AE107

IEEE® 802.15.4 Protocol Options Overview

Matt Maupin
Technical Marketer
IEEE® 802.15.4 breaks the “bigger and faster” mold to address the unique needs of monitoring and control

- Machine-to-machine
- Low cost
- Low power
- Low duty cycle
- Small packets
- Fast power-on latency
- Self-forming, self-healing mesh networking
802.15.4 Market Summary

► Market is maturing
  • Approximately 12 million chipset in 2008, 25 million cumulative
  • 292 million chipsets in 2012
  • Freescale #1 for 2008 with 61% market share (In-Stat 2008 report)

► Technology Advantages
  • Optimized for low duty cycle applications
    ▪ Longer battery life (months to years)
  • Interference avoidance

► Becoming the foundation for many protocol stacks
  • ZigBee® technology, WirelessHART™ technology, ISA 100.11a protocol stack, etc.

► Majority of market wants global 2.4GHz solution
  • Over 80% of market expected to be 2.4 GHz
    ▪ 98%+ of 2008 volume based on 2.4 GHz
    ▪ 900 MHz better propagation being offset by PA/LNA for 2.4 GHZ
    ▪ Higher volumes will drive lower cost for 2.4GHz solution
  • Sub 1GHz may get traction from release of 802.15.4 2006, 802.15.4c and 802.15.4d
    ▪ Increases throughput, number of channels and introduces frequency bands for Asia
IEEE® 802.15.4 Applications

- Proprietary Networks (802.15.4 and SMAC)
  - Gaming and Toys
  - Security
  - Medical Monitoring
- ZigBee®
  - Smart Energy
  - Building Control
  - Home Control
  - Remote Control
- ZigBee® RF4CE
- WirelessHART™
  - Industrial Control
- Zigbee®
- Building Control

Cost

Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2009.
IEEE® 802.15.4 Basics

Simple packet data protocol for lightweight wireless networks
- Released in 2003, update in 2006
- DSSS Energy Spreading Scheme
  - 2.4 GHz: 16 channels, 250 kbps
  - 868.3 MHz: 1 channel, 20 kbps
  - 902-928 MHz: 10 channels, 40 kbps
- AES 128 Encryption and Authentication
- Communication Features
  - Simple Frame Structure
  - Reliable Data Delivery
    - CSMA-CA
    - Message Acknowledgement
- Network Support
  - Employs 64-bit IEEE & 16-bit short addresses
  - Supports Mesh, Star and Peer-to-Peer
  - Support both Non-Beaconed and Beaconed networks
    - Optional super frame structure with beacons
    - Supports Guaranteed Time Slots (GTS)

<table>
<thead>
<tr>
<th>Frequency Band</th>
<th>License Required?</th>
<th>Region</th>
<th>Data Rate</th>
<th>Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>868.3 MHz</td>
<td>No</td>
<td>Europe</td>
<td>20kbps</td>
<td>1</td>
</tr>
<tr>
<td>902-928 MHz</td>
<td>No</td>
<td>Americas</td>
<td>40kbps</td>
<td>10</td>
</tr>
<tr>
<td>2405-2480 MHz</td>
<td>No</td>
<td>Worldwide</td>
<td>250kbps</td>
<td>16</td>
</tr>
</tbody>
</table>

Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2009.
IEEE® 802.15.4 Data Frame Format

- Provides up to 102 Byte data payload capacity
- Data sequence numbering to ensure that packets are tracked
- Frame Check Sequence (FCS) validates error-free data
  - min. 16 Bytes = 128 bits = 0.512 ms @ 250 kbps
  - max. 133 Bytes = 1064 bits = 4.256 ms @ 250 kbps

```
Octets:          2  1  4 to 20  n  2
                Frame Control Data Sequence Number Address Information Data Payload FCS
MAC sublayer
Octets:          4  1  1
                MHR  MSDU  MFR
PHY layer
                Preamble Start of Frame Delimiter Frame Length MPDU
                SHR   PHR   PSDU
                11 + (4 to 20) + n
                PPDU
```

Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2009.
IEEE® 802.15.4 Device Types

► 802.15.4 Device Types:

► Full function device (FFD)
  • Talks to several devices
  • Normally main powered (always on)
  • Can route messages

► Reduced Function Device (RFD)
  • Carries limited functionality to control cost and complexity
  • Talks to parent
  • Requires less memory
  • Can be a sleeping device
  • General usage will be in network edge devices

► Network Devices:

