZNP
- CC8520
- SimpliciTI
- preview

### System on Chip
- CC1101
- CC430
- CC243x
- CC2530
- CC2533
- CC2540
- CC2510
- CC2550
- CC2530
- CC8520
- SimpliciTI
- preview

### Transceiver
- CC1020
- CC1100E
- CC2520
- CC2550
- CC2533
- CC2540
- CC8520
- SimpliciTI
- preview

### Transmitter
- CC1070
- CC1150
- CC2590
- CC2591
- CC2550
- CC2533
- CC2540
- CC8520
- SimpliciTI
- preview

### RF Front End
- CC1190
- CC2590
- CC2591
- CC2550
- CC2533
- CC2540
- CC8520
- SimpliciTI
- preview

- **NEW**
**Design**

Block diagram of LPRF application example

**Minimum BOM:**
- LPRF System on Chip or MSP430 MCU + RF transceiver
- Antenna (PCB) & RF matching components
- Battery or power supply

**Additional components:**
- CC259x range extender
- Whip or chip antenna to improve RF performance

*ZigBee network processor
Design

Antenna Design

The **antenna** is a **key** component for the successful design of a wireless communication system.

The **purpose** of an antenna is to provide two way transmission of data electromagnetically in free space.

- Transform electrical signals into RF electromagnetic waves, propagating into free space (**transmit mode**)
- Transform RF electromagnetic waves into electrical signals (**receive mode**)

**Low Power RF Transmit / Receive System**
Design
Antenna Design

An Isotropic Antenna is a theoretical antenna that radiates a signal equally in all directions.

A Dipole Antenna is commonly used in wireless systems and can be modeled similarly to a doughnut.

The Dipole represents a directional antenna with a further reach in the X&Y Plane (at the cost of a smaller reach in the Z plane) to the Isotropic.

Power measurements are referenced to isotropic antenna (dBi) as a theoretical model for comparison with all other antennas.

Power Measurements of a Dipole Antenna (dBd) = 2.14 dBi.
Design

Antenna Design: Types

Two fundamental connection types for low power RF systems

*Single-ended* antenna connection
- Usually matched to 50 ohm
- Requires a balun if the Chipcon-chip has a differential output
- Easy to measure the impedance with a network analyzer
- Easy to achieve high performance

*Differential* antenna connection
- Can be matched directly to the impedance at the RF pins
- Can be used to reduce the number of external components
- Complicated to make good design, might need to use a simulation
- Difficult to measure the impedance
- Possible to achieve equivalent performance of single-ended
Design

Antenna Design: Types

PCB antennas
- No extra cost development
- Requires more board area
- Size impacts at low frequencies and certain applications
- Good to high range
- Requires skilled resources and software

Whip antennas
- Cost from (starting~ $1)
- Best for matching theoretical range
- Size not limiting application

Chip antennas
- Less expensive (below $1)
- Lower range
Design
Antenna Design: Frequency vs. Size

Lower frequency increases the antenna range
• Reducing the frequency by a factor of two doubles the range

Lower frequency requires a larger antenna
• $\lambda/4$ at 433 MHz is 17.3 cm (6.81 in)
• $\lambda/4$ at 915 MHz is 8.2 cm (3.23 in)
• $\lambda/4$ at 2.4 GHz is 3.1 cm (1.22 in)

A meandered structure can be used to reduce the size
• $\lambda/4$ at 2.4 GHz
Design
Antenna Design: TI Resources

General Antennas
- AN003: SRD Antennas (SWRA088)
- Application Report ISM-Band and Short Range Device Antennas (SWRA046A)

2.4 GHz
- AN040: Folded Dipole for CC24xx (SWRA093)
- AN043: PCB antenna for USB dongle (SWRA0117d)
- DN001: Antenna measurement with network analyzer (SWRA096)
- DN004: Folded Dipole Antenna for CC25xx (SWRA118)
- DN0007: Inverted F Antenna for 2.4 GHz (SWRU120b)
- AN058: Antenna Selection Guide (SWRA161)
- AN048: Chip Antenna (SWRA092b)

868/915 MHz
- DN008: 868 and 915 MHz PCB antenna (SWRU121)
- DN016: 915 MHz Antenna Design (SWRA160)
- DN023: 868 MHz and 915 MHz PCB inverted-F antenna (SWRA228)
Design

PCB Layout: Rules of thumb for RF Layout

• Keep via inductance as low as possible. Usually means larger holes or multiple parallel holes)

• Keep top ground continuous as possible. Similarly for bottom ground.

• Make the number of return paths equal for both digital and RF
  – Current flow is always through least impedance path. Therefore digital signals should not find a lower impedance path through the RF sections.

