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AN IEEE 802.15.4 COMPLIANT AND ZIGBEE-READY 2.4 GHz RF TRANSCEIVER

With numerous lucrative applications envisaged, the ZigBee Alliance is developing a standard-based wireless network platform, optimized for wireless monitoring and control applications, ensuring interoperability between products using the same application profile. The IEEE 802.15.4 standard, ratified in May 2003, specifies the physical (PHY) and medium access control (MAC) layers, while the ZigBee Alliance defines the network, security and application profile layers for an IEEE 802.15.4-based system. The 2.4 GHz PHY defined by IEEE 802.15.4 is highly attractive, as this unlicensed Industrial Scientific Medical (ISM) band is available worldwide for license exempt use.

The typical applications targeted by IEEE 802.15.4/ZigBee are home and building automation, industrial monitoring and control, and wireless sensor networks. All of these applications need reliable and secure wireless communication links with low data rates, low complexity and low costs. Furthermore, low power consumption of the radio devices and the communication protocol is of the utmost importance, as many systems are battery operated.

Designed specifically to meet these requirements, Chipcon's CC2420 is the first commercially available 2.4 GHz RF transceiver that is compliant with the IEEE 802.15.4 standard and ready to be used in ZigBee products. In fact, it surpasses the IEEE 802.15.4 standard in terms of selectivity and sensitivity performance, and ensures a long communication range as well as effective and reliable communication.

In addition, the RF transceiver supports packet handling, data buffering, burst transmissions, clear channel assessment (CCA), link quality indication (LQI) and timing information. Furthermore, it offers excellent security of the wireless communication links by providing extensive hardware support for AES-128-based data encryption and data authentication. This extensive hardware support drastically reduces the microcontroller workload and makes it possible to interface with a low cost microcontroller.

RF TRANSCEIVER OVERVIEW

A simplified block diagram of the CC2420 is shown in ***Figure 1***. In transmit mode data is fed to a 128 byte transmit FIFO via a four wire serial peripheral interface (SPI), while

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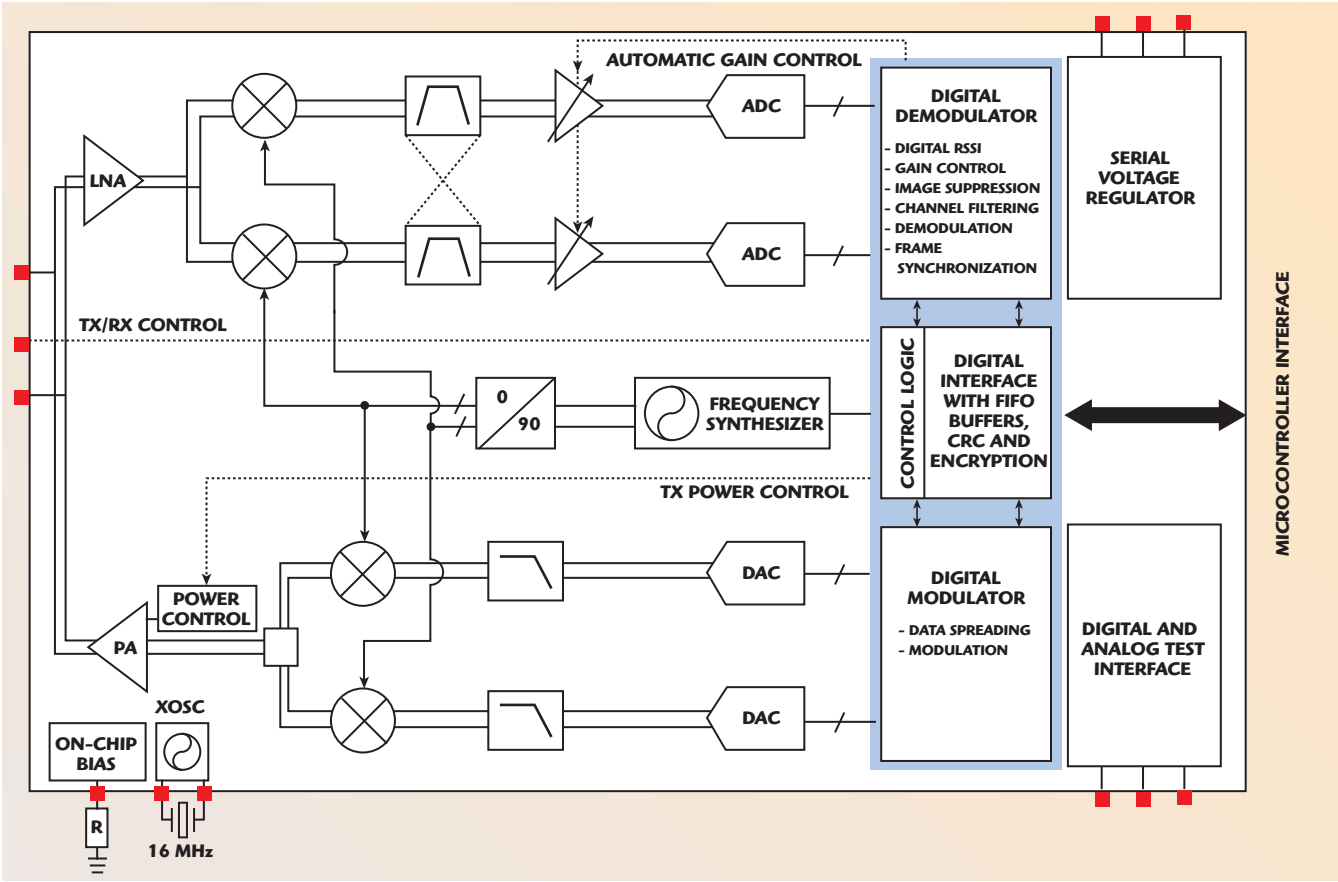