► Coordinator (FFD)
  • Establishes and the network
  • Maintains overall network knowledge
  • Only one per network
  • Routes messages

► Router (FFD)
  • Routes messages along the network
  • Always on device

► End Device (RFD)
  • Edge of network
  • Does not route
  • Battery powered
3 Common 802.15.4 Networks

Star Network
- Lowest complexity
- Limited Range
- Coordinator can become bottleneck

Full Function Device (FFD, Router)
Reduced Function Device (RFD)
Example Communication Path

PAN coordinator (PANC)
Network Topology Models

3 Common 802.15.4 Networks

Star Network
- Lowest complexity
- Limited Range
- Coordinator can become bottleneck

Tree Network
- Extends range of network
- More predictive
- Bottlenecks still exist

Example Communication Path

- PAN coordinator (PANC)
- Full Function Device (FFD, Router)
- Reduced Function Device (RFD)
- Example Communication Path
Network Topology Models

► 3 Common 802.15.4 Networks

► Star Network
  • Lowest complexity
  • Limited Range
  • Coordinator can become bottleneck

► Tree Network
  • Extends range of network
  • More predictive
  • Bottlenecks still exist

► Mesh Network
  • Most complex
  • Highest reliability
  • Reduces bottlenecks

Mesh

- PAN coordinator (PANC)
- Full Function Device (FFD, Router)
- Reduced Function Device (RFD)
- Example Communication Path
IEEE 802.15.4 Co-existence in the 2.4 GHz Band

802.11b/g Channel (North America)

802.11b Spectrum Occupancy (Typical)

802.15.4 Channel

► 802.15.4 open channels when Wi-Fi fully utilized the band
  • 15, 20, 25 and 26
IEEE® 802.15.4 Co-exists With Interference

Even when overlapping with Wi-Fi, 802.15.4 can find a quite period to transmit

**Wi-Fi Speaks at less than 100% duty cycle**

- 802.15.4 uses CSMA-CA to speak in the quiet periods
- **CSMA-CA Algorithm** (Carrier Sense Multiple Access – Collision Avoidance) listens before transmitting and “backs off” in the presence of interference
- Symbol rate is 62.5 kHz so a symbol only lasts 16 μs
802.15.4 2.4 GHz Frequency Coexistence

- General Concern exist around interference in 2.4 GHz space with devices such as WiFi, Microwave Ovens, cordless phones, wireless video systems, etc.
- 802.15.4 was designed from ground up with co-existence in mind
  - Direct Sequence Spread Spectrum
    - Energy spread so signal looks like noise to other systems
  - CCA listens to energy on channels to select the best one
    - Provides 16 channels to help avoid interference
      - Channel spacing provides slots in the 802.11 non-overlapping bands
      - Some networks modifying network to hop on 16 channels
  - Designed to minimize jamming susceptibility
    - Adjacent and alternate channel rejection reduce likelihood of interference
  - CSMA listens before transmitting and does a random back off in case of collision
    - Used in Wireless Ethernet networks
  - Message acknowledgement provides delivery status
- Several physical studies have been done and show little impact to 802.15.4 by these interferes
  - ZigBee and Wireless Frequency Coexistence White Paper
  - Freescale Entertainment Control Network Coexistence Test Report
- Conclusions
  - 802.15.4 has many features to ensure reliable communication in noisy interference environments
  - Even in environments with 100% duty cycle by interferes, 802.15.4 was still able to communicate
    - Latency will be impacted for retries
802.15.4 Summary

- 802.15.4 is designed to provide a solid foundation for sensing and control applications
- Providing a global standard
  - 2.4 GHz provides global support for products
  - Additional sub 1 GHz work adding options for Asia, Europe, and US
- Technology is real and available
  - Mass production since 2003
  - Over 25 Million units shipped
- Provides a variety of sources for chipsets and network stacks
  - Eliminates the concerns with a single source
  - Provides lower cost and increased competition
- Provides for key technology advantages for monitoring and control
  - Optimized for low duty cycle applications
  - Longer battery life (months to years)
- Proving to be robust in the presence of interference
  - Channel Alignment – ideal for co-existence with other 2.4 GHz technologies
  - Clear Channel Assessment – improves collision avoidance
  - Short burst transmission
- Used as the foundation for many protocol stacks
  - ZigBee® technology, WirelessHART™ technology, ISA 100.11a protocol stack
ZigBee® Protocol Overview
ZigBee 2007 and ZigBee RF4CE
What is ZigBee®