• Compact RF paths are better, but observe good RF isolation between pads and or traces.
Design

PCB Layout: Do’s and Don’ts of RF Layout

- Keep copper layer continuous for grounds. Keep connections to supply layers short
- Use SMT 402 packages which have higher self-resonance and lower package parasitic components.
- Use the chips star point ground return
- Avoid ground loops at the component level and or signal trace.
- Use vias to move the PCB self resonance higher than signal frequencies
- Keep trace and components spacing nothing less than 12 mils
- Keep via holes large at least 14.5 mils
- Separate high speed signals (e.g. clock signals) from low speed signals, digital from analog. Placement is critical to keep return paths free of mixed signals.
- Route digital signals traces so antenna field lines are not in parallel to lines of magnetic fields.
- Keep traces length runs under a ¼ wavelength when possible.
Design

PCB Layout: Do’s and Don’ts of RF Layout

• Avoid discontinuities in ground layers
• Keep vias spacing to minimize E fields that acts as current barriers, good rule to follow keep spacing greater than 5.2 x greater than hole diameter for separations.
• Don’t use sharp right angle bends

• Do not have vias between bypass caps

Poor Bypassing

Good Bypassing
Copy (for example) the CC1100EM reference design!
- Use the exact same values and placement on decoupling capacitors and matching components.
- Place vias close to decoupling capacitors.
- Ensure 50 ohm trace from balun to antenna.
- Remember vias on the ground pad under the chip.
- Use the same distance between the balun on layer 1 and the ground layer beneath.
- Implement a solid ground layer under the RF circuitry.
- Ensure that useful test pins are available on the PCB.
- Connect ground on layer 1 to the ground plane beneath with several vias.
- **Note:** different designs for 315/433 MHz and 868/915 MHz
Design

PCB Layout: RF Licensing

Design guidelines to meet the RF regulation requirements:

• Place **Decoupling capacitors** close to the DC supply lines of the IC
• Design a **solid ground plane** and avoid cutouts or slots in that area
• Use a low-pass or band-pass filter in the transmit path to **suppress the harmonics** sufficiently
• Choose the **transmit frequency** such that the harmonics do not fall into restricted bands
• In case of **shielding** may be necessary filter all lines leaving the shielded case with decoupling capacitors to reduce spurious emissions.
• Chose values of **decoupling capacitors** in series resonance with their parasitic inductance at the RF frequency that needs to be filtered out
• Design the **PLL loop filter** carefully according to the data rate requirements
• In case of a battery driven equipment, use a **brownout detector** to switch off the transmitter before the PLL looses lock due to a low battery voltage
Design
PCB Layout: RF Licensing

Documentation on LPRF frequency bands and licensing:

ISM-Band and Short Range Device Regulations

Using CC1100/CC1150 in European 433/868 MHz bands

SRD regulations for license free transceiver operation
Design

Development Tools: SmartRF® Studio

• **SmartRF® Studio** is a PC application to be used together with TI’s development kits for **ALL** CCxxxx RF-ICs.

• Converts user input to associated chip register values
  – RF frequency
  – Data rate
  – Output power

• Allows remote control/configuration of the RF chip when connected to a DK

• Supports quick and simple performance testing
  – Simple RX/TX
  – Packet RX/TX
  – Packet Error Rate (PER)
Design
Development Tools: Packet Sniffer

Packet sniffer captures packets going over the air

Protocols:
- SimpliciTI
- TIMAC
- ZigBee
- RemoTI
Design
Development Tools: IAR Embedded Workbench

- IDE for software development and debugging
- Supports
  - All LPRF SoCs
  - All MSP430s
- 30 day full-feature evaluation version
  - Extended evaluation time when buying a SoC DK or ZDK
- Free code-size limited version

