IEEE 802.15.4 Transceiver CA-8210

Datasheet

Rev. 1.4, April 2018

GENERAL DESCRIPTION

The CA-8210 is a fully featured transceiver modem solution for IEEE 802.15.4 communications in the 2.4GHz ISM band.

The device is based on a revolutionary radio architecture, which delivers improved receive performance for no penalty in power consumption. As a result, the CA-8210 has whole house coverage but for a fraction of the power consumption of alternative solutions.

PHY and MAC support functions are programmed via an intelligent co-processor, thereby minimizing the control overhead for the system host microcontroller.

This device is an ideal choice for manufacturers seeking IEEE 802.15.4 based connectivity, but for a fraction of the cost of existing solutions which require external RF power amplification to overcome range and reliability limitations.

FEATURES

- High performance transceiver modem
- Compliant to IEEE 802.15.4-2006
- Industrial temperature range: -40°C to +85°C
- Wide supply voltage range: 2.1V to 3.6V
- Low-power co-processor

Radio Features

- Industry-leading receive sensitivity of -105dBm
- Programmable transmit power of 0dBm to +9dBm
- Industry-leading link budget of 113dB

Low-Power Features

- Industry leading power consumption[1]
  Active mode (CPU Idle):
  Tx: 12mA at 0dBm transmit power
  19mA at +9dBm transmit power
  Rx: 10mA at -100dBm sensitivity
  14mA at -105dBm sensitivity
- Multiple options for sleep and power saving modes
- Sleep mode currents:
  32kHz Sleep timer 200nA

IEEE 802.15.4-2006 MAC Hardware Support

- Automatic Frame Check Sequence (FCS) generation, analysis and filtering
- Auto-Acknowledge
- Automatic frame filtering and address validation
- Energy Detection (ED, RSSI) and Carrier Sense (CS)
- Clear Channel Assessment (CCA) for CSMA-CA algorithm
- AES security hardware accelerator
- Random Number Generator
- MAC symbol timer

Simplified API

- API managed by on-chip co-processor
- SAP interface, following the IEEE 802.15.4 specification
- Synchronous SAP commands simplify user software

Configurable GPIO interface:

- SPI serial interface
- Interrupt output
- Configurable system clock outputs
- Configurable control outputs for transmit and receive enable

Package

- Available in a 32-PIN low-profile QFN package
  Package size 5mm x 5mm x 0.9mm

Development Tools

- Development kit
- Windows® based GUI connecting to devices via USB or serial UART
- API Driver functions for multiple microcontroller platforms

BENEFITS

Equipment cost: Increased range removes the need for external power amplifiers, thereby reducing component BOM.

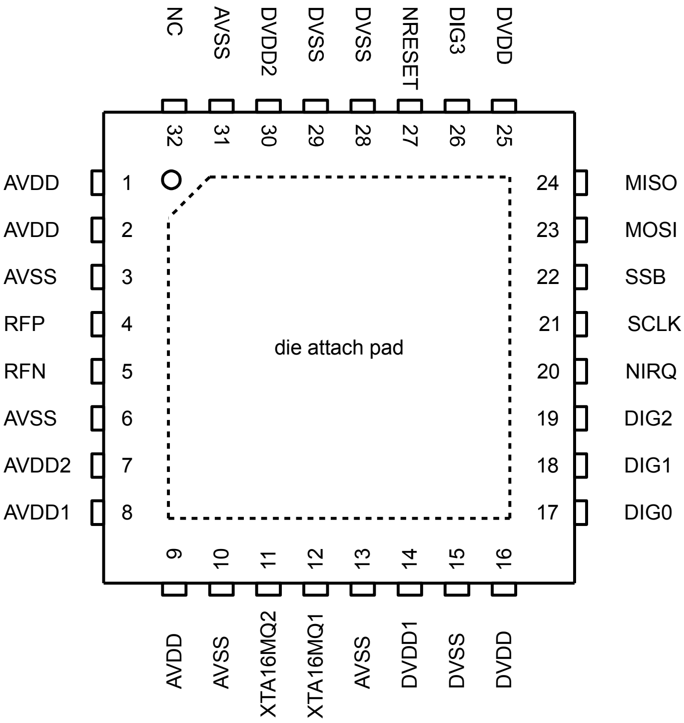
Installation cost: Greater datalink reliability lessens the need for skilled installers, and the consumer can self-install.

Maintenance cost: Lower power consumption means that batteries last longer, thereby minimizing maintenance cost.

APPLICATIONS

- Home and building automation
- Consumer electronics & cellphone
- Lighting systems
- Heating, ventilation & air-conditioning systems (HVAC)
- Smart grid (AMI/AMR)
- Asset tracking (active RFID)
- Industrial control and monitoring
- Assisted living & telecare

PIN CONFGURATION



1 VDD = 3V, f = 2.45 GHz, Top = 25°C

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1 Pin Description

1.1 Pin Configuration

The pin configuration of the CA-8210 device is given below.

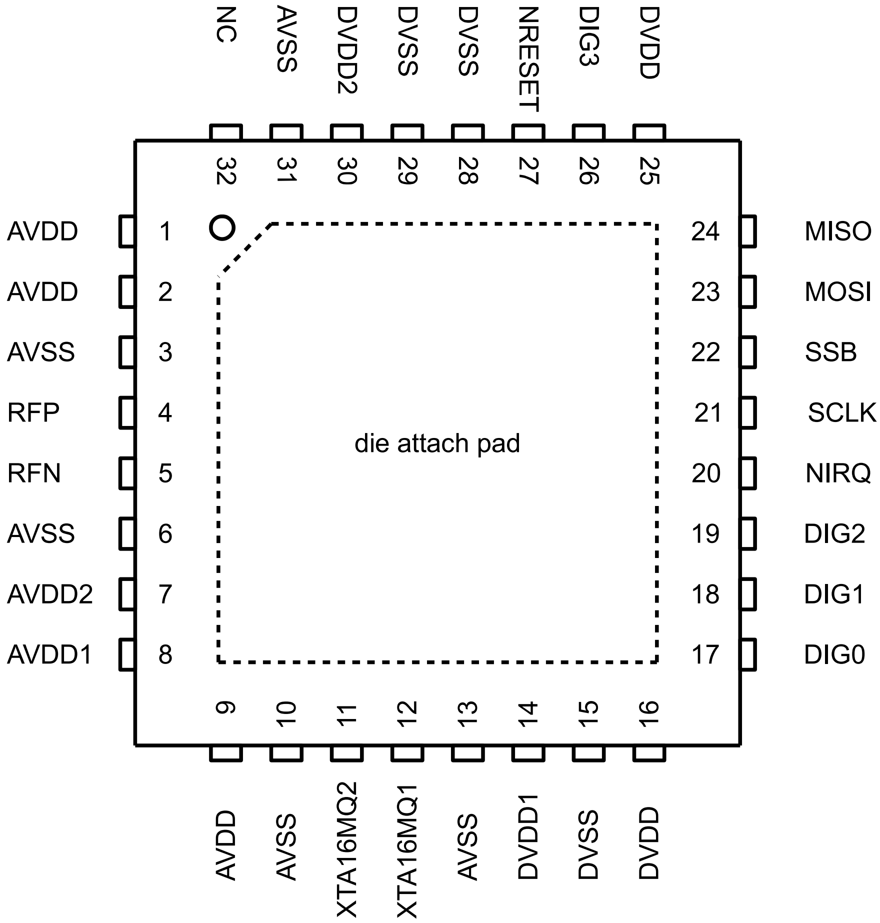

Figure 1.1: CA-8210 QFN32 Pin Configuration

1.2 Pin Descriptions

Pin	Name	Type	Description
1	AVDD	Power (Analog)	2.0-3.6V analog / digital power-supply connection
2	AVDD	Power (Analog)	2.0-3.6V analog / digital power-supply connection
3	AVSS	Ground (Analog)	Analog ground
4	RFP	RF I/O	Differential RF signal, positive
5	RFN	RF I/O	Differential RF signal, negative
6	AVSS	Ground (Analog)	Analog ground
7	AVDD2	Power (Analog)	Internal 1.8V power supply for decoupling
8	AVDD1	Power (Analog)	Internal 1.8V power supply for decoupling
9	AVDD	Power (Analog)	2.0-3.6V analog / digital power-supply connection
10	AVSS	Ground (Analog)	Analog ground
11	XTA16MQ2	Analog	16 MHz crystal oscillator pin.
12	XTA16MQ1	Analog	16 MHz crystal oscillator pin. Optional clock input.
13	AVSS	Ground (Analog)	Analog ground
14	DVDD1	Power (Digital)	Internal 1.8V power supply for decoupling
15	DVSS	Ground (Digital)	Digital ground
16	DVDD	Power (Digital)	2.0-3.6V digital power-supply connection
17	DIG0	Digital Output	Optional Rx enable for external LNA control
18	DIG1	Digital Output	Optional Tx enable for external PA control
19	DIG2	Digital Output	Optional programmable system clock output
20	NIRQ	Digital Output	SPI Interrupt, active low
21	SCLK	Digital Input	SPI SCLK
22	SSB	Digital Input	SPI slave select, active low
23	MOSI	Digital Input	SPI MOSI (master-out, slave-in)
24	MISO	Digital Output	SPI MISO (master-in, slave-out)
25	DVDD	Power (Digital)	2.0-3.6V digital power-supply connection
26	DIG3	Digital Output	Optional programmable system clock output
27	NRESET	Digital Input	Device reset, active low
28	DVSS	Ground (Digital)	Digital ground
29	DVSS	Ground (Digital)	Digital ground
30	DVDD2	Power (Digital)	Internal 1.1V power supply for decoupling
31	AVSS	Ground (Analog)	Analog ground
32	-	-	Not connected

Table 1.1: CA-8210 Pin Descriptions

2 Electrical Characteristics

2.1 Absolute Maximum Ratings

Parameter	Conditions	Min	Typ	Max	Units
Voltage (on any pin)		-0.3		3.9	V
Storage Temperature Range		-65		150	°C
Input RF Level				+10	dBm

Table 2.1: Absolute Maximum Ratings

Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

2.2 Environmental Conditions

Parameter	Conditions	Min	Typ	Max	Units
ESD	Human-body model, JEDEC STD 22 all pins except 4 and 5 (RFP, RFN)			2000	V
	Human-body model, JEDEC STD 22 pins 4 and 5 (RFP, RFN)			1000	V
	Charged-device model, JEDEC STD 22			500	V
MSL		MSL3			

Table 2.2: Environmental Conditions

2.3 Recommended Operating Conditions

Parameter	Min	Typ	Max	Units
Operating Supply Voltage – Device Supply (VDDA/VDDD)	2.1		3.6	V
Operating Temperature	-40		85	°C

Table 2.3: Recommended Operating Conditions

2.4 Digital Pin Characteristics

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input Low Voltage	V_{IL}		-0.3		0.8	V
Input High Voltage	V_{IH}		2.0		3.6	V
Schmitt Trigger Low to High Threshold	V_{T+}		1.54	1.60	1.68	V
Schmitt Trigger High to Low Threshold	V_{T-}		1.15	1.22	1.28	V
Pull-up Resistor	R_{PU}		34	48	74	kΩ
Input Leakage Current @ V_I=3.3V	I_I				1	uA
Output Low Voltage	V_{OL}				0.4	V
Output High Voltage	V_{OH}		2.4			V
Low Level Output Current @ V_{OL} (max)	I_{OL}		8.1	12.7	17.0	mA
High Level Output Current @ V_{OH} (min)	I_{OH}		10.5	21.4	35.6	mA

Table 2.4: Digital Pin Characteristics

2.5 Supply Currents

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Transmit	IDD_{Tx}	Tx Power +9 dBm Tx Power 0 dBm		19 12		mA mA
Receive	IDD_{Rx}	-105 dBm Sensitivity		14		mA
Active Mode: Co-processor active, XOSC on, regulators on	IDD_{ACTIVE}			2		mA
Active Mode: Co-processor idle, XOSC on, regulators on	IDD_{IDLE}			400		uA
Standby Mode: XOSC Off, digital regulators on	$IDD_{STANDBY}$			10		uA
Power-Off Mode 0: XOSC Off, core regulators off	IDD_{POFF0}			2		uA
Power-Off Mode 1: XOSC Off, all regulators off	IDD_{POFF1}			200		nA

Table 2.5: Supply Currents

2.6 General RF Characteristics

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Frequency Range	IFR	As specified by [1]	2405		2480	MHz
Channel Spacing		As specified by [1]		5		MHz
Number of Channels		As specified by [1]		16		
Chip Rate	CR	As specified by [1]		2000		kchip/s
Symbol Rate	SR	As specified by [1]		62.5		ksym/s
Data Rate	DR	As specified by [1]		250		kbit/s
Frame Length		As specified by [1]	6		133	bytes
Frame Duration		As specified by [1]	192		4256	μs
Reference Frequency	FREF			16		MHz
TX/RX Turnaround Time		As specified by [1]			192	μs

Table 2.6: General RF Characteristics

2.7 Receiver RF Characteristics

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Receiver Sensitivity		1% PER, PSDU 20 bytes		-105		dBm
Maximum Receiver Input Level		1% PER, PSDU 20 bytes		0		dBm
Symbol Rate Tolerance			-80		80	ppm
Adjacent Channel Rejection Low		-5 MHz		22		dB
Adjacent Channel Rejection High		+5 MHz		35		dB
Alternate Channel Rejection Low		-10 MHz		50		dB
Alternate Channel Rejection High		+10 MHz		50		dB
Spurious Emissions		30 MHz – 1 GHz 1 GHz – 12.75 GHz		-77 -52		dBm dBm
ED Range				83		dB
ED Low Range Limit				-104		dBm
ED High Range Limit				-21		dBm
ED Accuracy within Range				±2		dB
ED LSB Value				0.5		dB

Table 2.7: Receiver RF Characteristics

2.8 Transmitter RF Characteristics

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Output Power			0		9	dBm
Transmitter EVM				5	10	%
Transmitter Harmonics 2nd Harmonic 3rd Harmonic		@9dBm transmit power		 -52 -74		dBm
Transmitter Spurious Emissions		30 – ≤1000MHz >1 – 12.75GHz 1.8 – 1.9GHz 5.15 – 5.3GHz		-77 -50 -68 -67		dBm
Absolute PSD Limit		|F-Fc|>3.5MHz		-43		dBm
Relative PSD Limit		|F-Fc|>3.5MHz		-35		dB

Table 2.8: Transmitter RF Characteristics

2.9 Crystal Oscillator Specification

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Reference Frequency	F_{REF}			16		MHz
Reference Frequency Tolerance	F_{REFTOL}	As specified by [1]	-40		40	ppm
Load Capacitances	C_L			10		pF

Table 2.9: Crystal Oscillator Specification

3 Typical Performance Characteristics

All parameters measured at T_{OP} = 25°C, VDD=3.0V, f_{RF}=2.440 GHz (Channel 18) unless otherwise stated.

