RF System Design

Low Power Wireless
Texas Instruments
• Agenda
  – Development
  – Testing
  – Debugging
• **Choose correct chip**
  – Operating frequency
    • Range
    • Market
  – Data rate
  – Standard or proprietary solution
  – Available board size
    • Radio+uC or SoC solution
    • Antenna solution

• **Use Low-Power RF Selection Guide:**
  – Available at: [http://www.ti.com/lpw](http://www.ti.com/lpw)
<table>
<thead>
<tr>
<th>FEATURES/PRODUCT</th>
<th>CC2400</th>
<th>CC2420</th>
<th>CC2430</th>
<th>CC2431</th>
<th>CC2550</th>
<th>CC2560</th>
<th>CC2570</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product type</td>
<td>Transceiver</td>
<td>Transceiver</td>
<td>SoC</td>
<td>SoC</td>
<td>Transmitter</td>
<td>Transceiver</td>
<td>SoC</td>
</tr>
<tr>
<td>Frequency resolution</td>
<td>1 MHz</td>
<td>1 MHz</td>
<td>1 MHz</td>
<td>1 MHz</td>
<td>427 Hz</td>
<td>427 Hz</td>
<td>427 Hz</td>
</tr>
<tr>
<td>Operating supply voltage</td>
<td>1.8 – 3.6 V</td>
<td>2.1 – 3.6 V</td>
<td>2.0 – 3.6 V</td>
<td>2.0 – 3.6 V</td>
<td>1.8 – 3.6 V</td>
<td>1.8 – 3.6 V</td>
<td>2.0 – 3.6 V</td>
</tr>
<tr>
<td>Current consumption (RX) at 0 dBm (TX)</td>
<td>24.8 mA</td>
<td>17.4 mA</td>
<td>17.4 mA</td>
<td>17.4 mA</td>
<td>19.8 mA</td>
<td>22.8 mA</td>
<td>22.8 mA</td>
</tr>
<tr>
<td>Data rate (max)</td>
<td>1.0 Mbps</td>
<td>250 kbps</td>
<td>250 kbps</td>
<td>250 kbps</td>
<td>500 kbps</td>
<td>500 kbps</td>
<td>500 kbps</td>
</tr>
<tr>
<td>Receiver sensitivity</td>
<td>-101 dBm at 10 kbps and BER &gt; 10-3</td>
<td>-94 dBm at PER &gt; 1%</td>
<td>-94 dBm at PER &gt; 1%</td>
<td>-94 dBm at PER &gt; 1%</td>
<td>N/A</td>
<td>-89 dBm at 250 kbps BER &gt; 10-3</td>
<td>-88 dBm at 100 kbps BER &gt; 10-3</td>
</tr>
<tr>
<td>Programmable output power ranging from</td>
<td>25 to 0 dBm</td>
<td>25 to 0 dBm</td>
<td>24 to 0 dBm</td>
<td>24 to 0 dBm</td>
<td>20 to 1 dBm</td>
<td>20 to 1 dBm</td>
<td>30 to 1 dBm</td>
</tr>
<tr>
<td>Multi channel systems/FRSS</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>RSSI output</td>
<td>Digital</td>
<td>Digital</td>
<td>Digital</td>
<td>Digital</td>
<td>N/A</td>
<td>Digital</td>
<td>Digital</td>
</tr>
<tr>
<td>Integrated bit synchronizer</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Integrated packet handling</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Data buffering</td>
<td>32 bytes FIFO</td>
<td>128 bytes TX 128 bytes RX</td>
<td>128 bytes TX 128 bytes RX DMA</td>
<td>128 bytes TX 128 bytes RX DMA</td>
<td>64 bytes</td>
<td>64 bytes TX 64 bytes RX</td>
<td>128 bytes TX 128 bytes RX DMA</td>
</tr>
<tr>
<td>Internal RF switch/IF Filter</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Package type</td>
<td>QFN-48, 7x7 mm</td>
<td>QLP-48, 7x7 mm</td>
<td>QLP-48, 7x7 mm</td>
<td>QLP-48, 7x7 mm</td>
<td>QLP-16, 4x4 mm</td>
<td>QLP-20, 4x4 mm</td>
<td>QLP-36, 6x6 mm</td>
</tr>
<tr>
<td>Complies with EN 300 220, FCC CFR 47, part 15 and ARIB STD-T66</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Integrated microcontroller</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Voltage regulator</td>
<td>-</td>
<td>2.1 – 3.6 V</td>
<td>2.0 – 3.6 V</td>
<td>2.0 – 3.6 V</td>
<td>1.8 – 3.6 V</td>
<td>1.8 – 3.6 V</td>
<td>2.0 – 3.6 V</td>
</tr>
<tr>
<td>IEEE 802.15.4 compliant</td>
<td>-</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hardware MAC encryption/</td>
<td>-</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>authentication</td>
<td>-</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Program memory</td>
<td>-</td>
<td>32 kB/64 kB</td>
<td>128 kB Flash</td>
<td>-</td>
<td>-</td>
<td>32 kB Flash</td>
<td></td>
</tr>
<tr>
<td>Data memory</td>
<td>-</td>
<td>4 kB + 4 kB SRAM</td>
<td>4 kB + 4 kB SRAM</td>
<td>-</td>
<td>-</td>
<td>4 kB SRAM</td>
<td></td>
</tr>
</tbody>
</table>
• Get an overview of available resources
  – Software libraries and example code
  – EM Reference design
  – Antenna reference designs
  – Application Notes
  – Design Notes
  – Development kit
  – Development software

• Read available documentation
  – Data sheet
  – User manuals
  – FAQ
• Software development

  – Use or port our software functions.