A global protocol developed and supported by companies around the globe

- Based on 802.15.4
- Creates specifications for wireless sensing and control
  - ZigBee 2007
  - ZigBee RF4CE
- Defines certification and compliance testing
- Provides branding, market development and user education

Meets key market needs

- Reliability
  - Self healing mesh networks
- Scalability
  - Supports thousands of devices
- Secure
  - Symmetric Key with AES-128
- Long battery life
  - Years on AA batteries
- Interoperable
  - Platform Conformance Certification
- Low cost
ZigBee® 2007 Specification

► ZigBee Alliance released an update to the ZigBee Specification that includes additional features.
► Features are combined under two “Feature Sets” called ZigBee (Stack Profile 1) and ZigBee Pro (Stack Profile 2)
  • ZigBee – Initially part of the specification released in 2006
    ▪ Targets consumer products in the home and light commercial environments
    ▪ Designed for simpler, plug and forget networks that are typically less than 300 nodes
  • ZigBee Pro – Added in the specification released in 2007
    ▪ Targets commercial and industrial environments
    ▪ Larger (thousands of nodes), more complex networks that require higher level of expertise, security and commissioning
► Supports multiple application profiles
  • Home Automation
  • Commercial Building Automation
  • Smart Energy
  • Health Care
  • Telecom Applications
The RF4CE specification was adopted by the ZigBee Alliance in March 2009
- 80% of RF4CE protocol is based on Freescale SynkroRF technology
- RF4CE R1.0 standard ratified in December 2008

Purpose
- Provide a standardized RF networking layer for consumer electronics products
- Emphasis on robustness and ease of use
- Essential functionality to build and support a CE network

General Features
- Less than 40 KB code including 802.15.4 MAC, ZigBee RF4CE networking stack & CERC profile
  - Allows lower cost solutions then ZigBee 2007
- Supported Device types
  - Controller node
  - Target node
- Network services
  - Network Creation
  - AES 128-bit secured and non-secured Inter-device communications (2-way)
  - Power Management
- Interference avoidance
  - DSSS (provided by IEEE 802.15.4 MAC layer)
  - CSMA-CA (provided by IEEE 802.145.4 MAC layer)
  - Channel Agility
RF4CE devices can communicate on IEEE 802.15.4 channels 15, 20 & 25.
- Channel 15 – 2.425 GHz
- Channel 20 – 2.450 GHz
- Channel 25 – 2.475 GHz

- Target node selects the initial communication channel, based on start channel conditions.
- Target node can switch to another channel if surrounding environment changes.
- Each device that is paired to the Target communicates on last successful channel.
- If Target device has changed channels, the device trying to communicate will go look for Target on other RF4CE channels until communication is established.
  - Node will store new channel for Target device
ZigBee RF4CE Channel Agility

► RF4CE devices can communicate on IEEE 802.15.4 channels 15, 20 & 25.
  • Channel 15 – 2.425 GHz
  • Channel 20 – 2.450 GHz
  • Channel 25 – 2.475 GHz
► Target node selects the initial communication channel, based on start channel conditions.
► Target node can switch to another channel if surrounding environment changes
► Each device that is paired to the Target communicates on last successful channel.
► If Target device has changed channels, the device trying to communicate will go look for Target on other RF4CE channels until communication is established.
  • Node will store new channel for Target device
ZigBee RF4CE Channel Agility

- RF4CE devices can communicate on IEEE 802.15.4 channels 15, 20 & 25.
  - Channel 15 – 2.425 GHz
  - Channel 20 – 2.450 GHz
  - Channel 25 – 2.475 GHz
- Target node selects the initial communication channel, based on start channel conditions.
- Target node can switch to another channel if surrounding environment changes.
- Each device that is paired to the Target communicates on last successful channel.
- If Target device has changed channels, the device trying to communicate will go look for Target on other RF4CE channels until communication is established.
  - Node will store new channel for Target device.
ZigBee® Protocol Summary

► ZigBee technology relies upon the robust IEEE 802.15.4 PHY/MAC to provide reliable data transfer in noisy, interference-rich environments
  • Message acknowledgement
  • Mesh Networks
► Multiple stacks provide specific market support
  • ZigBee 2007
    ▪ ZigBee and ZigBee Pro
  • ZigBee RF4CE
    ▪ Initial support for consumer remote control
► Primary markets are monitoring and control in the residential and commercial environment
► Ideal For
  • Low data rate monitoring and control applications that require a robust network
    ▪ Low latency, infrequent, low data rate and small packet data
  • Ultra low power monitoring applications that operate for years on inexpensive alkaline batteries
► Not Ideal For
  • Applications requiring all battery operated devices (routers)
  • Mobile applications
  • Streaming data
WirelessHART™ Specification
WirelessHART™ Specification Organizational Overview