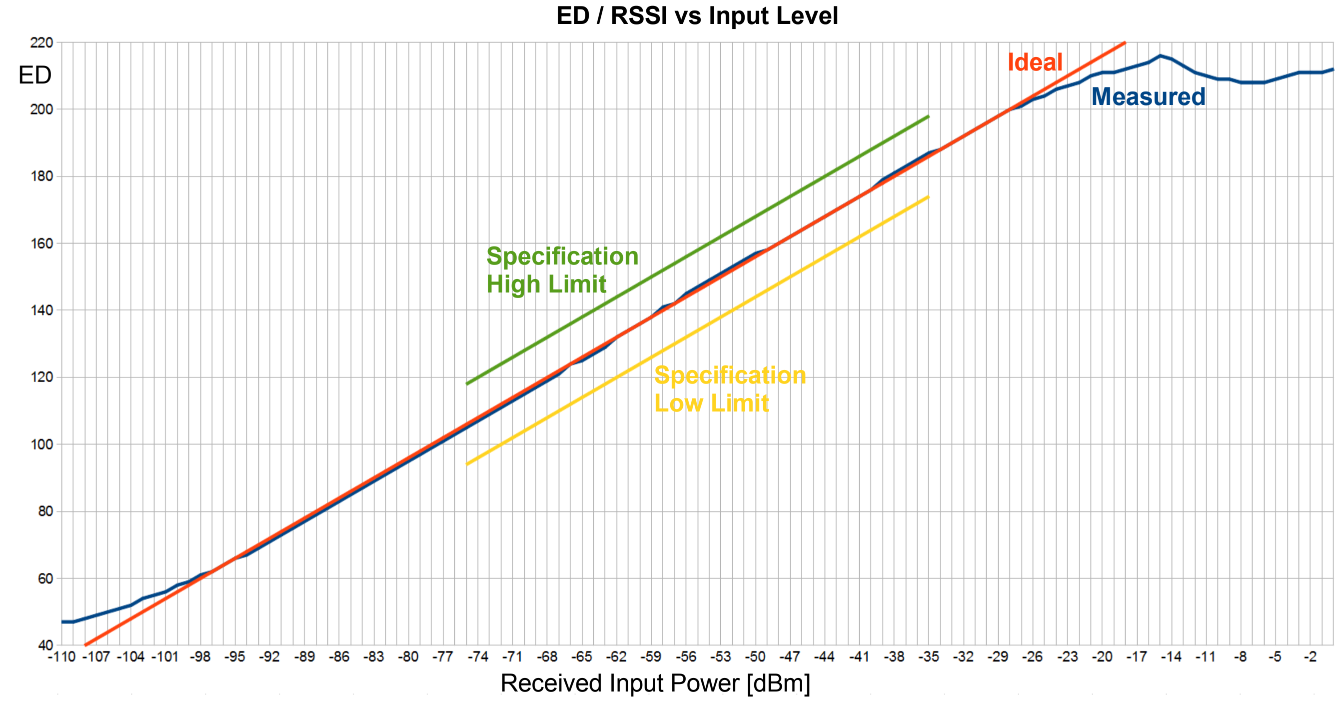

Figure 3.1: Receiver Energy Detect Value (ED, RSSI) vs Input Power Level

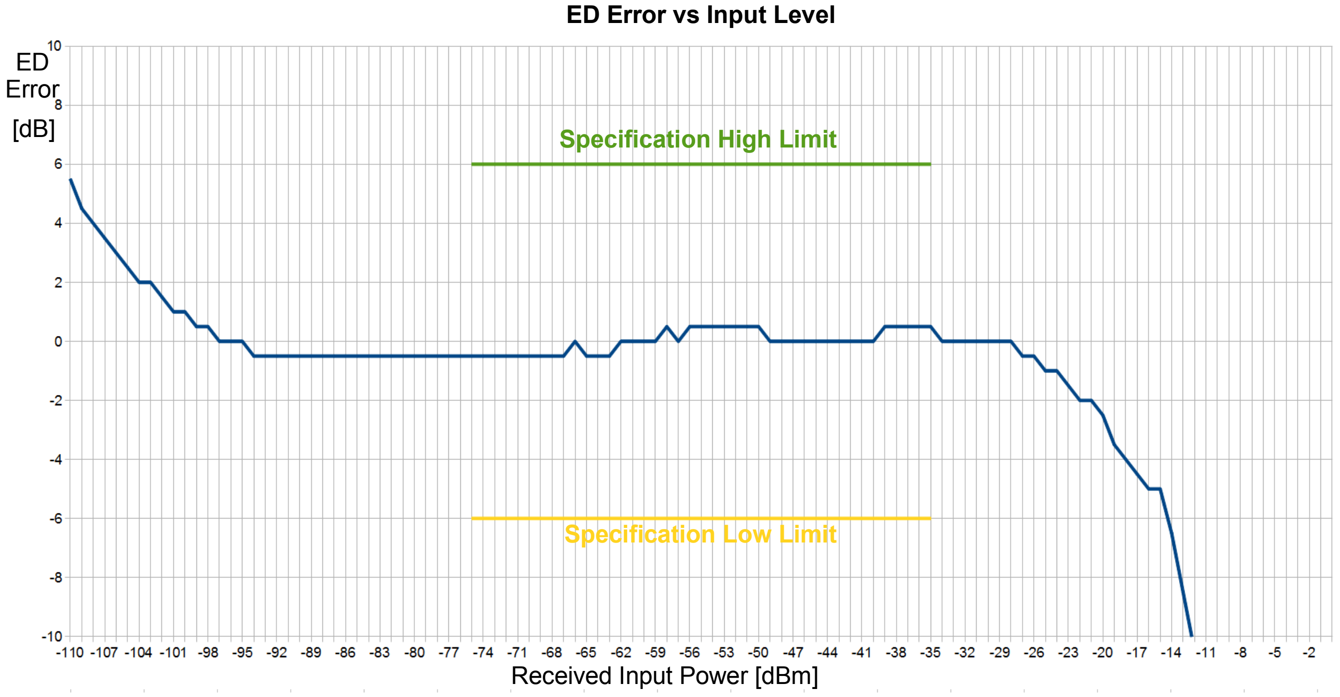

Figure 3.2: Receiver Energy Detect Error vs Input Power Level

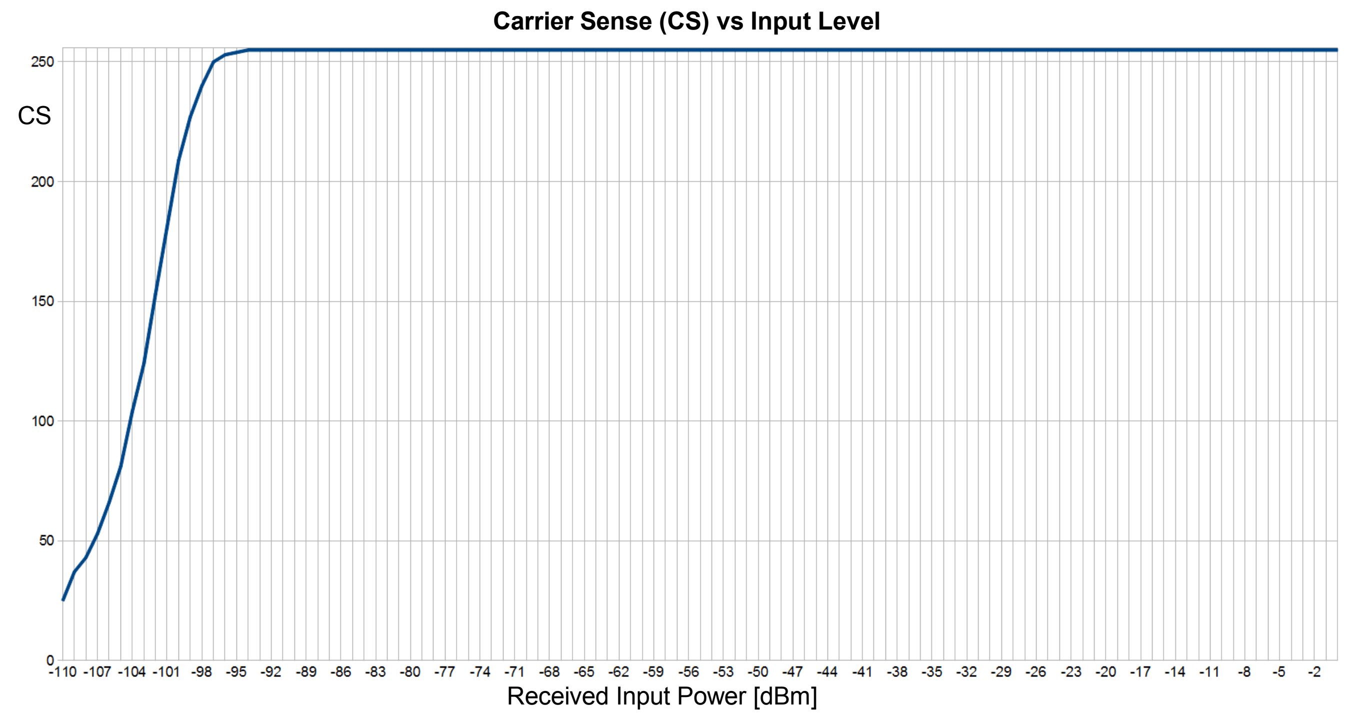

Figure 3.3: Receiver Carrier Sense (CS) vs Input Power Level

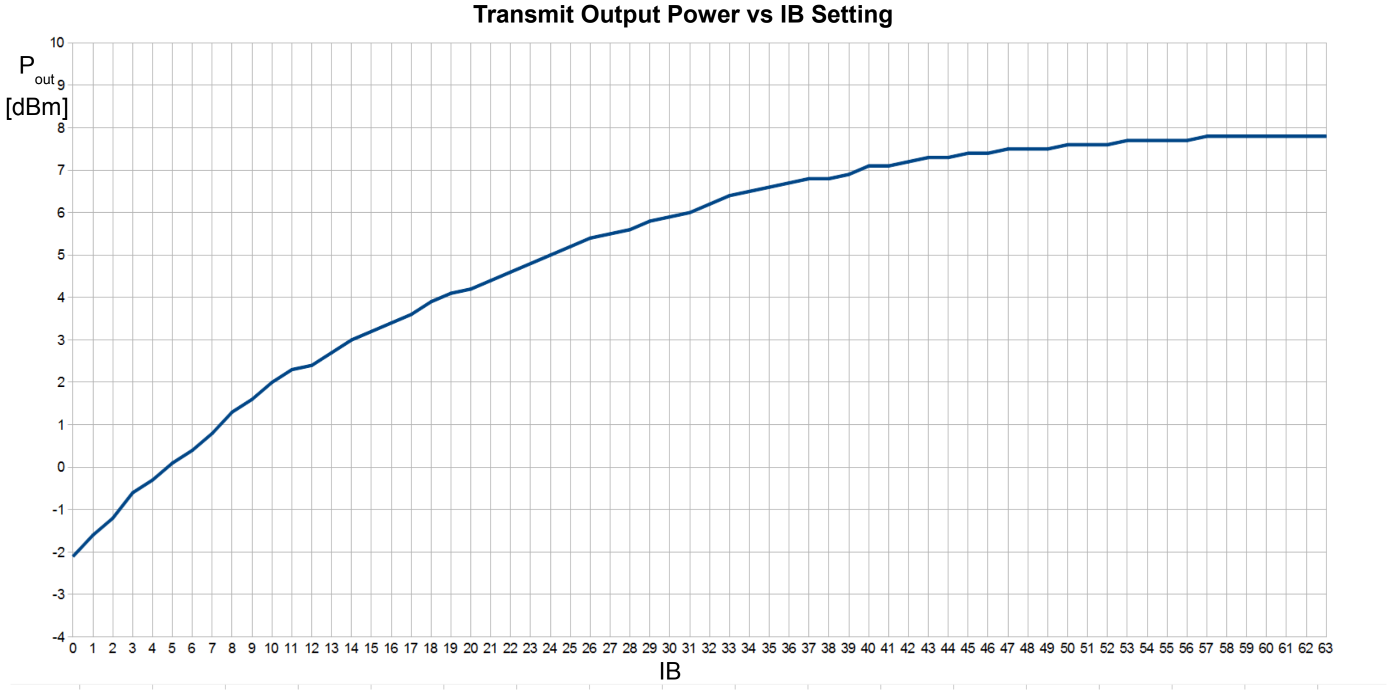

Figure 3.4: Transmit Output Power vs IB Setting

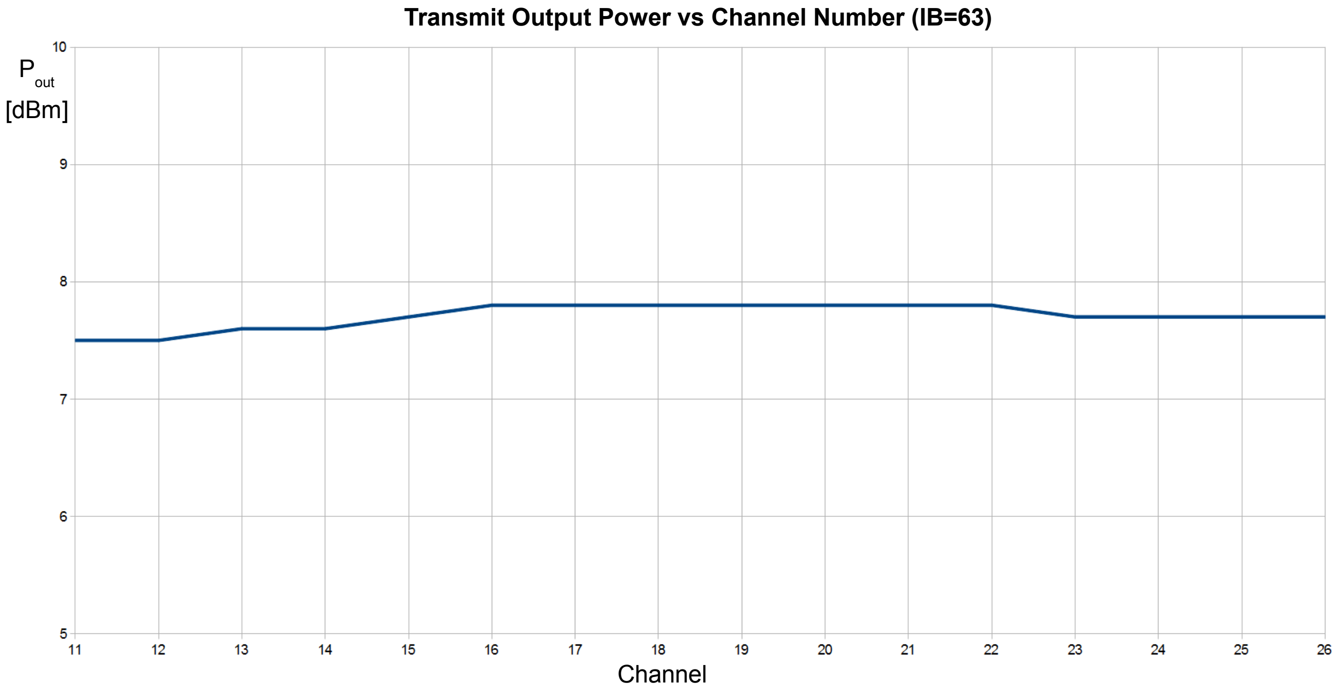

Figure 3.5: Transmit Output Power vs Channel Number

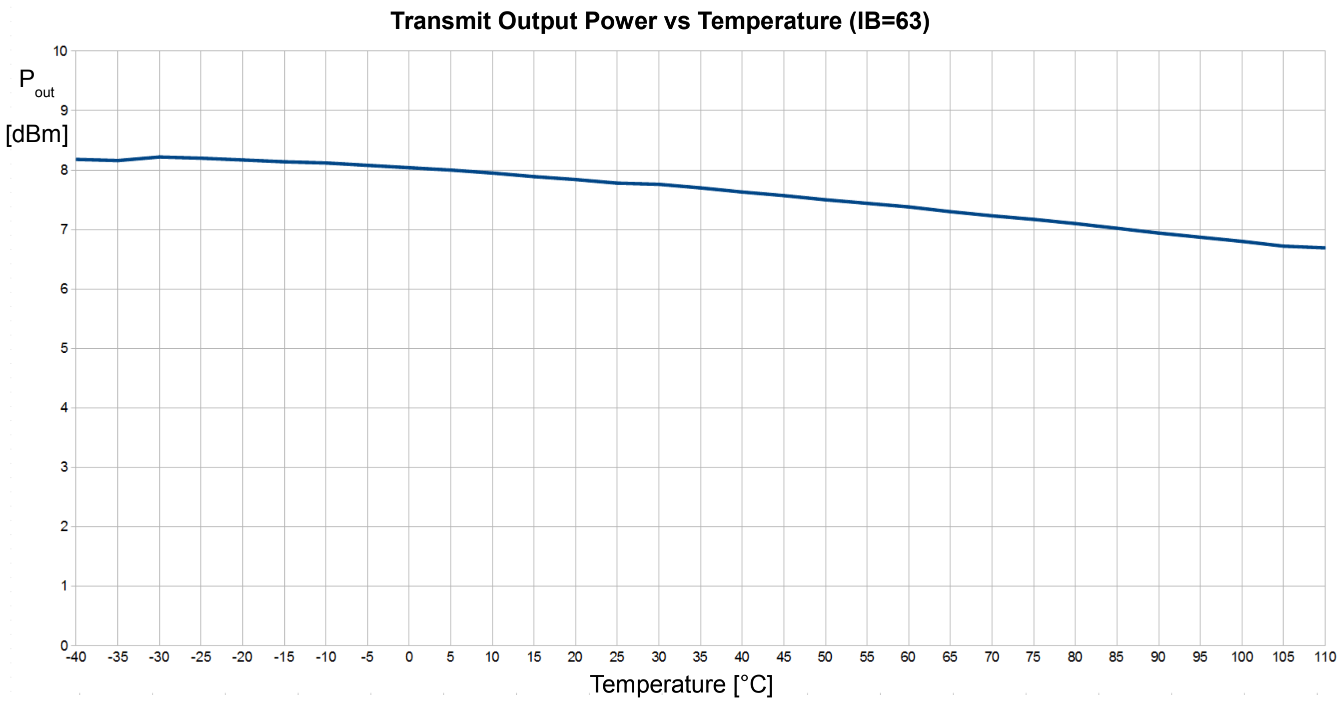

Figure 3.6: Transmit Output Power vs Temperature

4 Functional Description

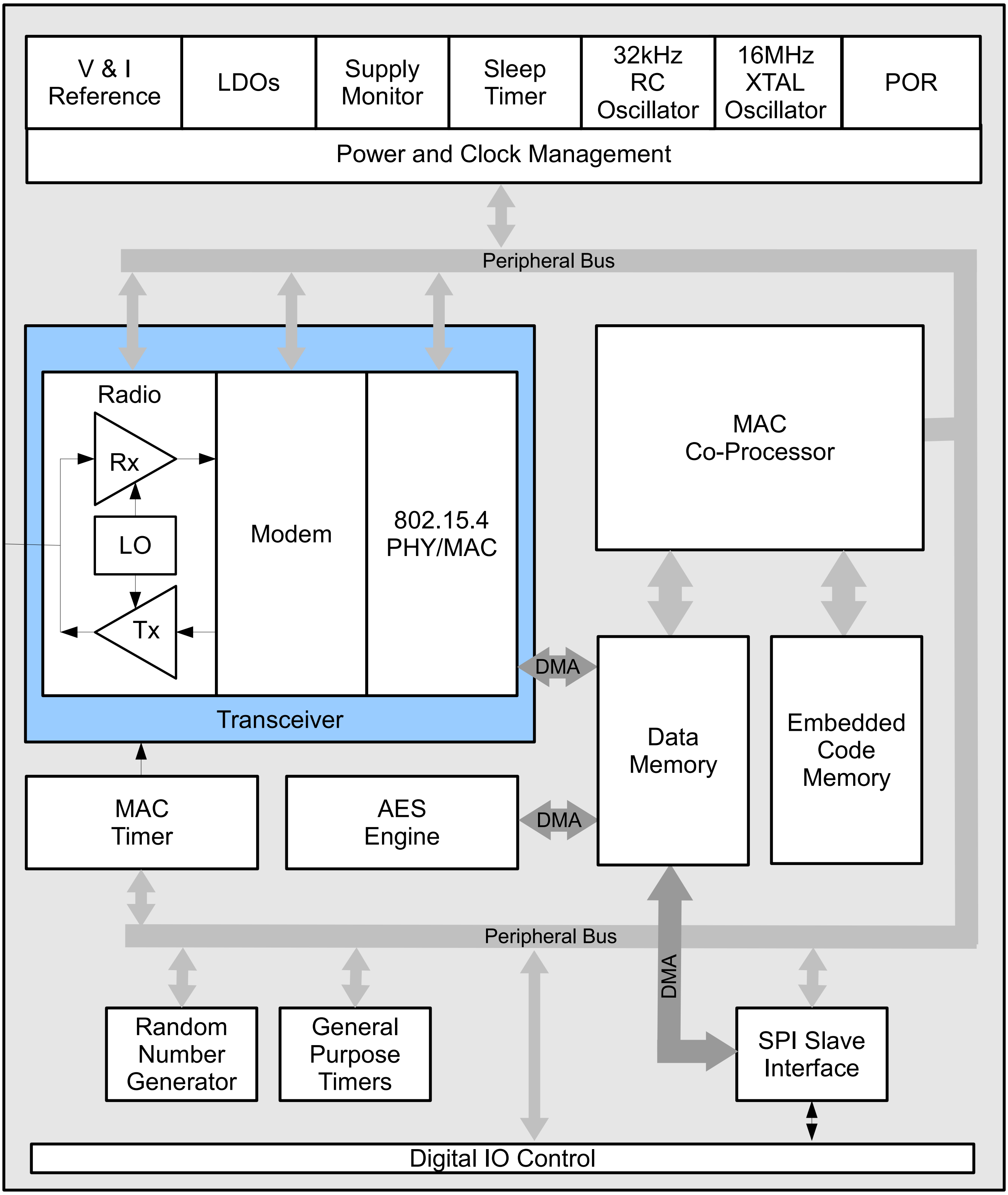

Figure 4.1: CA-8210 Functional Block Diagram

4.1 Overview

The CA-8210 is a single-chip transceiver modem for IEEE 802.15.4 applications and higher level protocol stacks implementing the complete PHY and MAC layers of the standard in the 2.4 GHz ISM band. It features a high-performance and low-power radio front-end and baseband processing engine, extended MAC hardware support and a dedicated co-processor which handles all higher-level MAC functionality. Communications to a host processor are through a SPI slave interface using an API which mirrors the IEEE 802.15.4 MCPS and MLME SAP specifications.

4.2 Receiver (Rx)

The differential signal at pins RFP and RFN is amplified primarily by a Low Noise Amplifier (LNA) and then down-converted in the receive section. A baseband amplification chain amplifies the down-converted signal further until it can be digitized by an ADC. All required filtering is performed on-chip without the need for external filter components. A demodulator with a novel energy-efficient and high-performance architecture correlates the data and extracts the data symbols. The digital section also controls the gain through the amplification path, and extracts values for Energy Detect (ED, or RSSI) and Carrier Sense (CS), which are used by the MAC for Clear Channel Assessment (CCA) and reported for routing and other purposes.

4.3 Transmitter (Tx)

An energy efficient architecture is used in the transmit section. Data for transmission is directly modulated onto the LO carrier and then amplified by a differential Power Amplifier (PA). Transmit and receive sections share the same RF pins. All calibration necessary for the transmit section is performed on-chip, and no external components are required. The transmit power can be programmed [in dBm] by the MLME-SET Request command with attribute phyTransmitPower when using the Cascoda API driver functions, or directly by the HWME-SET Request command with attribute TXPOWER (see 5.4.5.2) according to the following table:

Tx Power [dBm]	IB Setting [00H-3FH]	PB Setting [0H-7H]
0	03H	03H
1	05H	03H
2	07H	03H
3	0AH	03H
4	0EH	03H
5	13H	03H
6	18H	03H
7	1FH	03H
8	27H	03H
9	35H	03H

Table 4.1: Recommended Transmit Power Settings for HWME-SET TXPOWER Attribute

For more details of the relationship between IB setting and transmit output power see figure 3.5.

4.4 Local Oscillator (LO)

The local oscillator consists of a fractional-N frequency synthesizer PLL which uses the 16 MHz XOSC crystal as reference frequency. All required filtering components are integrated on-chip.

4.5 MAC Hardware Support

The CA-8210 features comprehensive hardware MAC support for functions which are timing critical or would require power-inefficient complex computational software. This includes:

- Automatic Frame Check Sequence (FCS) generation, analysis and filtering.
- Automatic frame filtering and address validation
- Automatic acknowledgment frame (ACK) generation and analysis, and retransmission of packets
- Energy Detection (ED, RSSI), Carrier Sense (CS) estimation and Link Quality Indication (LQI)
- Clear Channel Assessment (CCA) for the CSMA-CA algorithm
- AES-128 encryption engine for the acceleration of security processing
- Random number generator
- MAC symbol timer

4.5.1 Energy Detect (ED), Carrier Sense (CS) and Clear Channel Assessment (CCA)

Energy Detect (ED, also equivalent to Received Signal Strength Indication or RSSI) is an 8-bit value directly proportional to the signal strength received in the selected IEEE 802.15.4 channel. It does not make any distinctions about the type of signal. The received input power [in dBm] can be calculated by using the following formula:

$$P_{in} \text{ [dBm]} = (ED - 256)/2.$$

Figures 3.1 and 3.2 show the ED Value and its Error [in dB] respectively measured over input power level.

Carrier Sense (CS) is a measure of how well the received signal correlates to a IEEE 802.15.4 signal. It therefore measures the quality or Signal-to-Noise Ratio (SNR) of the received signal, with a value of 255 indicating high signal quality. Figure 3.3 shows the threshold behavior of the CS value (without interference), diminishing rapidly as the input level approaches the receiver sensitivity.

For the Clear Channel Assessment (CCA) used in the CSMA-CA algorithm either ED, CS or a combination of ED AND/OR CS can be used as specified in IEEE 802.15.4. The CCA mode can by set by by the MLME-SET attribute phyCCAMode, or by the HWME-SET attribute CCAMODE according to the following table:

PhyCCAMode / CCAMODE	Description
00H	Channel declared busy if ED OR CS is above threshold
01H	Channel declared busy if ED is above threshold
02H	Channel declared busy if CS is above threshold
03H	Channel declared busy if ED AND CS are above threshold

Table 4.2: Mode Selection for Clear Channel Assessment (CCA)

The thresholds above which the channel is declared busy are 8-bit values programmable by the HWME-SET attributes EDTHRESHOLD and CSTHRESHOLD, see 5.4.5.2. The measurement period for CCA is 8 symbols (128 us) as defined by the specification.

The Link Quality Indication (LQI) values reported by MCPS-DATA Indication and for PanDescriptors used for MLME-SCAN Confirm and MLME-BEACON-NOTIFY Indication are by default ED values, but can be reprogrammed to represent CS values by setting the HWME-SET attribute LQIMODE to 01H.

The values for ED and CS of the last packet (EDVALLP, CSVALLP) as well as momentary measured values (EDVALUE, CSVALUE) can be read using HWME-GET with the corresponding attribute, see 5.4.5.2.

4.5.2 AES Encryption Engine

In order to accelerate security computations, the CA-8210 features a hardware AES-128 encryption engine. It is used by the MAC co-processor to implement the IEEE 802.15.4 MAC security features.

4.5.3 Random Number Generator

The CA-8210 features a 16-bit true-random number generator with uniform distribution which is used by the MAC co-processor to generate values such as backoff exponents or initialization values, but can also be accessed in read-only mode by using the HWME-GET command and the attribute RANDOMNUM.

4.5.4 MAC Timer

