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MC13234/MC13237

ZigBee™- Compliant Platform
2.4 GHz Low Power Transceiver for the
IEEE® 802.15.4 Standard plus Microcontroller
Reference Manual

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About This Book

This manual describes Freescale's fourth-generation ZigBee™ platform (the MC13234/MC13237), which incorporates a low power 2.4 GHz radio frequency transceiver and an 8-bit microcontroller into a single 7x7x1 mm 48-pin LGA package. The MC13234/MC13237 solution can be used for wireless applications from simple proprietary point-to-point connectivity, to a complete ZigBee mesh network. The combination of the radio and a microcontroller in a small footprint package allows for a cost-effective solution.

Audience

This manual is intended for system designers.

Organization

This document is organized into 18 chapters and one appendix.

Chapter 1 **Introduction** — Briefly introduces the MC13234/MC13237. The MC13234/MC13237 is Freescale's fourth-generation ZigBee™ device. It incorporates a low power 2.4 GHz radio frequency transceiver and an 8-bit microcontroller into a single 7x7x1 mm 48-pin LGA package.

Chapter 2 **Pins and Connections** — Describes device pinout and functionality.

Chapter 3 **System Considerations** — Describes system level considerations of the MC13234/MC13237 modem and MCU.

Chapter 4 **Memory** — Describes on-chip memory in the HCS08 series of MCUs and shows that it consists of RAM, flash program memory for non-volatile data storage, plus I/O and control/status registers.

Chapter 5 **System Management** — Describes the various elements that manage and control operation of the HCS08.

Chapter 6 **IEEE 802.15.4 2.4 GHz Transceiver —** Provides an overview and general description for the radio and the modem and details the sequence manager, timer resources, and control functions.

Chapter 7 **Advanced Security Module (ASM)** — Details how the ASM engine encrypts using the Advanced Encryption Standard (AES).

Chapter 8 **Central Processor Unit (CPU)** — Provides summary information about the registers, addressing modes, and instruction set of the CPU of the HCS08 Family. This section provides summary information about the registers, addressing modes, and instruction set of the CPU of the HCS08 Family.

Chapter 9 **Parallel Input/Output** — Explains software controls related to parallel input/output (I/O).This section explains software controls related to parallel input/output (I/O).

Chapter 10 **Real Time Counter (RTC) —** Details the 16-bit counter, a 16-bit comparator, several binary-based and decimal-based prescaler dividers, three clock sources, and a programmable periodic interrupt request.

Chapter 11	**Keyboard Interrupt (KBI)** — Describes the KBI module. Eight keyboard interrupt inputs are shared with port B pins.
Chapter 12	**Analog-to-Digital Converter (ADC) Module** — Describes the ADC module. The 12-bit ADC is a successive approximation ADC designed for operation within an integrated microcontroller system-on-chip.
Chapter 13	**Inter Integrated Circuit (IIC) Module** — Describes how the IIC bus standard compatible IIC module functions the same in normal and monitor modes. A brief description of the IIC in the various MCU modes is provided in this chapter.
Chapter 14	**Serial Communications Interface (SCI)** — This chapter describes the SCI which allows full-duplex, asynchronous, NRZ serial communication among the MCU and remote devices, including other MCUs.
Chapter 15	**Serial Peripheral Interface —** This chapter details the serial peripheral interface (SPI).
Chapter 16	**Timer Pulse Width Modulator (PWM**) — Describes how the MC13234/MC13237 uses its internal Event Timer block to manage system timing.
Chapter 17	**Carrier Modulator Timer (CMT)** — The CMT module is an IR LED driver. The module can transmit data to IRO pin either in baseband or in FSK mode.
Chapter 18	**Debug —** Describes the MC13234/MC13237 comprehensive debug/development capability for the HCS08 MCU.
Appendix A	**IEEE 802.15.4 PHY Messaging Overview**— Provides a simple overview of the sequence manager.