The WirelessHART specification is focused on extending the HART protocol into secure wireless technology for process measurement and control applications

- Provides a total solution while maintaining the HART user experience
  - Transparent integration of wired and wireless devices
  - Works with existing HART tools, applications and installed devices
  - Robust and secure
  - Complimentary to Wired HART, extending user choice
  - WirelessHART specification increases the value of HART technology

- Targets the industrial market for process control
  - Smart process field devices
  - Existing HART communication installs
    - WirelessHART specification adapters
    - Connects to existing “Wired” HART device and wirelessly transmit the digital diagnostic and calibration capability of an existing installed HART device
WirelessHART™ Specification Technical Overview

► Based on 802.15.4 – 2006
  • Specification completed in 2007
► Focuses on features for reliability and co-existence
  • Adds channel hopping
    ▪ Uses TDMA with a fixed 10ms time slot
    ▪ Black listing of bad channels
    ▪ Provides for sleeping routers
  • Higher default transmit power
    ▪ +10dBm
  • Mesh Network Topology
    ▪ Based on DUST Networks TSMP (Time Synchronized Mesh Protocol)
    ▪ Provides flexible network organization
    ▪ Provides redundant paths
    ▪ Self organizing and self healing
  • Dynamic bandwidth allocation
    ▪ Fixed bandwidth for prioritized data and commands
  • Supports AES-128 ciphers and key support
► Supports common HART devices
  • Wireless Field devices
  • Bridges, Gateways and Access Points provide seamless access throughout the network
WirelessHART™ Specification Summary

► WirelessHART specification expands the possibilities
  • Compliments, not replaces wired HART
  • Reduces the install cost
  • Opens new opportunities while protecting investment
► 802.15.4 provides a standard foundation
  • Multiple chip providers
  • Relatively simple and low cost
  • 2.4Ghz for worldwide application support
► Reliability and co-existence are key driving requirements
► Specification complete
► Ideal For
  • Industrial applications that need increased robustness to interference and multipath
  • Environments with wired HART infrastructure
  • Applications where battery operated routers are required
► Not Ideal For
  • Low cost applications
ISA and ISA100 Organization Overview

► ISA Overview
  • Worldwide non profit organization founded in 1945
  • Develops standards; certifies industry professionals; provides education and training; publishes books and technical articles

► The ISA100.11a working group within ISA is defining wireless connectivity standard optimized for the unique performance of the industrial process control market
  • Addresses the needs in the industrial environment that includes sensors, actuators and other automation devices, as well as wireless workers, first responders and wireless infrastructure networks.
  • Addresses applications across the industrial industry including fluid processing, material processing, and discrete parts manufacturing environments.
  • Defines the OSI layer specifications (e.g. PHY, DLL, etc.), security specifications, and management specification (including network and device configuration)
  • Key attributes are robustness to interference, low complexity, reasonable cost and low power consumption while maintaining interoperability with wired plant infrastructure networks

► Specification is expect for release in 2nd half of 2009
  • Q3 2009 Ballot
ISA100.11a Technical Overview

- **Reliable low-power communication**
  - Based on IEEE 802.15.4 radios in the 2.4 GHz ISM band
  - Time-synchronized channel-hopping to sidestep RF interference and minimize power consumption
    - Allows for FFD devices such as routers to sleep

- **Adaptive Mesh Network**
  - Supports mesh, star-mesh and star topologies
  - Self-organizing intelligence simplifies installation and automatically adapts to changing conditions

- **Robust Security**
  - All messages protected with AES128 block cipher
  - Secure communication and device authentication enabled by exchange of secret keys and unique device identifiers

- **Unified Application Interface**
  - Provides an open and interoperable application environment
  - Provides a common integration point for multiple host systems
ISA100.11a Universality Promise

Application Protocols
- Native ISA100
- HART
- Foundation Fieldbus
- DeviceNet
- PROFIBUS

Vendor A
Vendor B
Vendor C
Vendor D
Vendor E
Vendor F
Vendor G
Vendor H
Vendor I
Vendor J