The CA-8210 does not support time-stamping. However, a 32-bit symbol timer can be externally programmed and accessed by the HWME-SET/GET attribute MACTIMER, see 5.4.5.2.

4.6 MAC Co-processor

The MAC co-processor is a low-power microcontroller implementing more complex IEEE 802.15.4 MAC functionality such as:

- SPI SAP command formatting
- Complete IEEE 802.15.4 security suite
- PIB storage and access
- CSMA-CA algorithm
- Transmit frame formatting and receive frame analysis
- Direct and indirect data transmission
- Beacon and command frame generation
- Scanning
- Association and disassociation sequences
- PAN start sequence and coordinator functionality
- Communication status notifications
- PHY test access required for PHY tests outlined in the IEEE 802.15.4 PHY specification

When there are no active or scheduled tasks for the co-processor to execute, it goes into idle mode. In this mode all interrupts are active so that it can respond immediately if required, but code execution is stopped, and no memory access is performed, thereby saving power.

Note that the MAC co-processor is not user-programmable.

4.7 Low-Power Modes

Multiple options of low-power modes have been implemented to allow a wide selection of combinations with a host microprocessor. The following table lists the low-power modes, the device state and wake-up conditions:

Mode	On-Chip Supplies	Data Retention	16 MHz Clock Status	Wake-Up Conditions
Active	On	Yes	CPU Idle modes internally controlled	All Interrupts
Standby	Standby	Yes	Crystal Oscillator off, all clocks halted	Sleep Timer, GPIO Activity

Mode	On-Chip Supplies	Data Retention	16 MHz Clock Status	Wake-Up Conditions
Power-Off 0	Off except I/O	No	Crystal Oscillator off, all clocks halted	Sleep Timer, GPIO Activity, System Reset
Power-Off 1	Off	No	Crystal Oscillator off, all clocks halted	Sleep Timer

Table 4.3: CA-8210 Low-Power Modes

The low-power modes and wake-up condition are programmable by the HWME-SET command and attribute POWERCON according to the following table (see also 5.4.5.2):

POWERCON (Byte 1)	Description
00H	Active
10H	Active – Use Sleep Timer
04H	Standby – Wake-Up by System Reset only
14H	Standby – Wake-Up by Sleep Timer
24H	Standby – Wake-Up by GPIO Activity
34H	Standby – Wake-Up by Sleep Timer or GPIO Activity
0AH	Power-Off Mode 0 – Wake-Up by System Reset only
1AH	Power-Off Mode 0 – Wake-Up by Sleep Timer
2AH	Power-Off Mode 0 – Wake-Up by GPIO Activity
3AH	Power-Off Mode 0 – Wake-Up by Sleep Timer or GPIO Activity
1CH	Power-Off Mode 1 – Wake-Up by Sleep Timer

Table 4.4: Low-Power Mode Programming with the HWME-SET Attribute POWERCON

4.8 System Clock Output

The CA-8210 has an optional system clock output on pins DIG2 or DIG3 which can be used to provide the system clock to the host microprocessor. The output pin and frequency are programmable by the HWME-SET command using the SYSCLKOUT attribute.

First Byte of SYSCLKOUT Attribute	System Clock Output
00H	No Clock generated, Pin configured as Input
01H	16 MHz
02H	8 MHz
03H	4 MHz
04H	2 MHz
05H	1 MHz

Table 4.5: Optional System Clock Output Frequencies

Should the system clock output be enabled, the spectral purity of the clock from the CA-8210 means that a first order RC filter should be used to minimise spurious emissions. In this case, Cascoda recommends a first order filter with a 3dB cut-off frequency of 100MHz.

4.9 System Clock Input

The CA-8210 will accept an external 16MHz clock source. In this configuration, pin XTA16MQ2 should be connected to the PLL domain ground. The clock should be applied to pin XTA16MQ1, with an amplitude between 1.0V to 1.8V.

If an external clock is required, the phase noise and accuracy of this clock must be within the tolerances determined by the IEEE 802.15.4 specification.

The spectral purity of this clock means that care must be taken to minimise spurious emissions. As such a first order RC filter should be used. This RC filter should be referred to the PLL domain ground.

Please contact Cascoda for further details.

4.10 Support for external PA and LNA

Pins DIG0 and DIG1 provide signals to control an external LNA and PA by signals that enable the receive path (rx_enable, DIG0) and transmit path (tx_enable, DIG1).

5 SPI Communications Interface

This section describes the CA-8210 SPI serial port slave interface protocol and defines the MAC level API for communications between a host processor acting as master and the CA-8210 transceiver modem chip as slave of a physical SPI interface.

The API is mainly defined by the transfer of IEEE 802.15.4-2006 MAC layer MCPS-SAP and MLME-SAP primitives. A hardware management entity (HWME) SAP has been added for handling control and status information which is not defined in the IEEE 802.15.4 specification. The HWME is used for example for controlling the low-power modes of the transceiver chip. The concept of service primitives used in IEEE 802.15.4 has been maintained, with Request and Response primitives being transferred from the host to the modem, and Indication and Confirm primitives being transferred from the modem to the host. A test and debug management entity (TDME) has also been added to allow running PHY tests according to the IEEE 802.15.4-2006 PHY layer implementation and general RF test procedures.

5.1 SPI Physical Specification

Serial data on the MOSI and MISO pins is synchronous to the serial clock, and is transmitted and received as 8-bit characters, MSB first. Data is usually expected in bursts (packets), with multiple bytes being transmitted in one access (without the chip select pin SSB being de-asserted).

In addition to the SPI interface pins SCLK, MOSI and MISO, a GPIO pin is required as interrupt (NIRQ) to indicate to the host that the slave has information (Indication or Confirm primitive) to be transferred. Although most microcontroller families provide a dedicated slave select signal (SSB, active low), the functionality is sometimes limited and fixed to one or several bytes of transfer length. In all cases a GPIO pin can be used to generate the slave select. The device reset (NRESET) can be controlled by a host processor GPIO, or can be connected to a common system reset.

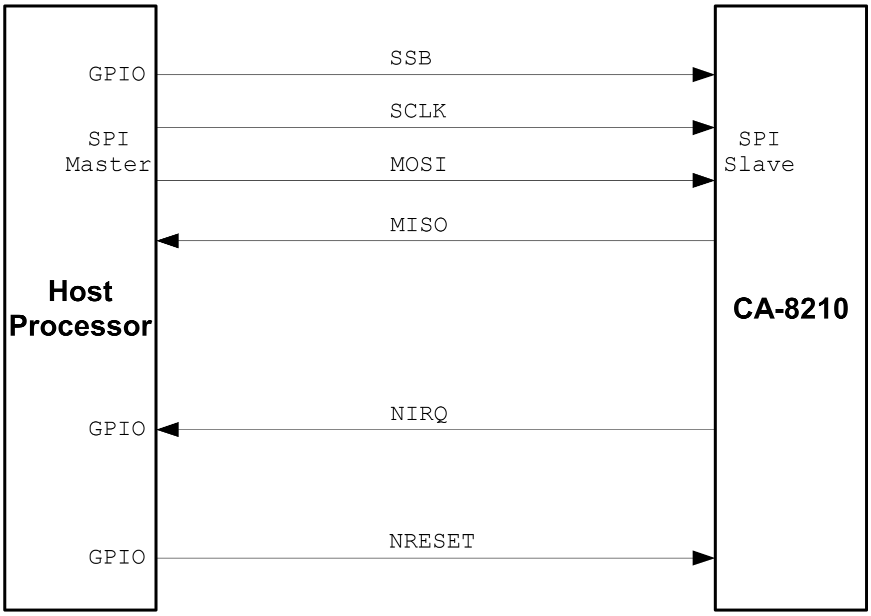

Figure 5.1: Interface Connections between Host and CA-8210

The specification for serial clock polarity and phase has been aligned to fit several commonly-used low-power microcontroller families. The Clock Phase (SCKPH) should be set to 0, and SPI data is centred on the first edge of the serial clock (received data on MOSI is captured on the first clock edge and transmitted data on MISO is shifted out on the following edge). The clock polarity (SCKPL) should be set to 1, and the serial clock is expected to be high when in inactive state. Note that for some microcontroller families the terminology can differ.