Revision History

The following table summarizes revisions to this document since the previous release (Rev 1.7).

Revision History

Location	Revision
Chapter 5	Added a new Section 5.7.6.6, “Stop3 and LPRun Mode Transition”
Throughout	Minor typos.

Definitions, Acronyms, and Abbreviations

The following list defines the acronyms and abbreviations used in this document.

ACK	Acknowledgement Frame
API	Application Programming Interface
BB	Baseband
CCA	Clear Channel Assessment
CRC	Cyclical Redundancy Check
DCD	Differential Chip Decoding
DME	Device Management Entity
FCS	Frame Check Sequence
FFD	Full Function Device
FFD-C	Full Function Device Coordinator
FIFO	First In, First Out
FLI	Frame Length Indicator
GTS	Guaranteed Time Slot
HW	Hardware
IRQ	Interrupt Request
ISR	Interrupt Service Routine
LO	Local Oscillator
MAC	Medium Access Control
MCPS	MAC Common Part Sublayer
MCU	Microcontroller Unit
MLME	MAC Sublayer Management Entity
MSDU	MAC Service Data Unit
NWK	Network
PA	Power Amplifier
PAN	Personal Area Network
PANID	PAN Identification
PHY	PHYsical Layer
PIB	PAN Information Base
PPDU	PHY Protocol Data Unit
PSDU	PHY Service Data Unit
RF	Radio Frequency
RFD	Reduced Function Device
SAP	Service Access Point

SFD	Start of Frame Delimiter
SPI	Serial Peripheral Interface
SSCS	Service Specific Convergence Layer
SW	Software
VCO	Voltage Controlled Oscillator

References

The following sources were referenced to produce this book:

1. IEEE 802.15.4 Standard
2. Freescale MC9S08GB/GT60 Data Sheet
3. Freescale MC13237 Data Sheet

Chapter 1
MC13237 Introduction

1.1 Overview

The MC13234/MC13237 is Freescale's low-cost System-on-Chip (SoC) for the IEEE® 802.15.4 Standard that incorporates a complete, low power, 2.4 GHz radio frequency transceiver with TX/RX switch, an 8-bit HCS08 CPU, and a functional set of MCU peripherals into a 48-pin LGA package. This solution is targeted for wireless RF remote control and other cost-sensitive applications ranging from home TV and entertainment systems such as ZigBee BeeStack Consumer (RF4CE) to low cost, low power, IEEE 802.15.4 and ZigBee end nodes. The MC13234/MC13237 is a highly integrated solution, with very low power consumption.

The MC13234/MC13237 contains an RF transceiver which is an 802.15.4 Standard - 2006 compliant radio that operates in the 2.4 GHz ISM frequency band. The transceiver includes a low noise amplifier, 1 mW nominal output power amplifier (PA), internal voltage controlled oscillator (VCO), integrated transmit/receive switch, on-board power supply regulation, 12-bit Analog-to-Digital Converter (ADC) and full spread-spectrum encoding and decoding.

The on-chip CPU is based on the Freescale HCS08 family of Microcontroller Units (MCU) and has 128 kilobyte (KB) of flash memory and 8 KB of RAM. The onboard MCU peripheral set has been defined to support the targeted applications. A dedicated DMA block transfers packet data between RAM and the transceiver to off-load the CPU and allow higher efficiency and increased performance.

1.2 Block Diagram

Figure 1-1 shows a simplified block diagram of the MC13234/MC13237.