Universal Gateway

Reliable Monitoring & Alerting
Asset Management
Predictive Maintenance
Condition Monitoring
ISA100.11a Summary

- ISA is an open standards body following ANSI consensus procedures
  - ISA100 will be a family of wireless standards focused on the needs of the Automation Markets
    - ISA100.11a which will focus on Process Automation
    - Future areas of interest are Factory/Building Automation and Discrete Manufacturing

- Designed to support multiple “wired” protocols into a single wireless infrastructure
  - Supports wired protocols such as Profibus, DeviceNet, etc. through tunneling
  - Working closely with IETF to use a 6loWPAN for IP support

- Increased Interference and Multi-path Fading Mitigation
  - Frequency hopping
    - Channel Blacklist (Avoids Congested Channels)
    - Frequency Selection (Uses specific channels)

- TDMA provides supports sleeping routers
  - Enhances network reliability through greater redundant paths

- Ideal For
  - Industrial applications that need increased robustness to interference and multipath
  - Environments with multiple wired protocols
  - Applications where battery operated routers are required

- Not Ideal For
  - Low cost applications
Protocol Positioning
802.15.4 Protocol Stack Positioning

- WirelessHART™ Specification
- ISA SP100.11a
- ZigBee® 2007 Protocol
- ZigBee® RF4CE Networking Protocol

- Less Sensitive
- Cost Sensitive
- Cost is King

- Consumer
- Commercial
- Industrial
## Comparison Table by major features

<table>
<thead>
<tr>
<th>Feature</th>
<th>ZigBee® RF4CE Protocol</th>
<th>ZigBee® 2007 Protocol</th>
<th>SP100™</th>
<th>WirelessHART™ Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Market</td>
<td>Consumer</td>
<td>Consumer and Commercial</td>
<td>Industrial</td>
<td>Industrial</td>
</tr>
<tr>
<td>Target Applications</td>
<td>RF Remote Control</td>
<td>Home Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003</td>
<td>2003</td>
<td>2006</td>
</tr>
<tr>
<td>802.15.4</td>
<td>2003</td>
<td>2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel Hopping/Agility</td>
<td>Agility</td>
<td>Agility - 2007 Spec</td>
<td>Hopping</td>
<td>Hopping</td>
</tr>
<tr>
<td>Topology</td>
<td>Co-existing Star</td>
<td>Mesh, Tree</td>
<td>Mesh</td>
<td>Mesh</td>
</tr>
<tr>
<td>Device Type</td>
<td>FFD, RFD</td>
<td>FFD, RFD</td>
<td>FFD</td>
<td>FFD</td>
</tr>
<tr>
<td>Battery Life</td>
<td>Best</td>
<td>Best</td>
<td>Better*</td>
<td>Good</td>
</tr>
<tr>
<td>Sleeping Routers</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Latency</td>
<td>4ms</td>
<td>4ms</td>
<td>10ms</td>
<td>10ms</td>
</tr>
<tr>
<td>Channel Blacklist / Preferred Channels</td>
<td>No</td>
<td>Preferred channel</td>
<td>Blacklist</td>
<td>Blacklist</td>
</tr>
<tr>
<td>Encryption</td>
<td>AES128</td>
<td>AES128</td>
<td>AES128</td>
<td>AES128</td>
</tr>
<tr>
<td>Cost</td>
<td>Lowest</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Message Priority (QOS)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Certification Program</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Technology</td>
<td>Pros</td>
<td>Cons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZigBee® RF4CE Protocol</td>
<td>► Ideal for high volume consumer RF remote control applications</td>
<td>► Still not on par with IR cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZigBee® Protocol</td>
<td>► General market appeal</td>
<td>► Not cost effective for high volume consumer</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>► Lots of backing in Smart Energy space</td>
<td>► Complex</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>► Products in market today</td>
<td>► Not “Industrial Grade”</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP100.11a</td>
<td>► Deterministic</td>
<td>► More costly components required</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>► Immune to Multipath</td>
<td>► Object Structure in the Application Layers adds structure which might be viewed by developers as too restrictive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>► Sleeping Routers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>► CSMA and TDMA tunable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>► Multiple Fieldbus support</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>► IPv6 Support</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WirelessHART™ Specification</td>
<td>► Deterministic</td>
<td>► More costly components required</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>► Immune to Multipath</td>
<td>► TDMA mode only</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>► Sleeping Routers</td>
<td>► Requires a Network Manager device</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>► Existing wired devices in market</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Freescale Offering
MC1321x Overview