The polarity of the GPIO interrupt from the slave to the host is active low. It is asserted when the slave wants to transfer information to the host, and de-asserted after the SPI transfer has started (after SSB has been asserted by the host).

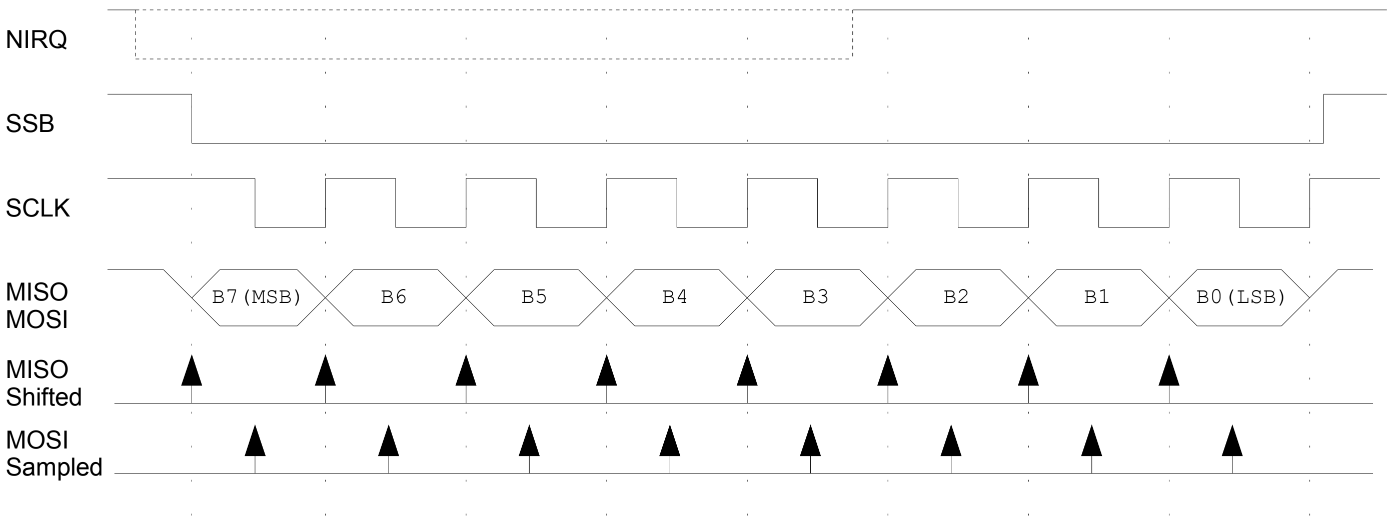

Figure 5.2: SPI Interface Timing Diagram

The following table shows SPI timing parameters, including the maximum SCLK frequency at which the SPI slave can operate. The maximum frequency depends on whether the SPI master is synchronous to the SPI slave (the host processor and the CA-8210 are using the same crystal clock as system clock) or asynchronous (the host processor and the CA-8210 are using different crystals). No minimum frequency is required for the SPI interface.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Maximum SCLK Frequency, Synchronous	FMAXS				4	MHz
Maximum SCLK Frequency, Asynchronous	FMAXA				3.5	MHz
Delay SSB low to MISO active					125	ns
Delay SCLK to MISO out					125	ns
MOSI to SCLK setup time	62.5					ns
MOSI to SCLK hold time	62.5					ns
SSB low to SCLK setup time	125					ns
Delay SSB to MISO tri-state					62.5	ns

Table 5.1: SPI Interface Timing Specification

5.2 SPI Protocol Message Encapsulation and Data Exchange

This section describes the SPI protocol message encapsulation and the data exchange procedures and scenarios for communication between master and slave. Encapsulation overhead has been kept to a minimum.

5.2.1 Message Encapsulation

The payload data of a protocol message packet is preceded by 2 bytes of encapsulation:

1. The message command (CMD), which is acting as command identifier as well as start byte.
2. The message packet length (PL), which is identifying the length of the message data payload in bytes.

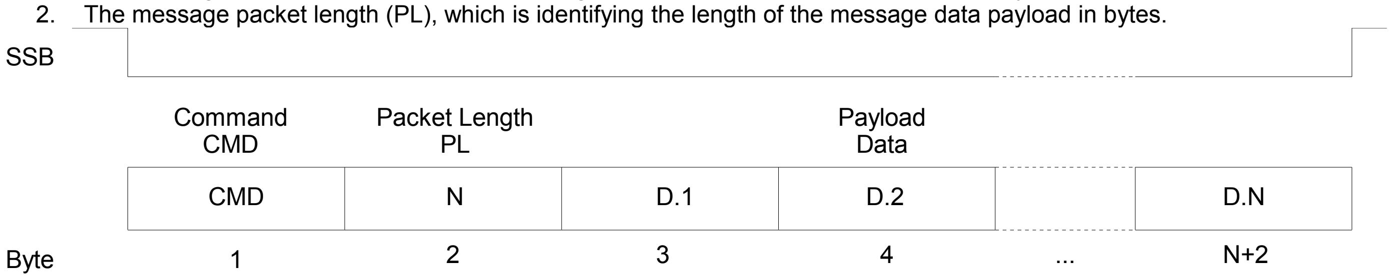

Figure 5.3: PI Message Encapsulation / Packet Framing

As the CMD and PL bytes are not included in the packet length, the packet length and size of the data payload is limited to 254 bytes.

5.2.2 Data Exchange between Master and Slave

In order to ensure robust 2-way communication, two message bytes, IDLE (FFH) and NACK (7FH) have been added which are returned when no return message is available, or the incoming data can not be processed by the slave as it is still evaluating the previous message packet in the SPI receive buffer. To illustrate this, flow diagrams are used in this section showing the message flow in both directions.

5.2.2.1 Data Exchange from Master to Slave

The first scenario shows a normal data exchange from the master to the slave, with the master sending either a SAP request or responding to a preceding SAP indication with a SAP response. The slave has no information to send back and signals IDLE.

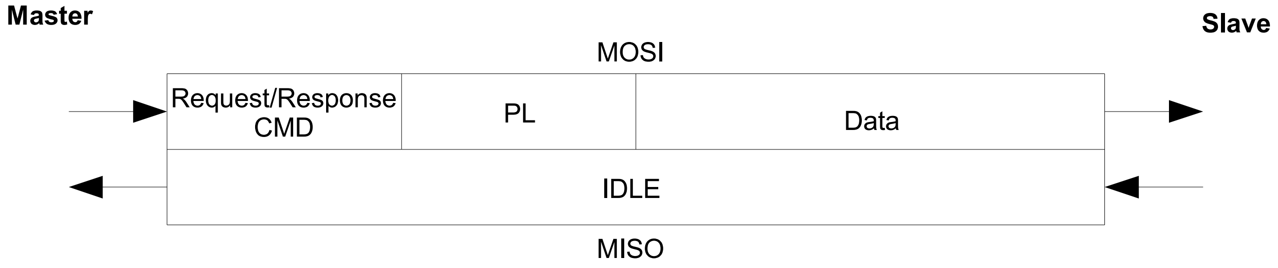

Figure 5.4: Message (Request or Response) from Master to Slave

The following figure illustrates the usage of NACK. The master sends 2 messages in quick succession. When the second message is being sent, the slave is still processing the first message and cannot store the second packet. It returns NACK instead of IDLE. The master knows that the second message has not been accepted, backs off, and re-sends the message after a wait period.

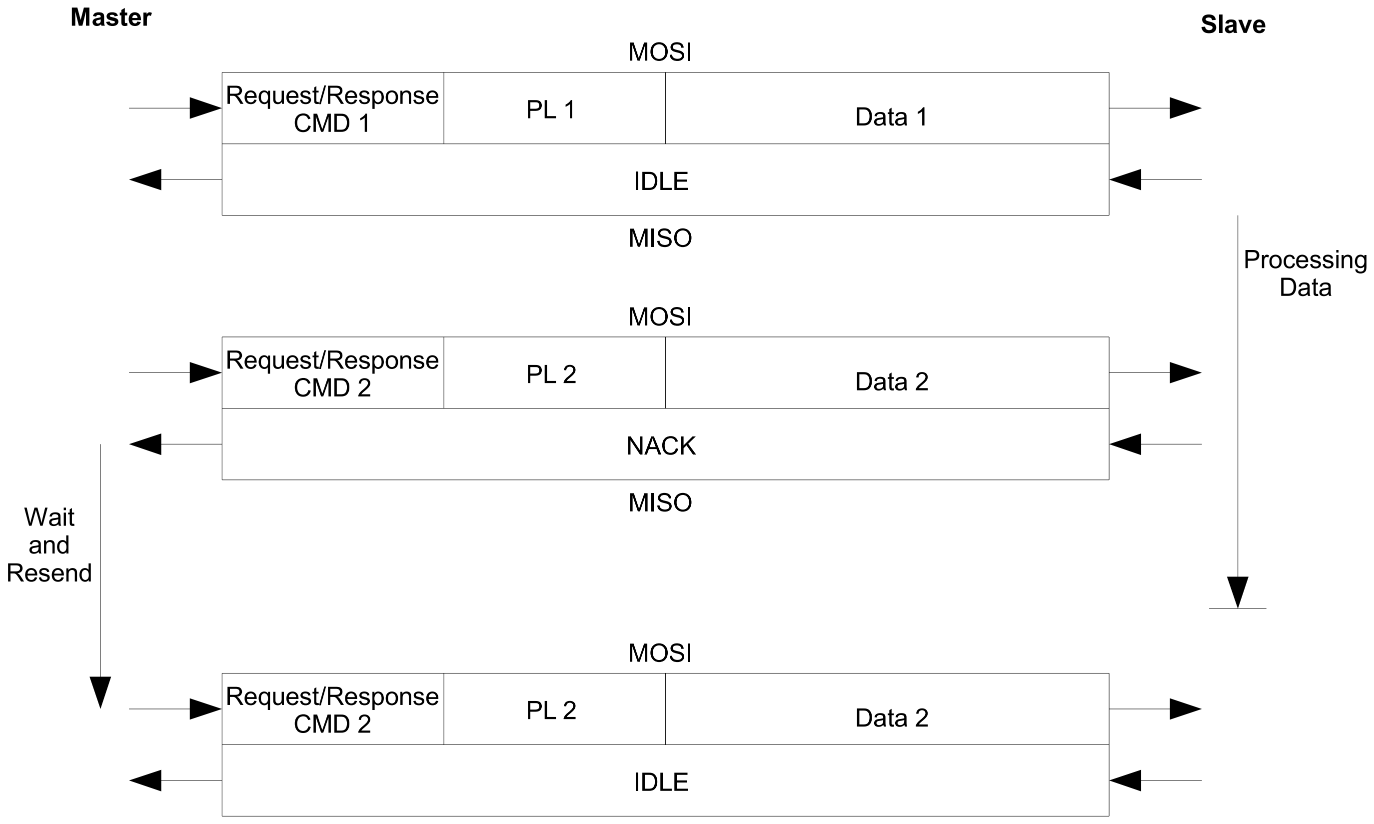

Figure 5.5: Successive Messages from Master to Slave with NACK

5.2.2.2 Data Exchange from Slave to Master

In order to exchange data from the slave to the master, the slave first needs to signal to the master that a message is available by raising an interrupt via a GPIO pin. The master then reads the message and returns IDLE if it has nothing to send. The active low interrupt will be kept asserted until the message transfer has started.

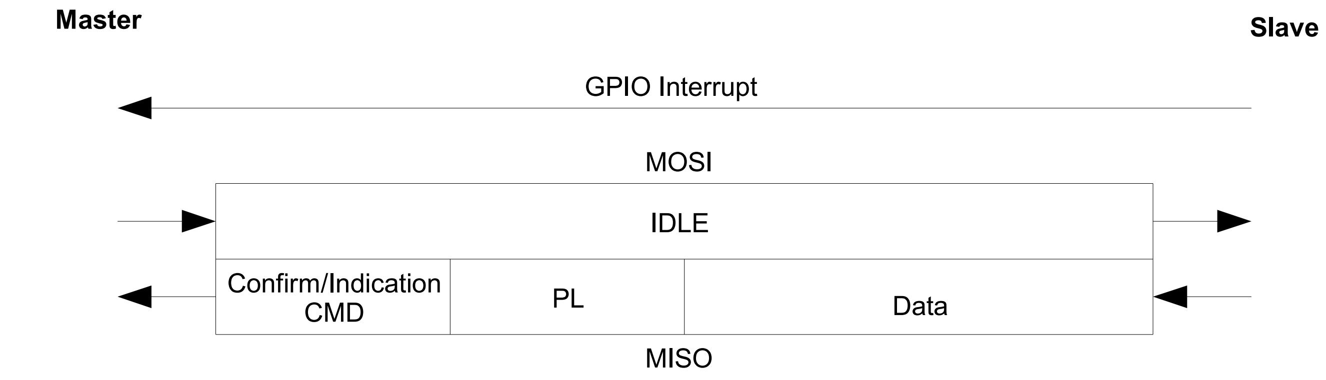

Figure 5.6: Message (Confirm or Indication) from Slave to Master

5.2.2.3 Bi-Directional Data Exchange

Although SAP message transfers are event-driven, a scenario can be envisaged where the master and slave have a message ready to send at the same time. In this case the message packets are unlikely to have the same length, and the master has to make sure that the SPI is enabled for the longer message to be completely transferred (maximum of PL1 and PL2). Bytes sent after the defined payload in the shorter message are ignored.

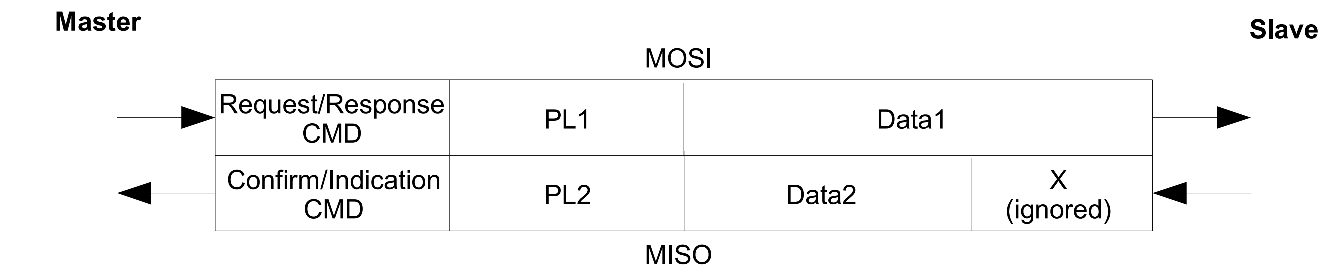

Figure 5.7: Bi-directional Data Exchange between Master and Slave

In order to facilitate the implementation of synchronous Request – Confirm pairs (see section 5.3 for further explanation) it is by default not allowed for the slave to send out data on the back of a Request or Response coming from the master. When it has information ready to send but detects a communication instigated by the master, the slave backs off and waits until the incoming packet has been received and processed.

5.3 Message Command Definitions

5.3.1 Message Exchange

The commands for the MAC layer MCPS-SAP and MLME-SAP are based on the service primitives as defined in section 7.1, "MAC sublayer service specification", of the IEEE 802.15.4-2006 standard. The HWME commands and primitives are further described in sections 5.4.4 and 5.4.5, and the TDME commands and primitives in sections 5.4.6 and 5.4.7.

For Request – Confirm primitive pairs there are 2 message types: synchronous and asynchronous messages. Although there is no distinction between the physical data exchange and SPI access procedure for a synchronous and asynchronous message packet, synchronous messages require an immediate response and are therefore treated with priority. Asynchronous messages do not require or cannot return an immediate response, such as a MCPS-DATA Request and Confirm, where the Confirm can only be issued once the data packet has been sent.

The following two flow diagrams illustrate the usage of asynchronous and synchronous Request and Confirm.