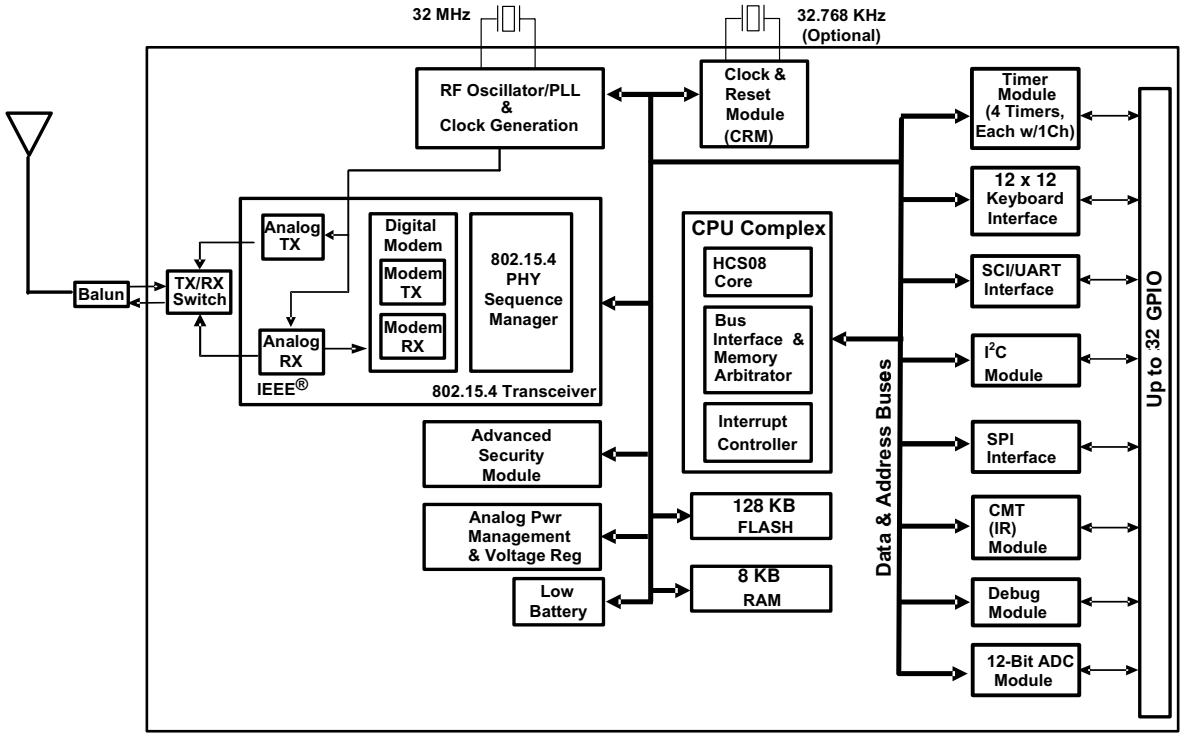

Figure 1-1. MC13234/MC13237 Simplified Block Diagram

1.3 Features Summary

- Fully compliant IEEE 802.15.4 Standard 2006 transceiver supports 250 kbps O-QPSK data in 5.0 MHz channels and full spread spectrum encode and decode
  - 2.4 GHz
  - Operates on one of 16 selectable channels per IEEE 802.15.4
  - Programmable output power with 0 dBm nominal output power, programmable from –30 dBm to +2 dBm typical
  - Receive sensitivity of –93 dBm (typical) at 1% PER, 20-byte packet, much better than the IEEE 802.15.4 Standard of –85 dBm
  - Partial Power Down “listen” mode (PPD_RX) available to reduce current while in receive mode and waiting for an incoming frame
- Small RF footprint
  - Integrated transmit/receive switch
  - Differential input/output port (typically used with a balun)
  - Low external component count