www.IAR.com
## Design

### Development Tools: Kits Overview

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<thead>
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<th>Part Number</th>
<th>Short Description</th>
<th>Development Kit</th>
<th>Evaluation Modules</th>
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| CC1020, CC1070 | Narrowband RF Transceiver Narrowband RF Transmitter | CC1020-CC1070DK433  
CC1020-CC1070DK868 | CC1020EMK433 / CC1020EMK868  
CC1070EMK433 / CC1070EMK868 |
| CC1101 | <1 GHz Transceiver | CC1101DK433 / CC1101DK868 | CC1101EMK433 / CC1101EMK868 |
| CC1110, CC1111 | 8051 MCU + <1 GHz Radio  
8051 MCU + <1 GHz Radio + USB | CC1110-CC1111DK  
CC1110DK-MINI-868 | CC1110EMK433 / CC1110EMK868  
CC1111EMK868 |
| CC2500 | 2.4 GHz Transceiver | CC2500-CC2550DK | CC2500EMK |
| CC2510, CC2511 | 8051 MCU + 2.4 GHz Radio  
8051 MCU + 2.4 GHz Radio + USB | CC2510-CC2511DK  
CC2510DK-MINI | CC2510EMK  
CC2511EMK |
| CC2520 | IEEE 802.15.4 compliant Transceiver | CC2520DK | CC2520EMK |
| CC2530, CC2531 | 8051 MCU + IEEE 802.15.4  
8051 MCU + IEEE 802.15.4 + USB | CC2530DK  
CC2530ZDK  
RemoTI-CC2530DK | CC2530EMK  
CC2531EMK |
| CC1190 | PA/LNA RF frontend | | CC1190EMK-915 |
| CC2591 | PA/LNA RF frontend | | CC2591EMK, CC2430-CC2591EMK  
CC2520-CC2591EMK, CC2530-CC2591EMK |
| CC2590 | PA/LNA RF frontend | | CC2590EMK, CC2430-CC2590EMK |
Design Support

Large selection of support collateral:

- Development tools
- Application & Design Notes
- Customer support
- LPRF Developer Network
- LPRF Community
Test
Get your products ready for the market

Important points before market release:

• Test the product on meeting certification standards
• Check Co-existence with other wireless networks
• Solutions to test products in production line
Test Certification

Perform in-house product characterization on key regulatory parameters to reveal any potential issues early on.

Pre-testing at an accredited test house can shave off considerable time in the Development cycle.
Coexistence of RF systems:

- How well does the radio operate in environments with interferers
- Selectivity and saturation important factors
- The protocol also plays an important part
  - Frequency hopping or frequency agility improves coexisting with stationary sources like WLAN
  - Listen Before Talk used to avoid causing collisions
- **GOOD COEXISTENCE = RELIABILITY**
Due to the world-wide availability the 2.4GHz ISM band it is getting more crowded day by day. Devices such as Wi-Fi, Bluetooth, ZigBee, cordless phones, microwave ovens, wireless game pads, toys, PC peripherals, wireless audio devices and many more occupy the 2.4 GHz frequency band.

WLAN vs ZigBee vs Bluetooth
Test

Coexistence: Selectivity / Channel rejection

How good is the receiver at handling interferers at same frequency and close by frequencies?

Desired signal / Interferer

Power

Adjacent channel rejection [dB]

Alternate channel rejection [dB]

Co-channel rejection [dB]

Channel separation

Channel separation

Desired channel Frequency
Good quality depends highly on a good Production Line Test. Therefore a Strategy tailored to the application should be put in place. Here are some recommendations for RF testing:

- Send / receive test
- Signal strength
- Output power
- Interface test
- Current consumption (especially in RX mode)
- Frequency accuracy
Produce
Production support from TI

• TI obsolescence policy

• TI product change notification

• Huge Sales & Applications teams ready to help solving quality problems
Produce
TI Obsolescence Policy

◆ TI will not obsolete a product for “convenience” (JESD48B Policy)

◆ In the event that TI can no longer build a part, we offer one of the most generous policies providing the following information:
  – Detailed Description
  – PCN Tracking Number
  – TI Contact Information
  – Last Order Date (12 months after notification)
  – Last Delivery Date (+6 month after order period ends)
  – Product Identification (affected products)
  – Identification of Replacement product, if applicable

◆ TI will review each case individually to ensure a smooth transition
TI complies with JESD46C Policy and will provide the following information a minimum of 90 days before the implementation of any notifiable change:

- Detailed Description
- Change Reason
- PCN Tracking Number
- Product Identification (affected products)
- TI Contact Information
- Anticipated (positive/negative) impact on Fit, Form, Function, Quality & Reliability
- Qualification Plan & Results (Qual, Schedule if results are not available)
- Sample Availability Date
- Proposed Date of Production Shipment
Produce

Quality: TI Quality System Manual (QSM)

• TIs Semiconductor Group Quality System is among the finest and most comprehensive in the world. This Quality System satisfied customer needs long before international standards such as ISO-9001 existed, and our internal requirements go far beyond ISO-9001.

• The **Quality System Manual (QSM)** contains the 26 top-level SCG requirement documents.... What must be done.... for its worldwide manufacturing base to any of our global customers.

• Over 200 Quality System Standards (QSS), internal to TI, exist to support the QSM by defining key methods... How to do things... such as product qualification, wafer-level reliability, SPC, and acceptance testing.

• The Quality System Manual is reviewed routinely to ensure its alignment with customer requirements and International Standards.
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