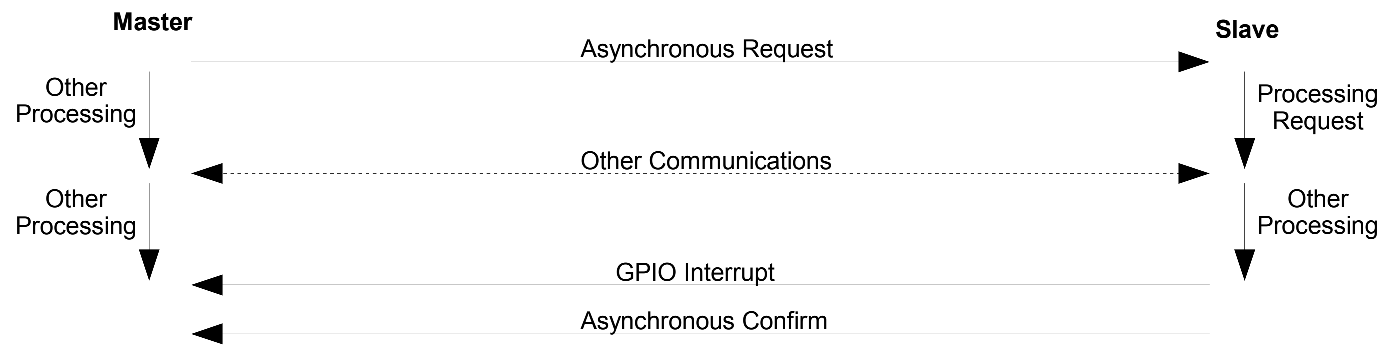

Figure 5.8: Asynchronous Request - Confirm

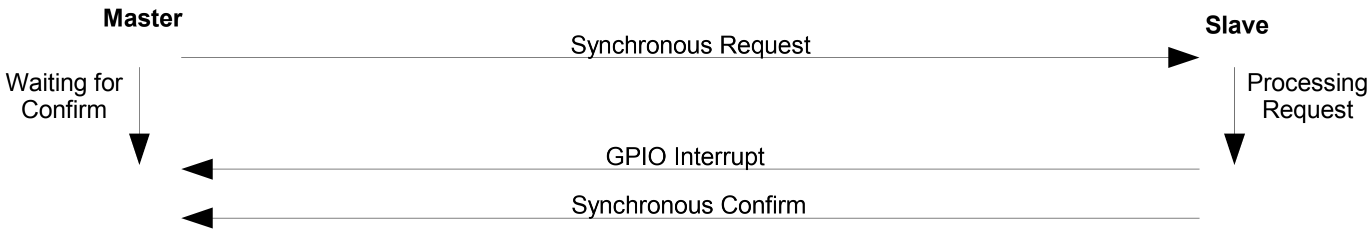

Figure 5.9: Synchronous Request - Confirm

5.3.2 Message Command Summary

The following table summarises the message command types used for the CA-8210 API.

CMD	Direction	Message Primitive	SAP Type	Message Type
FFH	Slave->Master, Master->Slave	IDLE	-	-
F0H	Slave->Master	NACK	-	-
00H	Master->Slave	MCPS-DATA	Request	Asynchronous
41H	Master->Slave	MCPS-PURGE	Request	Synchronous
02H	Master->Slave	MLME-ASSOCIATE	Request	Asynchronous
03H	Master->Slave	MLME-ASSOCIATE	Response	Asynchronous
04H	Master->Slave	MLME-DISASSOCIATE	Request	Asynchronous
45H	Master->Slave	MLME-GET	Request	Synchronous
06H	Master->Slave	MLME-ORPHAN	Response	Asynchronous
47H	Master->Slave	MLME-RESET	Request	Synchronous
48H	Master->Slave	MLME-RX-ENABLE	Request	Synchronous
09H	Master->Slave	MLME-SCAN	Request	Asynchronous
4AH	Master->Slave	MLME-SET	Request	Synchronous
4BH	Master->Slave	MLME-START	Request	Synchronous
0CH	Master->Slave	MLME-SYNC	Request	Asynchronous
4DH	Master->Slave	MLME-POLL	Request	Synchronous
4EH	Master->Slave	HWME-SET	Request	Synchronous
4FH	Master->Slave	HWME-GET	Request	Synchronous
51H	Master->Slave	TDME-SETSFR	Request	Synchronous
52H	Master->Slave	TDME-GETSFR	Request	Synchronous
53H	Master->Slave	TDME-TESTMODE	Request	Synchronous
54H	Master->Slave	TDME-SET	Request	Synchronous
55H	Master->Slave	TDME-TXPKT	Request	Synchronous
20H	Slave->Master	MCPS-DATA	Indication	Asynchronous
21H	Slave->Master	MCPS-DATA	Confirm	Asynchronous
62H	Slave->Master	MCPS-PURGE	Confirm	Synchronous
23H	Slave->Master	MLME-ASSOCIATE	Indication	Asynchronous
24H	Slave->Master	MLME-ASSOCIATE	Confirm	Asynchronous
25H	Slave->Master	MLME-DISASSOCIATE	Indication	Asynchronous
26H	Slave->Master	MLME-DISASSOCIATE	Confirm	Asynchronous
27H	Slave->Master	MLME-BEACON-NOTIFY	Indication	Asynchronous
68H	Slave->Master	MLME-GET	Confirm	Synchronous
29H	Slave->Master	MLME-ORPHAN	Indication	Asynchronous
6AH	Slave->Master	MLME-RESET	Confirm	Synchronous
6BH	Slave->Master	MLME-RX-ENABLE	Confirm	Synchronous
2CH	Slave->Master	MLME-SCAN	Confirm	Asynchronous
2DH	Slave->Master	MLME-COMM-STATUS	Indication	Asynchronous
6EH	Slave->Master	MLME-SET	Confirm	Synchronous
6FH	Slave->Master	MLME-START	Confirm	Synchronous
30H	Slave->Master	MLME-SYNC-LOSS	Indication	Asynchronous
71H	Slave->Master	MLME-POLL	Confirm	Synchronous
72H	Slave->Master	HWME-SET	Confirm	Synchronous
73H	Slave->Master	HWME-GET	Confirm	Synchronous
35H	Slave->Master	HWME-WAKEUP	Indication	Asynchronous
36H	Slave->Master	TDME-MESSAGE	Indication	Asynchronous

CMD	Direction	Message Primitive	SAP Type	Message Type
77H	Slave->Master	TDME-SETSFR	Confirm	Synchronous
78H	Slave->Master	TDME-GETSFR	Confirm	Synchronous
79H	Slave->Master	TDME-TESTMODE	Confirm	Synchronous
7AH	Slave->Master	TDME-SET	Confirm	Synchronous
7BH	Slave->Master	TDME-TXPKT	Confirm	Synchronous
3CH	Slave->Master	TDME-RXPKT	Indication	Asynchronous
3DH	Slave->Master	TDME-EDDET	Indication	Asynchronous
3EH	Slave->Master	TDME-ERROR	Indication	Asynchronous

Table 5.2: Message Command Definitions

5.4 Message Data

The parameters, data and enumerations for the MAC layer MCPS-SAP and MLME-SAP messages are defined in section 7.1, "MAC sublayer service specification", of the IEEE 802.15.4-2006 standard.

Multiple byte data is always transmitted little-endian (least-significant byte first).

Device addresses are always sent in 8 byte fields. Depending on the address mode parameter (AddrMode), the address field contains either the 64-bit extended address, the 16-bit short address, or no address. Unused bytes are padded with zeros. The following table illustrates this.

Byte	AddrMode		
	00H	02H	03H
Address [0]	00H	ShortAddress [0]	LongAddress [0]
Address [1]	00H	ShortAddress [1]	LongAddress [1]
Address [2]	00H	00H	LongAddress [2]
Address [3]	00H	00H	LongAddress [3]
Address [4]	00H	00H	LongAddress [4]
Address [5]	00H	00H	LongAddress [5]
Address [6]	00H	00H	LongAddress [6]
Address [7]	00H	00H	LongAddress [7]

Table 5.3: Address Parameter Fields

If the security level is zero, security parameters other than SecurityLevel are omitted. If SecurityLevel is non-zero the security parameters follow in 10 bytes, with KeySource fixed to 8 bytes.

Byte	Parameter
n	SecurityLevel = 0

Table 5.4: Security Parameters with SecurityLevel set to zero

Byte	Parameter
n	SecurityLevel > 0
n+1	KeyIdMode
n+2 - n+9	KeySource [0] - KeySource [7]
n+10	KeyIndex

Table 5.5: Security Parameters with SecurityLevel set to non-zero

In the parameter tables in sections 5.4.1 and 5.4.2, the packet length is calculated for SecurityLevel > 0. For SecurityLevel 0 the packet length can generally be calculated with PL_{SL0} = PL – 10.

The ChannelPage parameter has been omitted in all parameter sets for all primitives.

TimeStamp parameters (defined in IEEE 802.15.4-2006 as 24-bit values) are treated as 32-bit values (long values).

In order to ease the burden on software drivers, no further data compression by omission of redundant parameters is done.

5.4.1 MCPS-SAP Primitives

5.4.1.1 MCPS-DATA Request

Byte	Parameter
CMD	(00H)

Byte	Parameter
PL	(26+MsduLength)
1	SrcAddrMode
2	DstAddrMode
3 - 4	DstPANId [0] - DstPANId [1]
5 - 12	DstAddress [0] - DstAddress [7]
13	MsduLength
14	MsduHandle
15	TxOptions
16 - 16+MsduLength-1	Msdu [0] - Msdu [MsduLength-1]
16+MsduLength	SecurityLevel
17+MsduLength	KeyIdMode
18+MsduLength - 25+MsduLength	KeySource [0] - KeySource [7]
26+MsduLength	KeyIndex

5.4.1.2 MCPS-DATA Confirm

Byte	Parameter
CMD	(21H)
PL	(6)
1	MsduHandle
2	Status
3-6	TimeStamp [0] - TimeStamp [3]

Note that time-stamping is not supported, therefore the TimeStamp parameter will always be read as 0x00000000.

5.4.1.3 MCPS-DATA Indication

Byte	Parameter
CMD	(20H)
PL	(40+MsduLength)
1	SrcAddrMode
2 - 3	SrcPANId [0] - SrcPANId [1]
4 - 11	SrcAddress [0] - SrcAddress [7]
12	DstAddrMode
13 - 14	DstPANId [0] - DstPANId [1]
15 - 22	DstAddress [0] - DstAddress [7]
23	MsduLength
24	MpduLinkQuality
25	DSN
26 - 29	TimeStamp [0] - TimeStamp [3]
30 - 30+MsduLength-1	Msdu [0] - Msdu [MsduLength-1]
30+ MsduLength	SecurityLevel
31+ MsduLength	KeyIdMode
32+ MsduLength - 39+ MsduLength	KeySource [0] - KeySource [7]
40+ MsduLength	KeyIndex

Note that time-stamping is not supported, therefore the TimeStamp parameter will always be read as 0x00000000.

The reported MpduLinkQuality can be selected to be either Energy Detect (ED) or Carrier Sense (CS) of the received packet by using the HWME-SET attribute LQIMODE.

5.4.1.4 MCPS-PURGE Request

Byte	Parameter
CMD	(41H)
PL	(1)

Byte	Parameter
1	MsduHandle

5.4.1.5 MCPS-PURGE Confirm

Byte	Parameter
CMD	(62H)
PL	(2)
1	MsduHandle
2	Status

5.4.2 MLME-SAP Primitives

5.4.2.1 MLME-ASSOCIATE Request

Byte	Parameter
CMD	(02H)
PL	(24)
1	LogicalChannel
2	CoordAddrMode
3 - 4	CoordPANId [0] - CoordPANId [1]
5 - 12	CoordAddress [0] - CoordAddress [7]
13	CapabilityInformation
14	SecurityLevel
15	KeyIdMode
16 - 23	KeySource [0] - KeySource [7]
24	KeyIndex

5.4.2.2 MLME-ASSOCIATE Confirm

Byte	Parameter
CMD	(24H)
PL	(14)
1 - 2	AssocShortAddress [0] - AssocShortAddress [1]
3	Status
4	SecurityLevel
5	KeyIdMode
6 - 13	KeySource [0] - KeySource [7]
14	KeyIndex

5.4.2.3 MLME-ASSOCIATE Indication

Byte	Parameter
CMD	(23H)
PL	(20)
1 - 8	DeviceAddress [0] - DeviceAddress [7]
9	CapabilityInformation
10	SecurityLevel
11	KeyIdMode
12 - 19	KeySource [0] - KeySource [7]
20	KeyIndex

5.4.2.4 MLME-ASSOCIATE Response

Byte	Parameter
CMD	(03H)
PL	(22)
1 - 8	DeviceAddress [0] - DeviceAddress [7]

Byte	Parameter
9 - 10	AssocShortAddress [0] - AssocShortAddress [1]
11	Status
12	SecurityLevel
13	KeyIdMode
14 - 21	KeySource [0] - KeySource [7]
22	KeyIndex

5.4.2.5 MLME-DISASSOCIATE Request

Byte	Parameter
CMD	(04H)
PL	(24)
1	DeviceAddrMode
2 - 3	DevicePANId [0] - DevicePANId [1]
4 - 11	DeviceAddress [0] - DeviceAddress [7]
12	DisassociateReason
13	TxIndirect
14	SecurityLevel
15	KeyIdMode
16 - 23	KeySource [0] - KeySource [7]
24	KeyIndex

5.4.2.6 MLME-DISASSOCIATE Confirm

Byte	Parameter
CMD	(26H)
PL	(12)
1	Status
2	DeviceAddrMode
3 - 4	DevicePANId [0] - DevicePANId [1]
5 - 12	DeviceAddress [0] - DeviceAddress [7]

5.4.2.7 MLME-DISASSOCIATE Indication

Byte	Parameter
CMD	(25H)
PL	(20)
1 - 8	DeviceAddress [0] - DeviceAddress [7]
9	DisassociateReason
10	SecurityLevel
11	KeyIdMode
12 - 19	KeySource [0] - KeySource [7]
20	KeyIndex

5.4.2.8 MLME-BEACON-NOTIFY Indication

Byte	Parameter
CMD	(27H)
PL	(35+2*NS+8*NL+SduLength)
1	BSN
2	PanDescriptor.CoordAddrMode
3 - 4	PanDescriptor.CoordPANId [0] - PanDescriptor.CoordPANId [1]
5 - 12	PanDescriptor.CoordAddress [0] - PanDescriptor.CoordAddress [7]
13	PanDescriptor.LogicalChannel

Byte	Parameter
14 - 15	PanDescriptor.SuperframeSpec [0] - PanDescriptor.SuperframeSpec [1]
16	PanDescriptor.GTSPermit
17	PanDescriptor.LinkQuality
18 - 21	PanDescriptor.TimeStamp [0] - PanDescriptor.TimeStamp [3]
22	PanDescriptor.SecurityFailure
23	PanDescriptor.SecurityLevel
24	PanDescriptor.KeyIdMode
25 - 32	PanDescriptor.KeySource [0] - PanDescriptor.KeySource [7]
33	PanDescriptor.KeyIndex
34	PendAddrSpec
35 - 35+2*NS-1	AddrList.ShortAddress [0][0] - AddrList.ShortAddress [1][NS-1]
35+2*NS - 35+2*NS+8*NL-1	AddrList.LongAddress [0][0] - AddrList.LongAddress [7][NL-1]
35+2*NS+8*NL	SduLength
36+2*NS+8*NL - 36+2*NS+8*NL+SduLength-1	Sdu [0] – Sdu [SduLength-1]

NS is the number of short addresses and NL is the number of long addresses in the address list as defined in the address specification field PendAddrSpec. According to 802.15.4-2006 section 7.2.2.1.7 the maximum total number of addresses (NS+NL) is limited to 7.

In accordance with all other security parameter definitions, the security parameters KeyIdMode, KeySource and KeyIndex are omitted from the PanDescriptor parameter list if PanDescriptor.SecurityLevel is 0. This will shorten the packet length PL by 10 bytes.

Note that time-stamping is not supported, therefore the TimeStamp parameter in the PanDescriptors will always be read as 0x00000000.

The reported LinkQuality in the PanDescriptors can be selected to be either Energy Detect (ED) or Carrier Sense (CS) of the received beacon by using the HWME-SET attribute LQIMODE.

5.4.2.9 MLME-GET Request

Byte	Parameter
CMD	(45H)
PL	(2)
1	PIBAttribute
2	PIBAttributeIndex

5.4.2.10 MLME-GET Confirm

Byte	Parameter
CMD	(68H)
PL	(4+PIBAttributeLength)
1	Status
2	PIBAttribute
3	PIBAttributeIndex
4	PIBAttributeLength
5 – 5+PIBAttributeLength-1	PIBAttributeValue [0] - PIBAttributeValue [PIBAttributeLength-1]

The parameter PIBAttributeLength has been added to the IEEE 802.15.4-2006 parameter set.