- Hardware acceleration for IEEE® 802.15.4 applications
  - DMA interface
  - AES-128 Security module
  - 16-Bit random number generator
  - 802.15.4 Auto-sequence support
  - 802.15.4 Receiver Frame filtering
- 32 MHz crystal reference oscillator; onboard load trim capability supplements external load capacitors
- Onboard 1 kHz oscillator for wake-up timing or an optional 32.768 kHz crystal for accurate low power timing.
- Transceiver Event Timer module has 4 timer comparators available to help manage the auto-sequencer and to supplement MCU TPM resources
- HCS08 8-bit, 32 MHz CPU
- Flash memory
  - 131072_{dec} Bytes organized as 128 segments by 1024 bytes
  - Programmable over the full power supply range of 1.8–3.6 V
  - Automated program and erase algorithms
  - Flexible protection scheme to prevent accidental program or erase
  - Security feature to prevent unauthorized access to the Flash
- RAM
  - 8 KBytes RAM
- Powerful In-circuit debug and flash programming available via on-chip module (BDM)
  - Two comparator and 9 trigger modes
  - Eight deep FIFO for storing change-of-flow addresses and event-only data
  - Tag and force breakpoints
  - In-circuit debugging with single breakpoint
- Multiple low power modes (less than 1 µA in Stop3)
- Keyboard interrupt (KBI) module
  - MC13234
    - Two keyboard control modules capable of supporting up to a 12 x 12 keyboard matrix
    - 12 dedicated KBI pins support a 6 x 6 matrix without impacting other IO resources
    - 12 KBI interrupts with selectable polarity
  - MC13237
    - One keyboard control module capable of supporting up to a 8 x 8 keyboard matrix
    - 8 dedicated KBI pins support a 4 x 4 matrix without impacting other IO resources
    - 8 KBI interrupts with selectable polarity
- Serial communication interface (SCI)
  - Full duplex non-return to zero (NRZ)

  - Baud rates as high as 1 Mbps can be supported
  - LIN master extended break generation
  - LIN slave extended break detection
  - Wake-up on active edge
- Serial peripheral interface (SPI)
  - Full-duplex or single-wire bidirectional
  - Double-buffered transmit and receive
  - Master or Slave mode; MSB-first or LSB-first shifting
- Inter-integrated circuit (IIC) interface
  - Up to 100 kbps baud rate with maximum bus loading
  - Baud rates as high as 800 kbps can be programmed
  - Multi-master operation
  - Programmable slave address
  - Interrupt driven byte-by-byte data transfer;
  - Supports broadcast mode and 10-bit addressing
- Four 16-bit timer/pulse width modulators (TMP[4:1]) — each TPM module has an assigned GPIO pin and provides
  - Single channel capability
  - Input capture
  - Output compare
  - Buffered edge-aligned or center-aligned PWM
- 8-Channel, 12-bit resolution ADC
  - 2.5 µs conversion time
  - Internal 1.7 mV/°C temperature sensor
  - Internal bandgap reference
  - Operation in Stop3
  - Fully functional from 1.8 V to 3.6 V
- Carrier Modulator Timer (CMT) — IR Remote carrier generator, modulator, and transmitter.
- Real-time counter (RTC)
  - 16-bit modulus counter with binary or decimal based prescaler;
  - External clock source for precise time base, time-of-day, calendar or task scheduling functions
  - Capable of greater than one day interrupt.
- System protection features
  - Programmable low voltage warning and interrupt (LVI)
  - Optional watchdog timer (COP)
  - Illegal opcode detection
- 1.8 V to 3.6 V operating voltage with on-chip voltage regulators.

- Up to 32 GPIO
  - MC13234: 32 GPIOs
  - MC13237: 28 GPIOs
  - Hysteresis and configurable pull up resistors on all input pins
  - Configurable slew rate and drive strength on all output pins
- –40°C to +85°C temperature range
- RoHS-compliant 7x7 mm 48-pin LGA package

Table 1-1. MC13234 and MC13237 Comparison

Feature	MC13234	MC13237
Radio	IEEE 802.15.4 compliant	
CPU	32 MHz HCS08	
Flash memory	128K	
RAM	8K	
BDM	Yes	
Low power modes	Yes	
KBI	Two (12 interrupts)	One (8 interrupts)
SCI	Yes	
SPI	Yes	
IIC	Yes	
TPM	Yes	
CMT	Yes	
RTC	Yes	
LVD	Yes	
COP	Yes	
ADC	No	Yes
GPIO	32	28

1.4 Software Solutions

Freescale provides a powerful software environment called the Freescale BeeKit Wireless Connectivity Toolkit. BeeKit is a comprehensive codebase of wireless networking libraries, application templates, and sample applications. The BeeKit Graphical User Interface (GUI), part of the BeeKit Wireless Connectivity Toolkit, allows users to create, modify, and update various wireless networking implementations. A wide range of software functionality is available to complement the MC13234/MC13237 and these are provided as codebases within BeeKit. The following sections describe the available tools.