► MCU Features
- 40 MHz HCS08 low-voltage, low-power core
- Flash and memory dependent on part
- Multiple 16-bit timers
- Up to 38 GPIO
- 8-bit port keyboard interrupt (KBI)
- 8-channel 10-bit analog-to-digital converter (ADC)
- SCI interface supporting up to 115.2 kBaund
- I2C with 100 kbps maximum bus loading
- Low-voltage detection
- In-circuit debug and Flash programming
- Common on-chip processor (COP) watchdog timer

► RF Features
- 802.15.4 compliant 2.4 GHz RF transceiver
  - 250 kbps O-PQSK modulation
  - 16 selectable channels
- Auto-trim feature for crystal accuracy
  - Eliminate need for external variable capacitors
  - Allows for automated production frequency calibration
- Programmable from -27 dBm to +3 dBm
- RX sensitivity of -92 dBm
- Integrated Transmit/Receive switch
  - Supports single-ended or full differential operation

► Features
- -40 to +85 degrees C operating temperature
- 2V to 3.4V
- Low external component count
  - Requires a single 16 MHz crystal
  - Programmable frequency clock output for MCU
- 9x9x1 mm 71-pin LGA package
- RoHS compliant

► Availability
- Shipping in volume since September 2006

---

## Features

<table>
<thead>
<tr>
<th>Features</th>
<th>MC13211</th>
<th>MC13212</th>
<th>MC13213</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocol Stack</td>
<td>SMAC</td>
<td>SMAC IEEE 802.15.4</td>
<td>SMAC IEEE 802.15.4 SynkroRF ZigBee RF4CE</td>
</tr>
<tr>
<td>Memory</td>
<td>16 KB Flash 1KB RAM</td>
<td>32 KB Flash 2 KB RAM</td>
<td>60 KB Flash 4KB RAM</td>
</tr>
<tr>
<td>2009 1K SRP</td>
<td>$3.10</td>
<td>$3.38</td>
<td>$3.71</td>
</tr>
</tbody>
</table>
MC1321x End Product Benefits

► MC1321x is the ideal platform for SMAC, IEEE 802.15.4, SynkroRF, and RF4CE
  • Low cost solution for applications that do not require full mesh networks
  • Fully compliant 802.15.4 platform integrates the MC13202 2.4 GHz transceiver with the MC9S08GT MCU to provide a single package solution.

► Memory Scalability
  • Three flash memory configurations are available to optimize solution costs based on application needs.

► Integrates MC9S08GT MCU
  • The System in Package (SiP) integrates an 8-bit HCS08 MCU with a low voltage and a low power core further reducing the size and cost of the MC1321x solution.
**Features**

- Integrated 2.4 GHz transceiver with 32-bit CPU
  - 802.15.4 Compliant transceiver
  - ARM7TDMI up to 26MHz
- Lowest power
  - Significant power reduction – up to 45%
  - 22 mA Rx & 29 mA Tx with radio and MCU
- Plenty of memory for ZigBee Applications
  - ROM, Flash, RAM
- Improved RF performance
  - -96 dBm sensitivity (DCD mode)
  - -100 dBm (NCD mode, +3-4 mA current)
  - +4 dBm power output
- Hardware accelerator reduces MCU overhead
  - MAC accelerator
  - AES 128-bit hardware encryption/decryption
- Best in class peripherals
  - UART, SPI, KBI, 8 channel 12-bit ADC, 4x16-bit timer, I²C, SSI (I²S), 64 GPIO
- Unique platform in a package
  - RF matching in package
  - Requires power, crystal and 50 Ohm antenna
  - 9.5 mm x 9.5 mm 99-pin LGA

**Availability – Now**
MC1322x End Product Benefits

► MC13224 is the ideal platform for ZigBee, WirelessHART and ISA100.11a
  • Flexible memory configuration provides enough memory to run the complete stack and application profile
► RAM based part allows Firmware to be upgraded without an external storage such as and EEPROM
  • Can update Flash directly
► Lower RX and TX power consumption lowers power budget requirements
  • Ideal for battery applications as well as main powered applications were power budget is low
► Highly integrated package reduces design time and cost
  • Reduces design complexity and through reduced integrated RF front end
  • Reduces total cost through lower component inventories, less board space, etc.
Thank you for attending this presentation. We’ll now take a few moments for the audience’s questions and the we’ll begin the question and answer session.