5.4.2.11 MLME-ORPHAN Indication

Byte	Parameter
CMD	(29H)
PL	(19)
1 - 8	OrphanAddress [0] - OrphanAddress [7]
9	SecurityLevel
10	KeyIdMode
11 - 18	KeySource [0] - KeySource [7]
19	KeyIndex

5.4.2.12 MLME-ORPHAN Response

Byte	Parameter
CMD	(06H)
PL	(22)
1 - 8	OrphanAddress [0] - OrphanAddress [7]
9 – 10	ShortAddress [0] - ShortAddress [1]
11	AssociatedMember
12	SecurityLevel
13	KeyIdMode
14 - 21	KeySource [0] - KeySource [7]
22	KeyIndex

5.4.2.13 MLME-RESET Request

Byte	Parameter
CMD	(47H)
PL	(1)
1	SetDefaultPIB

5.4.2.14 MLME-RESET Confirm

Byte	Parameter
CMD	(6AH)
PL	(1)
1	Status

5.4.2.15 MLME-RX-ENABLE Request

Byte	Parameter
CMD	(48H)
PL	(9)
1	DeferPermit
2 - 5	RxOnTime [0] - RxOnTime [3]
6 - 9	RxOnDuration [0] - RxOnDuration [3]

The parameter RxOnDuration specifies the duration for which the receiver is on in number of units of number of symbols (16 us periods). The parameters DeferPermit and RxOnTime are not used in nonbeacon-enabled mode and are ignored.

5.4.2.16 MLME-RX-ENABLE Confirm

Byte	Parameter
CMD	(6BH)
PL	(1)
1	Status

5.4.2.17 MLME-SCAN Request

Byte	Parameter
CMD	(09H)
PL	(17)
1	ScanType
2 - 5	ScanChannels [0] - ScanChannels [3]
6	ScanDuration
7	SecurityLevel
8	KeyIdMode
9 - 16	KeySource [0] - KeySource [7]
17	KeyIndex

5.4.2.18 MLME-SCAN Confirm

Byte	Parameter
CMD	(2CH)
PL	(7+variable ResultList)
1	Status
2	ScanType
3 - 6	UnscannedChannels [0] - UnscannedChannels [3]
7	ResultListSize
8 - 8+ResultListSize-1	EnergyDetectList [0] - EnergyDetectList [ResultListSize-1]
8 - 8+32*ResultListSize-1	PanDescriptorList [0] - PanDescriptorList [ResultListSize-1]

The result list is EITHER an EnergyDetectList OR a PanDescriptorList OR may not be present at all. An EnergyDetectList is only returned in the confirm to an Energy Detect scan. A PanDescriptorList will be returned in the confirm to an Active or Passive scan if the PIB variable macAutoRequest is set to True. No result list is present if the scan type is an Orphan scan or if it is an Active or Passive scan and macAutoRequest is false. The elements of an EnergyDetectList are one byte long. The elements of a PanDescriptorList are 32 bytes or 22 bytes long depending on whether or not they contain a full security parameter descriptor. For a detailed description of PanDescriptor elements see section 5.4.2.8, MLME-BEACON-NOTIFY Indication (or IEEE 802.15.4-2006, section 7.1.5.1, Table 55). In accordance with all other security parameter definitions, the security parameters KeyIdMode, KeySource and KeyIndex are omitted from a specific PanDescriptor in PanDescriptorList if its PanDescriptor.SecurityLevel is zero. This will shorten the packet length PL by up to 10*ResultListSize bytes.

Note that the packet length PL is limited to 254 bytes, which in the worst case (all SecurityLevel > 0) limits the maximum ResultListSize for a PanDescriptorList to 7.

5.4.2.19 MLME-COMM-STATUS Indication

Byte	Parameter
CMD	(2DH)
PL	(32)
1 - 2	PANId [0] - PANId [1]
3	SrcAddrMode
4 - 11	SrcAddress [0] - SrcAddress [7]
12	DstAddrMode
13 - 20	DstAddress [0] - DstAddress [7]
21	Status
22	SecurityLevel
23	KeyIdMode
24 - 21	KeySource [0] - KeySource [7]
32	KeyIndex

5.4.2.20 MLME-SET Request

Byte	Parameter
CMD	(4AH)
PL	(3+PIBAttributeLength)
1	PIBAttribute
2	PIBAttributeIndex
3	PIBAttributeLength
4 – 4+PIBAttributeLength-1	PIBAttributeValue [0] - PIBAttributeValue [PIBAttributeLength-1]

The parameter PIBAttributeLength has been added to the IEEE 802.15.4-2006 parameter set.

5.4.2.21 MLME-SET Confirm

Byte	Parameter
CMD	(6EH)
PL	(3)
1	Status
2	PIBAttribute
3	PIBAttributeIndex

5.4.2.22 MLME-START Request

Byte	Parameter
CMD	(4BH)
PL	(30)
1 - 2	PANId [0] - PANId [1]
3	LogicalChannel
4	BeaconOrder
5	SuperframeOrder
6	PANCoordinator
7	BatteryLifeExtension
8	CoordRealignment
9	CoordRealignSecurityLevel
10	CoordRealignKeyIdMode
11 - 18	CoordRealignKeySource [0] - CoordRealignKeySource [7]
19	CoordRealignKeyIndex
20	BeaconSecurityLevel
21	BeaconKeyIdMode
22 - 29	BeaconKeySource [0] - BeaconKeySource [7]
30	BeaconKeyIndex

The parameter StartTime specified in IEEE 802.15.4-2006 is not used and has been taken out of the parameter set.

In accordance with all other security parameter definitions, the security parameters KeyIdMode, KeySource and KeyIndex are omitted from the CoordRealign or Beacon security parameters if the corresponding SecurityLevel is zero. If both CoordRealignSecurityLevel and BeaconSecurityLevel are zero, the packet length is reduced to PL=10.

5.4.2.23 MLME-START Confirm

Byte	Parameter
CMD	(6FH)
PL	(1)
1	Status

5.4.2.24 MLME-SYNC Request

This command is not featured in this version because it is only used in Beacon mode which has not been implemented.

5.4.2.25 MLME-SYNC-LOSS Indication

Byte	Parameter
CMD	(30H)
PL	(15)
1	LossReason
2 - 3	PANId [0] - PANId [1]
4	LogicalChannel
5	SecurityLevel
6	KeyIdMode
7 - 14	KeySource [0] - KeySource [7]
15	KeyIndex

5.4.2.26 MLME-POLL Request

Byte	Parameter
CMD	(4DH)
PL	(24)
1	CoordAddressMode
2 - 3	CoordinatorPANId [0] - CoordinatorPANId [1]
4 - 11	CoordAddress [0] - CoordAddress [7]
12 - 13	IntervalTime [0] – IntervalTime [1]

Byte	Parameter
14	SecurityLevel
15	KeyIdMode
16 - 23	KeySource [0] - KeySource [7]
24	KeyIndex

The parameter IntervalTime has been added to the IEEE 802.15.4-2006 parameter set for periodic polling functionality. When greater than zero it specifies a polling interval in 0.1 second units in which the slave will periodically poll and send out data request frames without a further MLME-POLL Confirm. When set to zero, the MLME-POLL Request will poll only once, as originally specified in IEEE 802.15.4-2006 (see Figure 40, page 135). In both cases, the MLME-POLL Confirm will be returned synchronously after the first polling. Setting Interval to FFFFH will disable polling, e.g. when periodic polling was enabled.

5.4.2.27 MLME-POLL Confirm

Byte	Parameter
CMD	(71H)
PL	(1)
1	Status

5.4.3 MLME Attribute Specifications

This section specifies the format of attribute values used in MLME-GET Confirm (see 5.4.2.10) and MLME-SET Request (see 5.4.2.20) messages. A more detailed description of the parameter items can be found in IEEE 802.15.4-2006. Other versions of the IEEE specification may vary. Attributes marked as (RO) are read-only.

Attribute Name	Identifier	Length	Format
phyCurrentChannel	0x00	1 byte	Integer: 0x0B-0x1A
phyChannelsSupported (RO)	0x01	4 bytes	Little endian Integer 0x07FFF800
phyTransmitPower	0x02	1 byte	Integer: 0x00-0xBF
phyCCAMode	0x03	1 byte	Integer: 0x00-0x03
phyCurrentPage (RO)	0x04	1 byte	Integer: 0x00
phyMaxFrameDuration (RO)	0x05	2 bytes	Little endian Integer: 0x010A
phySHRDuration (RO)	0x06	1 byte	Integer: 0x0A
phySymbolsPerOctet (RO)	0x07	1 byte	Integer: 0x02
macAckWaitDuration (RO)	0x40	1 byte	Integer (symbol periods): 0x00-0xFF
macAssociationPermit	0x41	1 byte	Boolean: 0/1
macAutoRequest	0x42	1 byte	Boolean: 0/1
macBattLifeExt	0x43	1 byte	Boolean: 0/1
macBattLifeExtPeriods	0x44	1 byte	Integer: 6-41
macBeaconPayload	0x45	variable bytes	In order of transmission
macBeaconPayloadLength	0x46	1 byte	Integer: 0-aMaxBeaconPayloadLength
macBeaconOrder	0x47	1 byte	Integer: 0-15 (15 supported)
macBeaconTxTime (RO)	0x48	3 bytes	Little endian Integer: 0x000000-0xFFFFFF
macBSN	0x49	1 byte	Integer: 0x00-0xFF
macCoordExtendedAddress	0x4A	8 bytes	Little endian Integer
macCoordShortAddress	0x4B	2 bytes	Little endian Integer
macDSN	0x4C	1 byte	Integer: 0x00-0xFF
macGTSPermit	0x4D	1 byte	Boolean: 0/1
macMaxCSMABackoffs	0x4E	1 byte	Integer: 0-5
macMinBE	0x4F	1 byte	Integer: 0-macMaxBE
macPANId	0x50	2 bytes	Little endian Integer
macPromiscuousMode	0x51	1 byte	Boolean: 0/1
macRxOnWhenIdle	0x52	1 byte	Boolean: 0/1

Attribute Name	Identifier	Length	Format
macShortAddress	0x53	2 bytes	Little endian Integer
macSuperframeOrder	0x54	1 byte	Integer: 0-15 (15 supported)
macTransactionPersistenceTime	0x55	2 bytes	Little endian Integer
macAssociatedPANCoord	0x56	1 byte	Boolean 0/1
macMaxBE	0x57	1 byte	Integer: 3-8
macMaxFrameTotalWaitTime	0x58	2 bytes	Little endian Integer (symbol periods)
macMaxFrameRetries	0x59	1 byte	Integer: 0-7
macResponseWaitTime	0x5A	1 byte	Integer: 2-64
macSyncSymbolOffset (RO)	0x5B	2 bytes	Little endian Integer: 0x000-0x100
macTimestampSupported (RO)	0x5C	1 bytes	Boolean: 0/1
macSecurityEnabled	0x5D	1 byte	Boolean: 0/1
macMinLIFSPeriod (RO)	0x5E	1 byte	Not supported
macMinSIFSPeriod (RO)	0x5F	1 byte	Not supported
macKeyTable	0x71	Indexed variable length entries	See section 5.4.3.1
macKeyTableEntries	0x72	1 byte	Integer: 0-4
macDeviceTable	0x73	Indexed 17 byte entries	See section 5.4.3.2
macDeviceTableEntries	0x74	1 byte	Integer: 0-16
macSecurityLevelTable	0x75	Indexed 4 byte entries	See section 5.4.3.3
macSecurityLevelTableEntries	0x76	1 byte	Integer: 0-8
macFrameCounter	0x77	4 bytes	Little endian Integer: 0x00-0xFFFFFFFF
macAutoRequestSecurityLevel	0x78	1 byte	Integer: 0-7
macAutoRequestKeyIdMode	0x79	1 byte	Integer: 0-3
macAutoRequestKeySource	0x7A	0, 4 or 8 bytes	Little endian Integer
macAutoRequestKeyIndex	0x7B	1 byte	Integer: 0x00-0xFF
macDefaultKeySource	0x7C	8 bytes	Little endian Integer
macPANCoordExtendedAddress	0x7D	8 bytes	Little endian Integer
macPANCoordShortAddress	0x7E	2 bytes	Little endian Integer
nsIEEEAddress	0xFF	8 bytes	Little endian Integer

Table 5.6: List of MLME Attributes

5.4.3.1 MacKeyTable Entry Format

Byte	Parameter
0	KeyIdLookupListEntries – Number of 10-byte entries N1 in KeyIdLookupList
1	KeyDeviceListEntries – Number of 1 byte entries N2 in KeyDeviceList
2	KeyUsageListEntries – Number of 1 byte entries N3 in KeyUsageList
3 - 18	Key - 16 byte Key - Little endian
19 – (19+(N1*10)-1)	KeyIdLookupList – Array of N1 * KeyIdLookupDescriptors (See below)
(19+(N1*10)) - ((19+(N1*10))+N2-1)	KeyDeviceList – Array of N2 * KeyDeviceDescriptors (See below)
((19+(N1*10))+N2) - (((19+(N1*10))+N2)+N3-1)	KeyUsageList – Array of N3 * KeyUsageDescriptors (See below)

A KeyIdLookupDescriptor consists of ten bytes as below:

Byte	Parameter
0 - 8	LookupData – 5 or 9 bytes to identify the key IF 5 BYTES LONG: LookupData[0] = 0 or the KeyIndex LookupData[1] = LS byte of Short Address LookupData[2] = MS byte of Short Address LookupData[3] = LS byte of PANID LookupData[4] = MS byte of PANID

Byte	Parameter
	IF 9 BYTES LONG: LookupData[0] = 0 or the KeyIndex LookupData[1] = LS byte of the IEEE Address …… LookupData[8] = MS byte of the IEEE Address
9	LookupDataSize – 0 or 1 to specify 5 or 9 bytes of LookupData

A KeyDeviceDescriptor consists of one byte as below:

Bit	Parameter
Bits 0 - 5	DeviceDescriptorHandle – index to an entry in macDeviceTable
Bit 6	UniqueDevice – boolean: 0/1
Bit 7	BlackListed – boolean: 0/1

A KeyUsageDescriptor consists of one byte as below:

Bit	Parameter
Bits 0 - 1	FrameType – value 0x00 - 0x03
Bits 2 - 3	Reserved – value 0x00
Bits 4 - 7	CommandFrameIdentifier – value 0x00 - 0x09

5.4.3.2 MacDeviceTable Entry Format

Byte	Parameter
0 - 1	PANId – Little endian integer
2 - 3	ShortAddress – Little endian integer
4 - 11	ExtAddress – Little endian integer
12 -15	FrameCounter – Little endian integer
16	Exempt – boolean: 0/1

5.4.3.3 MacSecurityLevelTable Entry Format

Byte	Parameter
0	FrameType - Integer: 0x00 - 0x03
1	CommandFrameIdentifier – Integer: 0x00 - 0x09
2	SecurityMinimum – Integer: 0x00 - 0x07
3	DeviceOverrideSecurityMinimum – Boolean: 0/1

5.4.4 HWME Primitives

The Hardware Management Entity (HWME) specifies an additional set of primitives, mainly SET and GET, that allow access to control and status information which is not defined in the MAC PIB Attributes (IEEE 802.15.4-2006 Tables 86 and 88).

5.4.4.1 HWME-SET Request

HWME-SET Request gives write access to HWME attributes. It's usage is equivalent to MLME-SET Request.

Byte	Parameter
CMD	(4EH)
PL	(2+HWAttributeLength)
1	HWAttribute
2	HWAttributeLength
3 – 3+HWAttributeLength-1	HWAttributeValue [0] - HWAttributeValue [HWAttributeLength-1]

5.4.4.2 HWME-SET Confirm

The usage of HWME-SET Confirm is equivalent to MLME-SET Confirm.

Byte	Parameter
CMD	(72H)
PL	(2)
1	Status
2	HWAttribute

5.4.4.3 HWME-GET Request

HWME-GET Request gives read access to HWME attributes. It's usage is equivalent to MLME-GET Request.

Byte	Parameter
CMD	(4FH)
PL	(1)
1	HWAttribute

5.4.4.4 HWME-GET Confirm

The usage of HWME- GET Confirm is equivalent to MLME- GET Confirm.

5.4.4.5 HWME-WAKEUP Indication

HWME-WAKEUP indication is issued when the transceiver is powered up, reset or woken up from a low-power mode. For further details see section 5.4.5.