  – Plan how to test the software before writing it.

  – We recommend IAR as compiler and debugger for our SoCs.

  – Use SmartRF Studio to calculate register settings.

  – Texas Instruments offers free software that can be used to program the flash on SoC.
• Choice of protocol

  – Standard or proprietary solution

  – Mesh or star network

  – Battery or main powered devices

  – How to handle binding and addressing

  – Single channel, frequency agility or frequency hopping
• Copy the reference design

  – TI provides a reference design for all LPW products

  – Important to make an exact copy of both layout and schematics

  – The balun, matching and decoupling should be implemented exactly as on the reference design.
• Recommended layout for solder resist and solder paste

- CC2430
  - Solder resist
  - Paste

- CC2500/CC1100
  - Solder resist
  - Paste
• Choice of antenna
  – Big impact on the total system performance
  – Lower frequency requires larger antennas
  – Not straight forward to simulate PCB antennas
  – Cost and performance vs board size
  – Several reference designs available at: www.ti.com/lpw
• Agenda
  – Development phase
  – Testing
  – Debugging
• How and what to test

– Testing should be divided up in separate parts, independent on each other.

– Hardware and software should be tested separately.

– Hardware testing should be done with known working software, e.g. SmartRF Studio.

– Software testing should be performed with known working hardware, e.g. evaluation modules.
Software Testing

- Verify that the IO interface, typically SPI, is working, by ensuring that register access (writing and reading) functions are working correctly.

- Test RX and TX functionality before the whole protocol is tested.

- Use test signals when testing the software (GDO).
• **Hardware Testing**

  – **Output power**
    - Solder a semi rigid coax cable to the connection point of the antenna and disconnect the antenna.
    - Transmit a carrier, deviation = 0.
    - Measure with a spectrum analyzer or power meter.

  – **Sensitivity**
    - Solder a semi rigid coax cable to the connection point of the antenna and disconnect the antenna.
    - Use a RF generator or development kit as transmitter
    - Monitor the received data on an oscilloscope or a dedicated BER/PER tester.
• Antenna testing
  
  – Reflection
    • Measured with a network analyzer.
    • Should be less than -10dB or VSWR=2 across the desired frequency band.
  
  – Radiation pattern
    • Should be measured in an anechoic chamber.
  
  – Bandwidth
    • Use a test program that steps a carrier across the desired frequency band. Use max hold on spectrum analyzer to measure the variation in output power.
Testing

- Mounting of semi rigid coax cable

- Important to solder the shielding to ground as close as possible to the end of the cable.
• Agenda
  – Development phase
  – Testing
  – Debugging
Check if the problem is SW or HW related.
  – Test the SW with well known working HW, evaluation modules
  – Test the HW with well known working SW, SmartRF Studio

If it is hardware related:
  – Compare the design with our reference design.
  – Check mounting of the chip and other components.
  – Mount the radio on our EM to check if the chip is damaged.

If it is software related:
  – Compare the code with our software examples and libraries.
  – Test the functionality of each “module” to isolate the problem.
  – Compare register settings with values in SmartRF Studio.
Connecting a custom module to SmartRF04EB

- Transceivers: CSn, SCLK, SI, SO, VCC, GND.
- SoC: DD, DC Reset_n, VCC, GND.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>VDD</td>
<td>Used to set correct voltage for the voltage level converter</td>
</tr>
<tr>
<td>3</td>
<td>Debug Clock (DC)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Debug Data (DD)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>CSn</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>SCLK</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Reset_N</td>
<td>Delivers VDD from SmartRF04EB</td>
</tr>
<tr>
<td>8</td>
<td>MOSI</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>3.3V VDD, alt. NC</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>MISO</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: P14 SoC debug connector pin-out
• Common problems with SmartRF04EB.

  – The jumper on the power terminal is not in place.
  – SoC EM is not removed when upgrading the SmartRF04EB firmware.
  – The SmartRF04EB boot loader has been erased.
  – CCXX50 is used instead of CCXX00.
  – Different voltage level on SmartRF04EB and prototype
Thank you for your attention.

Questions?
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</tr>
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<td>Automotive</td>
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<tr>
<td>DSP</td>
<td>Broadband</td>
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<tr>
<td>Interface</td>
<td>Digital Control</td>
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<tr>
<td>Logic</td>
<td>Military</td>
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</tbody>
</table>

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