1.4.1 Simple Media Access Controller (SMAC)

The Freescale Simple Media Access Controller (SMAC) is a simple ANSI C based code stack available as sample source code. The SMAC can be used for developing proprietary RF transceiver applications using the MC13234/MC13237.

- Supports point-to-point and star network configurations
- Proprietary networks
- Source code and application examples provided

1.4.2 IEEE 802.15.4 2006 Standard-Compliant MAC

The Freescale 802.15.4 Standard-Compliant MAC is a code stack available as object code. The 802.15.4 MAC can be used for developing MC13234/MC13237 networking applications based on the full IEEE® 802.15.4 Standard that use custom Network Layer and application software.

- Supports star, mesh and cluster tree topologies
- Supports beaconed networks
- Supports GTS for low latency
- Multiple power saving modes
- AES-128 Security module
- 802.15.4 Sequence support
- 802.15.4 Receiver Frame filtering

1.4.3 BeeStack Consumer

Freescale's ZigBee RF4CE stack, called BeeStack Consumer, is a networking layer that sits on top of the IEEE® 802.15.4 MAC and PHY layers. It is designed for standards-based Wireless Personal Area Networks (WPANs) of home entertainment products and conveys information over short distances among the participants in the network. It enables small, power efficient, inexpensive solutions to be implemented for a wide range of applications. Targeted applications include DTV, set top box, A/V receivers, DVD players, security, and other consumer products.

Some key characteristics of a BeeStack Consumer network are:

- An over the air data rate of 250 kbps in the 2.4 GHz band
- 3 independent communication channels in the 2.4 GHz band
- 2 network node types, controller node and target node
- Channel Agility mechanism
- Provides robustness and ease of use
- Includes essential functionality to build and support a CE network

The BeeStack Consumer layer uses components from the standard HCS08 Freescale platform, which is also used by the Freescale implementations of 802.15.4. MAC or ZigBee™ layers. For more details about the platform components, see the *Freescale Platform Reference Manual*.

1.4.4 ZigBee-Compliant Network Stack

Freescale's BeeStack architecture builds on the ZigBee protocol stack. Based on the OSI Seven-Layer model, the ZigBee stack ensures inter-operability among networked devices. The physical (PHY), media access control (MAC), and network (NWK) layers create the foundation for the application (APL) layers. BeeStack defines additional services to improve the communication between layers of the protocol stack.

At the Application Layer, the application support layer (ASL) facilitates information exchange between the Application Support Sub-Layer (APS) and application objects. Finally, ZigBee Device Objects (ZDO), in addition to other manufacturer-designed applications, allow for a wide range of useful tasks applicable to home and industrial automation.

BeeStack uses the IEEE 802.15.4-compliant MAC/PHY layer that is not part of ZigBee itself. The NWK layer defines routing, network creation and configuration, and device synchronization. The application framework (AF) supports a rich array of services that define ZigBee functionality. ZigBee Device Objects (ZDO) implement application-level services in all nodes via profiles. A security service provider (SSP) is available to the layers that use encryption (NWK and APS), i.e., Advanced Encryption Standard (AES) 128-bit security.

The complete Freescale BeeStack protocol stack includes the following components:

- ZigBee Device Objects (ZDO) and ZigBee Device Profile (ZDP)
- Application Support Sub-Layer (APS)
- Application Framework (AF)
- Network (NWK) Layer
- Security Service Provider (SSP)
- IEEE 802.15.4-compliant MAC and Physical (PHY) Layer