Byte	Parameter
CMD	(35H)
PL	(1)
1	WakeUpCondition

5.4.5 HWME Enumerations and Attributes

5.4.5.1 HWME Enumerations

The following status enumeration values have been implemented for HWME Confirm primitives:

Status Enumeration	Value	Description
HWME_SUCCESS	00H	The requested Primitive has been executed successfully
HWME_UNKNOWN	01H	Unknown HWME Attribute or Parameter
HWME_INVALID	02H	Invalid HWME Attribute Value or Parameter Value
HWME_NO_ACCESS	03H	The requested Attribute cannot currently be accessed

Table 5.7: HWME Confirm Status Enumerations

The HWME-WAKEUP Indication primitive is used to signal to the master that the device has woken up from a low-power mode. The following values are defined for the WakeUpCondition parameter:

Status Enumeration	Value	Description	Data Retention
HWME_WAKEUP_POWERUP	00H	Transceiver woken up from Power Up / System Reset	No
HWME_WAKEUP_POFF_SLT	02H	Transceiver woken up from Power-Off by Sleep Timer Time-Out	No
HWME_WAKEUP_POFF_GPIO	03H	Transceiver woken up from Power-Off by GPIO Activity	No
HWME_WAKEUP_STBY_SLT	04H	Transceiver woken up from Standby by Sleep Timer Time-Out	Yes
HWME_WAKEUP_STBY_GPIO	05H	Transceiver woken up from Standby by GPIO Activity	Yes
HWME_WAKEUP_ACTIVE_SLT	06H	Sleep-Timer Time-Out in Active Mode	Yes

5.4.5.2 HWME Attributes

The following table gives a list of all accessible hardware attributes, their enumeration identifier (ID), length in number of bytes, and whether the specific attribute can be accessed by the HWME-SET primitive or is read-only by HWME-GET.

Attribute	ID	Description	Length	SET	GET
POWERCON	00H	Low-Power Mode Control	5	Yes	No
CHIPID	01H	Product ID and Version Number	2	No	Yes
TXPOWER	02H	Transmit Power Setting	3	Yes	Yes
CCAMODE	03H	Clear Channel Assessment Mode, according to IEEE 802.15.4-2006 Section 6.9.9	1	Yes	Yes
EDTHRESHOLD	04H	Energy Detect (ED) Threshold for CCA	1	Yes	Yes
CSTHRESHOLD	05H	Carrier Sense (CS) Threshold for CCA	1	Yes	Yes
EDVALUE	06H	Energy Detect (ED) Value of current Channel	1	No	Yes
CSVALUE	07H	Carrier Sense (CS) Value of current Channel	1	No	Yes
EDVALLP	08H	Energy Detect (ED) Value of last received Packet	1	No	Yes
CSVALLP	09H	Carrier Sense (CS) Value of last received Packet	1	No	Yes
FREQOFFS	0AH	Frequency Offset of last received Packet	1	No	Yes
MACTIMER	0BH	MAC Symbol Timer Value	4	Yes	Yes
RANDOMNUM	0CH	Random Number Value	2	No	Yes

Attribute	ID	Description	Length	SET	GET
SYSCLKOUT	0FH	System Clock Output to GPIO	2	Yes	Yes
LQIMODE	10H	LQI Reporting Mode for MCPS Data Indications and MLME PanDescriptors	1	Yes	Yes

Table 5.8: HWME Attributes

A detailed description of the values for each attribute is given below, Values that are not explicitly specified in the table are considered invalid for HWME-SET Requests.

Attribute	Byte	Value	Description
POWERCON	1	00H 10H 04H 14H 24H 34H 0AH 1AH 2AH 3AH 1CH	Active Active – Use Sleep Timer Standby – Wake-Up by System Reset only Standby – Wake-Up by Sleep Timer Standby – Wake-Up by GPIO Activity Standby – Wake-Up by Sleep Timer or GPIO Activity Power-Off Mode 0 – Wake-Up by System Reset only Power-Off Mode 0 – Wake-Up by Sleep Timer Power-Off Mode 0 – Wake-Up by GPIO Activity Power-Off Mode 0 – Wake-Up by Sleep Timer or GPIO Activity Power-Off Mode 1 – Wake-Up by Sleep Timer
	2-5	00000000H - 07FFFFFFH	Sleep Timer Wake-Up time in [ms]
CHIPID	1	00H - FFH	Product Identification
	2	00H - FFH	Version Number
TXPOWER	1	00H - 3FH	IB – Power Amplifier Current Setting. See Table 4.1.
	2	00H - 07H	PB – Power Amplifier Frequency Trim Setting. See Table 4.1.
	3	00H	Not used, should be set to 00H
CCAMODE	1	00H 01H 02H 03H	Channel declared busy if ED OR CS are above threshold Channel declared busy if ED is above threshold Channel declared busy if CS is above threshold Channel declared busy if ED AND CS are above threshold
EDTHRESHOLD	1	00H - FFH	Energy Detect (ED) Threshold for CCA
CSTHRESHOLD	1	00H - FFH	Carrier Sense (CS) Threshold for CCA
EDVALUE	1	00H - FFH	Energy Detect (ED) Value of current Channel
CSVALUE	1	00H – FFH	Carrier Sense (CS) Value of current Channel
EDVALLP	1	00H - FFH	Energy Detect (ED) Value of last received PHY Frame
CSVALLP	1	00H – FFH	Carrier Sense (CS) Value of last received PHY Frame
FREQOFFS	1	00H - FFH	Frequency Offset of last received PHY Frame in [ppm]
MACTIMER	1-4	00000000H - FFFFFFFFH	MAC Timer Value in [symbols]
RANDOMNUM	1-2	0000H - FFFFH	Random Number Value
SYSCLKOUT	1	00H – 05H	Division Ratio from 16 MHz (1/2/4/8/16). 0 (00H) turns SYSCLK output off
	2	02H or 09H	Output on GPIO2 or GPIO9
LQIMODE	1	00H 01H	CS (Carrier Sense) is reported as LQI ED (Energy Detect) is reported as LQI

Table 5.9: HWME Attribute Values

Bytes 2 to 5 of POWERCON containing the wake-up time value are ignored if the sleep timer is not used as a wake-up condition. If the HWME-SET Request has been successful, the HWME-GET Confirm primitive will be returned before entering a power saving mode. After wake-up a GPIO interrupt is issued to the host, and the HWME-WAKEUP Indication primitive is issued.

The POWERCON mode 10H (Active – Use Sleep Timer) is not an actual low-power mode and has been implemented so that the sleep timer can be accessed and used in active mode. On time-out the GPIO interrupt will be raised, and HWME-WAKEUP Indication will be issued with WakeUpCondition set to HWME_ACTIVE_SLT.

HWME-GET of attribute FREQOFFS returns the frequency offset value (signed, 2s-complement) in [ppm] (-128 to +127) of the last received PHY frame. The value is valid from the start of a received packet after a synchronization header (including SFD) has been received, and is kept until the next start-of-frame delimiter is received.

HWME-SET of attribute MACTIMER loads the value and starts the timer. When used with the HWME layer, the timer is configured as simple up-counter. Setting a value of FFFFFFFFH will stop and disable the MAC timer. Note that, unlike the sleep timer, the MAC timer will not run when entering low-power modes.

5.4.6 TDME Primitives

5.4.6.1 TDME-SETSFR Request

TDME-SETSFR Request writes the value SFRValue into an 8-bit CA-8210 SFR at address SFRAddress (80H-FFH) on page SFRPage (0-1).

Byte	Parameter
CMD	(51H)
PL	(3)
1	SFRPage
2	SFRAddress
3	SFRValue

5.4.6.2 TDME-SETSFR Confirm

TDME-SETSFR Confirm synchronously returns the status of a TDME-SETSFR Request.

Byte	Parameter
CMD	(77H)
PL	(3)
1	Status
2	SFRPage
3	SFRAddress

5.4.6.3 TDME-GETSFR Request

TDME-GETSFR Request requests the value SFRValue of an 8-bit CA-8210 SFR at address SFRAddress (80H-FFH) on page SFRPage (0-1) to be read.

Byte	Parameter
CMD	(52H)
PL	(2)
1	SFRPage
2	SFRAddress

5.4.6.4 TDME-GETSFR Confirm

TDME-GETSFR Confirm synchronously returns the value and status of a TDME-GETSFR Request.

Byte	Parameter
CMD	(78H)
PL	(4)
1	Status
2	SFRPage
3	SFRAddress
4	SFRValue

5.4.6.5 TDME-TESTMODE Request

TDME-TESTMODE Request configures the chip in PHY test mode, with the PHY layer (air interface) directly accessible for test purposes. The implemented test modes, their description and the enumeration for the TestMode parameter can be found in table 5.11.

Byte	Parameter
CMD	(53H)
PL	(1)
1	TestMode

5.4.6.6 TDME-TESTMODE Confirm

TDME-TESTMODE Confirm confirms the status following a TDME-TESTMODE Request. For TDME status enumerations see 5.4.7.1.

Byte	Parameter
CMD	(79H)
PL	(2)

Byte	Parameter
1	Status
2	TestMode

5.4.6.7 TDME-SET Request

TDME-SET Request gives write access to TDME attributes. Its usage is equivalent to MLME-SET and HWME-SET requests. TDME-SET allows all relevant parameters such as IEEE 802.15.4 channel to be set without having to use the MLME.

Byte	Parameter
CMD	(54H)
PL	(2+TestAttributeLength)
1	TestAttribute
2	TestAttributeLength
3 - 3+TestAttributeLength-1	TestAttributeValue[0] - TestAttributeValue[TestAttributeLength-1]

5.4.6.8 TDME-SET Confirm

The usage of TDME-SET Confirm is equivalent to MLME-SET and HWME-SET confirms.

Byte	Parameter
CMD	(7AH)
PL	(2)
1	Status
2	TestAttribute

5.4.6.9 TDME-TXPKT Request

TDME-TXPKT is a Synchronous request to immediately transmit an IEEE 802.15.4 PHY packet.

Byte	Parameter
CMD	(55H)
PL	3 or (3+TestPacketLength)
1	TestPacketDataType
2	TestPacketSequenceNumber
3	TestPacketLength
4 - 4+TestPacketLength-1	TestPacketData[0] - TestPacketData[TestPacketLength-1]

The TestPacketDataType determines type of the PHY payload according to table 5.12. If TestPacketDataType is set to TDME_TXD_APPENDED the PHY payload data is generated externally and defined within the TDME-TXPKT Request. In this case the packet length PL has to be set to 3+TestPacketLength. In all other cases the data is generated internally and PL is fixed to 3, but TestPacketLength will still specify the PSDU length.

5.4.6.10 TDME-TXPKT Confirm

TDME-TXPKT Confirm confirms that the IEEE 802.15.4 PHY packet requested by a TDME-TXPKT Request has been sent. The PHY payload data sent is returned.

Byte	Parameter
CMD	(7BH)
PL	3+TestPacketLength
1	Status
2	TestPacketSequenceNumber
3	TestPacketLength
4 - 4+TestPacketLength-1	TestPacketData[0] - TestPacketData[TestPacketLength-1]

5.4.6.11 TDME-RXPKT Indication

TDME-RXPKT Indication indicates that an IEEE 802.15.4 PHY packet has been received. All relevant packet parameters as well as the PHY payload data are returned. The Status parameter indicates if there was an error during reception.

Byte	Parameter
CMD	(3CH)
PL	5+TestPacketLength
1	Status
2	TestPacketEDValue

Byte	Parameter
3	TestPacketCSValue
4	TestPacketFoffsValue
5	TestPacketLength
6 - 6+TestPacketLength-1	TestPacketData[0] - TestPacketData[TestPacketLength-1]

5.4.6.12 TDME-EDDET Indication

TDME-EDDET Indication is used in energy detect test mode TDME_TEST_ED to indicate that the received energy level has been above a certain threshold for a certain amount of time. The detected energy and carrier sense values and the time above threshold in [us] are returned.

Byte	Parameter
CMD	(3DH)
PL	5
1	TestEDThreshold
2	TestEDValue
3	TestCSValue
4-5	TestTimeAboveThreshold_us[0] - TestTimeAboveThreshold_us[1]

5.4.6.13 TDME-ERROR Indication

TDME-ERROR Indication reports a system error such as an unexpected or not allowed interrupt, or a invalid received SPI packet.

Byte	Parameter
CMD	(3EH)
PL	1
1	ErrorCode

5.4.7 TDME Enumerations and Attributes

5.4.7.1 TDME Enumerations

For Confirm primitives the following status values have been implemented:

Status Enumeration	Value	Description
TDME_SUCCESS	00H	The requested Primitive has been executed successfully
TDME_UNKNOWN	01H	Unknown TDME Value or Parameter
TDME_INVALID	02H	Invalid TDME Value or Parameter Value
TDME_NO_ACCESS	03H	The requested Value cannot currently be accessed
TDME_LO_ERROR	04H	LO Locking Error
TDME_FCS_ERROR	05H	Received Packet Frame Check Sequence (CRC) Error
TDME_SHR_ERROR	06H	Received Packet Synchronisation Header Error
TDME_PHR_ERROR	07H	Received Packet Packet Header Error

Table 5.10: TDME Confirm Status Enumerations

TDME-TESTMODE Request sets the PHY into the following test modes:

Test Mode Enumeration	Value	PHY Test Mode Description
TDME_TEST_OFF	00H	All Test Modes are disabled (default)
TDME_TEST_IDLE	01H	Idle Test Mode. Test mode is enabled, but transmitter and receiver are off
TDME_TEST_TX	02H	Transmit Test Mode
TDME_TEST_RX	03H	Receive Test Mode
TDME_TEST_ED	04H	Energy Detect Test Mode (Energy Sniffer)
TDME_TEST_LO_1	05H	LO Test Mode 1 (Tx/Rx with no Modulation, PA enabled)
TDME_TEST_LO_2	06H	LO Test Mode 2 (VCO Open Loop / Initialisation, PA enabled)

Table 5.11: PHY Test Mode Enumerations for TDME-TESTMODE Request

Test mode TDME_TEST_TX is used for transmitter tests such as PSD and EVM, or to act as a reference transmitter for receiver tests.
Test mode TDME_TEST_RX is used for receiver tests such as sensitivity / PER or energy detect (ED) performance. It can also be used as a packet sniffer.

Test mode TDME_TEST_ED is used as an energy detect mode. In this mode an indication is given when the received energy level has been above a certain threshold level for an amount of time.
The following table defines the enumerations for the TestPacketDataType parameter for the TDME-TXPKT Request primitive.

Data Type Enumeration	Value	Payload Data Description
TDME_TXD_RANDOM	00H	Random Data, internally generated
TDME_TXD_SEQRANDOM	01H	Sequence Number in 1st Byte and all other Data Random, internally generated
TDME_TXD_COUNT	02H	Count (Increment) Data, internally generated
TDME_TXD_APPENDED	03H	Data external and appended to TDME-TXPKT Request

Table 5.12: TestPacketDataType Enumerations for TDME-TXPKT Request

5.4.7.2 TDME Attributes

The following table gives a list of all accessible TDME test attributes that can be accessed by the TDME-SET primitive. All attributes have a length of one byte.

Attribute	ID	Description	Length
TDME_CHANNEL	00H	IEEE 802.15.4 Channel Selection	1
TDME_TX_CONFIG	01H	Transmit (Tx) Test Configuration	4
TDME_ED_CONFIG	02H	Energy Detect Configuration	1
TDME_LO_1_CONFIG	04H	LO Test 1 Configuration (Tx/Rx with no Modulation on IEEE 802.15.4 Channel)	2
TDME_LO_2_CONFIG	05H	LO Test 2 Configuration (VCO Open Loop / Initialisation)	1

Table 5.13: TDME Test Attributes

A detailed description of the values for each attribute is given below, Values that are not explicitly specified in the table are considered invalid for TDME-SET Requests.

Attribute	Byte	Value	Description
TDME_CHANNEL	1	0BH - 1AH	Channel Number (11 to 26)
TDME_TX_CONFIG	1	00H - 3FH	IB – Power Amplifier Current Setting. See Table 4.1.
	2	00H - 07H	PB – Power Amplifier Frequency Trim Setting. See Table 4.1.
	4	00H 01H	Transmit Normal Mode (Packets) Transmit Continuous Mode
TDME_ED_CONFIG	1	00H - FFH	Energy Detect (ED) Threshold
TDME_LO_1_CONFIG	1	00H 01H	LO Tx Mode LO Rx Mode
	2	0BH - 1AH	Channel Number (11 to 26)
TDME_LO_2_CONFIG	1	00H - 30H	LO Tuning DAC Value (0 to 48)

Table 5.14: TDME Test Attribute Values

6 Typical Application Circuit

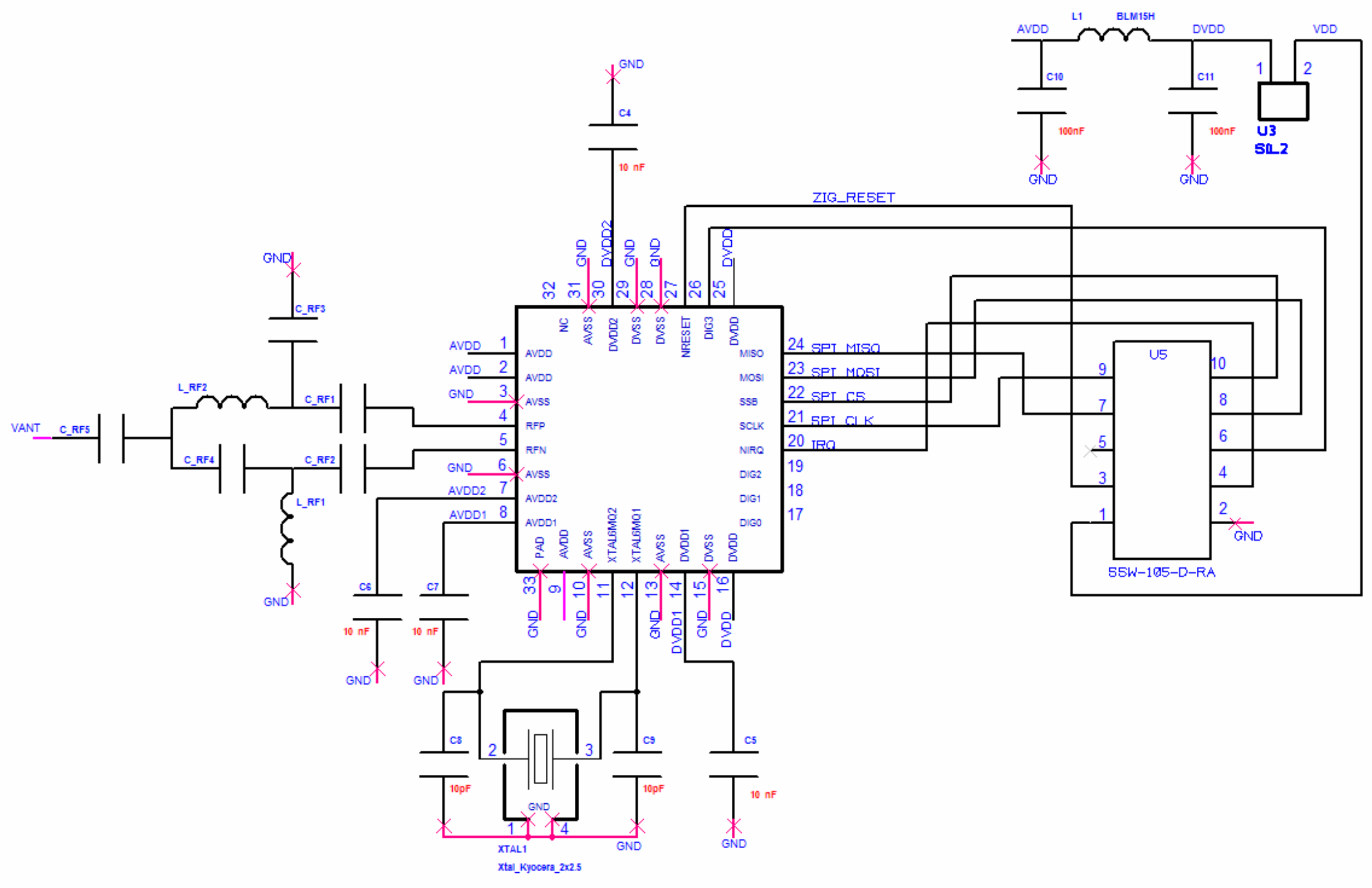

Figure 6.1: Typical Application Circuit Schematics with passive Balun

Component	Size	Ground domain	Value	Part Number
RF capacitor, C_RF1, C_RF2	0402	RF	27pF	201R07S270JV4S
Passive Balun C_RF3, C_RF4	0402	RF	TBD	TBD
Passive Balun L_RF1, L_RF2		RF	TBD	TBD
RF capacitor, C_RF5	402	RF	TBD	TBD
C4, C5	0402	Analog	10nF	any
C6	0402	RF	10nF	any
C7	0402	RF	10nF	any
C10	0402	Analog	100nF	any
C11	0402	Digital	100nF	any
L1	0402	Digital->Analog	<2Ω	Murata BLM15H series
C8, C9	0402	PLL	10pF	any
Crystal	2.5mm x 2mm	PLL	16.0000 MHz	AVX/Kyocera: CX252016000D0FZZC1 Epson: FA-20H 16.0000MF10Z

Table 6.1: Recommended Components

7 Mechanical Details

7.1 Package Drawing QFN32 5x5 mm

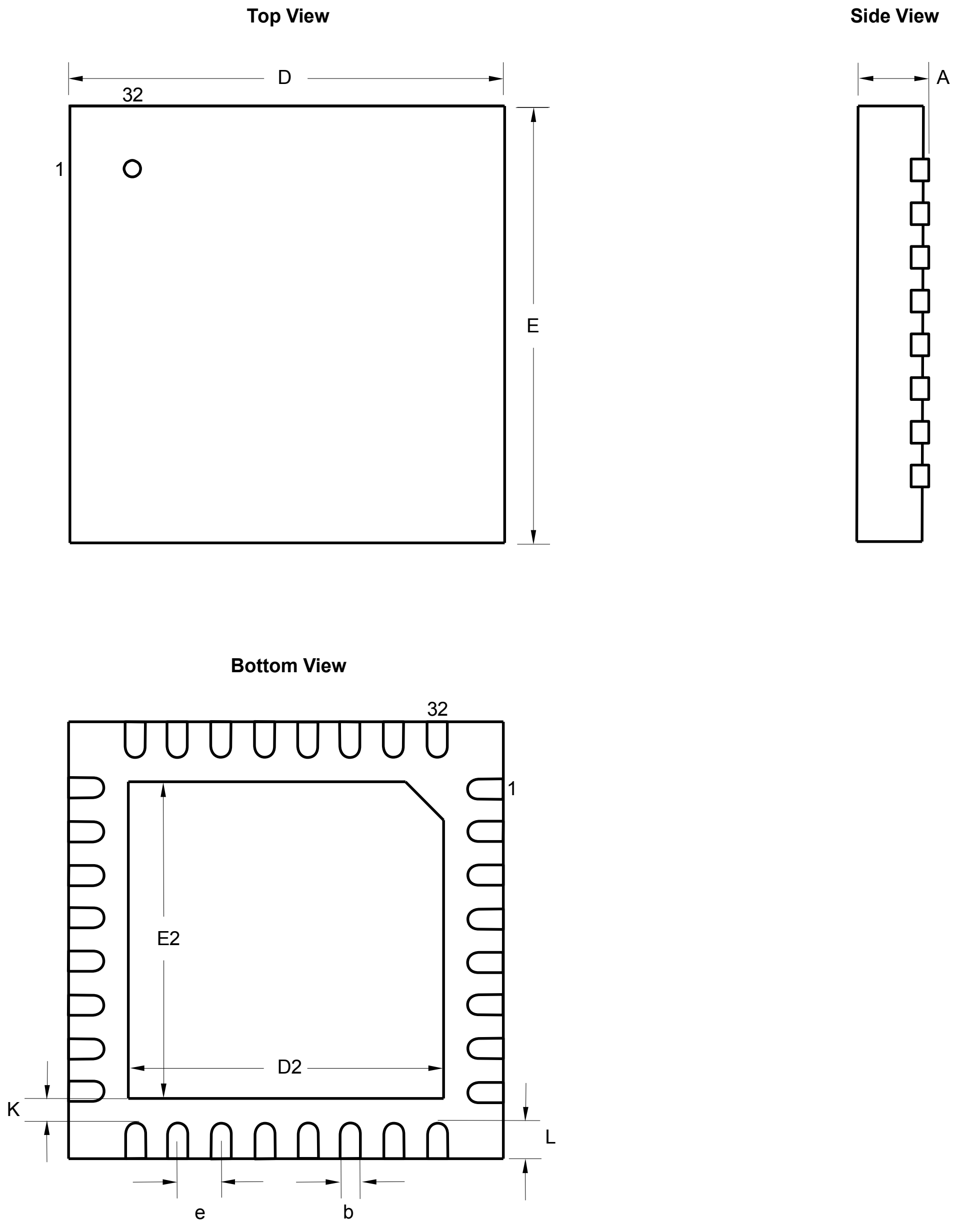

Figure 7.1: QFN32 Package Drawing

Symbol	MIN	NOM	MAX
D	4.95	5.00	5.05
E	4.95	5.00	5.05
A	0.80	0.85	0.90
D2	3.60	3.70	3.80
E2	3.60	3.70	3.80
e	0.50 BSC.		
b	0.20	0.25	0.30
L	0.30	0.40	0.50
K	0.25 REF.		

Table 7.1: QFN32 5x5mm Package Dimensions [mm]

7.2 Recommended Land Pattern

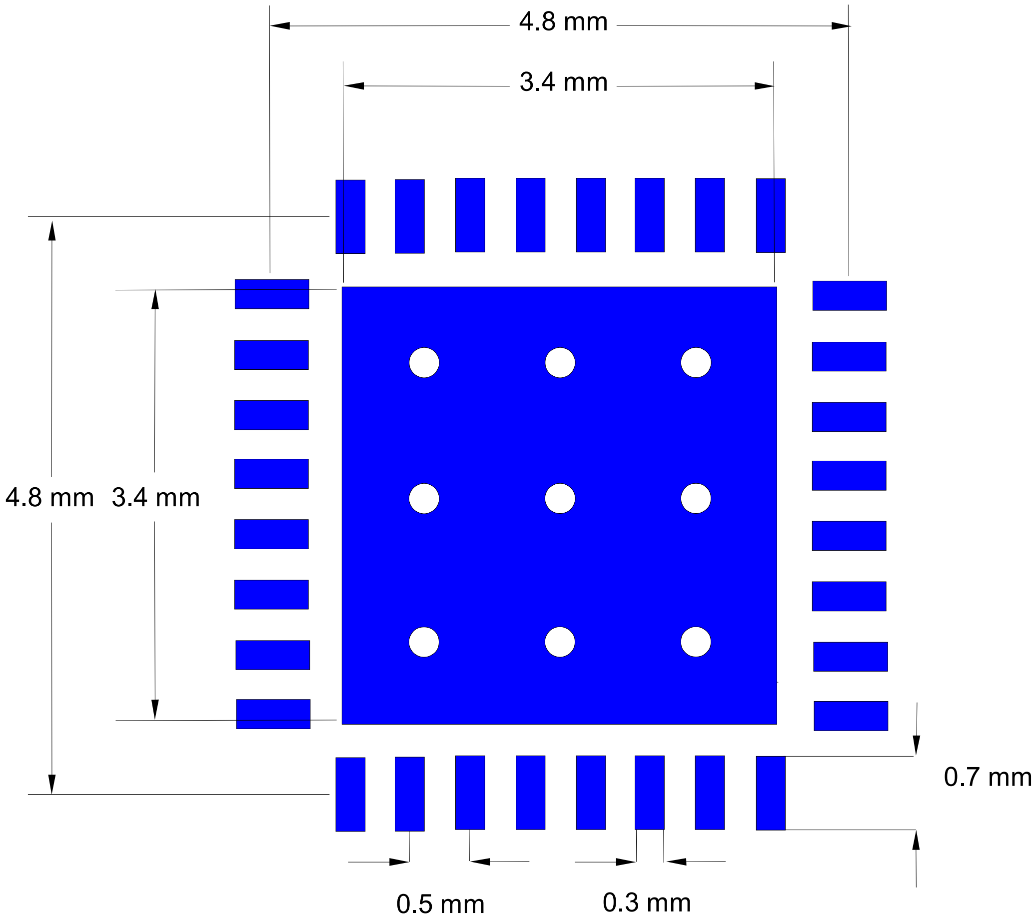

Figure 7.2: Recommended Land Pattern for QFN32 Package

To ensure a low-impedance ground connection from the ground pad of the CA-8210 through to the bottom of the PCB, the footprint land pattern used for the QFN32 device should have nine plated vias, each with a drill dimension of 0.3-0.33mm.

8 References

[1] IEEE Std 802.15.4™-2006: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)

[2] IEEE Std 802.15.4™-2003: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)

9 Revision History

Revision	Date	Status	Comments
1.0	18. Jan. 2016	Preliminary	Initial Release
1.1	05. May 2016		Minor Corrections
1.2	12. Oct 2016		Revised Capacitor Values for Regulators
1.3	13. Jan 2017		Added US Patent Number

10 Glossary of Terms and Abbreviations

AMI	(Advanced Metering Infrastructure)
AMR	(Automatic Meter Reading)
API	(Application Programming Interface)
ASIC	(Application Specific Integrated Circuit)
BER	(Bit Error Rate) The number of bit errors per unit time.
BOM	(Bill Of Materials)
BSC	(BaSiC dimension) Theoretically exact value shown without tolerances.
CBC-MAC	(Cipher Block Chaining - Message Authentication Code) A encryption method for constructing a message authentication code from a block cipher.
CCA	(Clear Channel Assessment)
CCM	(Counter with CBC-MAC) see CBC-MAC
CCM*	(Counter with CBC-MAC with additional capabilities) see CBC-MAC
CMD	(CoMmanD)
CPU	(Central Processing Unit)
CRC	(Cyclic Redundancy Check)
CS	(Carrier Sense)
CTS	(Clear To Send)
CSMA-CA	(Carrier Sense Multiple Access-Collision Avoidance) A media access control (MAC) protocol, which requires each node to verify the absence of other traffic using CCA before transmitting.
CMOS	(Complementary Metal Oxide Semiconductor) A major class of integrated circuit.
DMA	(Direct Memory Access)
DSSS	(Direct-Sequence Spread Spectrum) A Spread Spectrum modulation method in which the signal is modulated according to a bit sequence known as a Pseudo Noise (PN) code.
ED	(Energy Detect)
ESD	(Electro Static Discharge)
EVBME	(EValuation Board Management Entity).
EVM	(Error Vector Magnitude) A measure used to quantify the modulation accuracy of a digital radio transmitter
GPIO	(General Purpose Input/Output)
HWME	(HardWare Management Entity)
I2C	A two-wire serial bus interface standard, invented by Philips Semiconductor.
IC	(Integrated Circuit) A set of electronic circuits integrated onto a piece of semiconductor material.
IEEE	(Institute of Electrical and Electronics Engineers) A non-profit, professional organization for the advancement of technology related to electricity.
LNA	(Low Noise Amplifier)
LO	(Local Oscillator)
LQI	(Link Quality Indicator)
LSB	(Least Significant Bit)
MAC	(Medium Access Control)
MCPS	(Media access control Common Part Sublayer)
MCU	(MicroController Unit)
MISO	(Master In, Slave Out)

MLME	(Media access control subLayer Management Entity)
MOSI	(Master Out, Slave In)
MSB	(Most Significant Bit)
MSL	(Moisture Sensitivity Level)
NACK	(Negative ACKnowledgement)
PA	(Power Amplifier)
PAN	(Personal Area Network)
PIB	(PAN Information Base)
PER	(Packet Error Rate) The number of packet errors per unit time.
PHY	(PHYsical Layer)
PL	(Packet Length)
PLL	(Phase-Locked Loop)
PSDU	(Physical layer Service Data Unit)
REF	(REFerence dimension) Usually without tolerance, for information purposes only.
RF	(Radio Frequency)
RFID	(Radio Frequency IDentification)
PoR	(Power-on-Reset)
PSD	(Power Spectral Density)
QFN	(Quad Flat No-leads) A type of package for semiconductor devices.
RAM	(Random Access Memory)
RC	(Resistive-Capacitive)
RF	(Radio-frequency)
RMS	(Root Mean Squared)
RoHS	(Restriction of Hazardous Substances)
RSSI	(Receive Signal Strength Indicator)
Rx	Receive/Receiver
SAP	(Service Access Point)
SFD	(Start of Frame Delimiter)
SPI	(Serial Peripheral Interface) A four-wire full-duplex serial bus interface standard. Initially developed by Motorola, SPI is now a de facto standard.
Spread Spectrum	A modulation method that intentionally varies the frequency of the transmitted signal
TDME	(Test & Debug Management Entity)
Transceiver	A device that has both a transmitter and a receiver combined in a single housing
Tx	Transmit/Transmitter
VCO	(Voltage Controlled Oscillator)
WLAN	(Wireless Local Area Network) A network that links two or more devices using a wireless communications protocol.
XOSC	Crystal Oscillator

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