▲ *Fig. 1 The CC2420 transceiver's block diagram.*

TABLE I

THE CC2420 TRANSCEIVER'S MAIN PERFORMANCE PARAMETERS

Specifications (1.8 V, 25 °C)	*Minimum*	*Typical*	*Maximum*
General:			
frequency range (MHz)	2400		2483.5
data rate (kbps)		250	
operating voltage (V)	2.1		3.6
operating temperature (°C)	–40		85
Rx mode:			
receiver sensitivity (dBm)		–94	
adjacent channel rejection, +5 MHz (dB)		47	
adjacent channel rejection, –5 MHz (dB)		38	
alternate channel rejection, +10 MHz (dB)		57	
alternate channel rejection, –10 MHz (dB)		53	
Power supply:			
current consumption, Rx (mA)		19.7	
current consumption, Tx, –10 dBm (mA)		11	
current consumption, Tx, –5 dBm (mA)		14	
current consumption, Tx, 0 dBm (mA)		17.4	
current consumption, power down (µA)			1

the generation of preamble, start of frame delimiter (SFD) and frame check sequence (FCS) is performed automatically.

The modulation format is defined by the IEEE 802.15.4 standard — the four least significant bits of a data byte are mapped to one symbol and the four most significant bits are mapped to the next symbol. There are 16 different symbols, each consisting of 32 chip pseudo-random sequences. This effectively implements a direct sequence spread spectrum (DSSS) scheme with a raw data rate of 250 kbps and a chip rate of 2 Mchips/s. Each chip is half-sine shaped and fed to a digital offset-QPSK modulator.

The resulting I/Q baseband signal is converted to the analog domain by the digital-to-analog converters (DAC). The outputs from the DACs are low pass filtered and directly up-converted to RF by quadrature mixers. Due to the modulation used, the resulting signal has a constant envelope. Finally, the RF signal is amplified by the power amplifier and fed to the antenna. A summary of the main performance parameters of the RF transceiver is shown in ***Table 1***.

The receiver is based on a low IF architecture. The received RF signal is amplified by the low noise amplifier and down-converted in quadrature to a 2 MHz intermediate frequency. Here the signal is filtered and amplified, and then digitized by analog-to-digital converters. Automatic gain control, channel filtering, symbol correlation (with inherent de-spreading of the DSSS signal) and byte synchronization is performed digitally. The

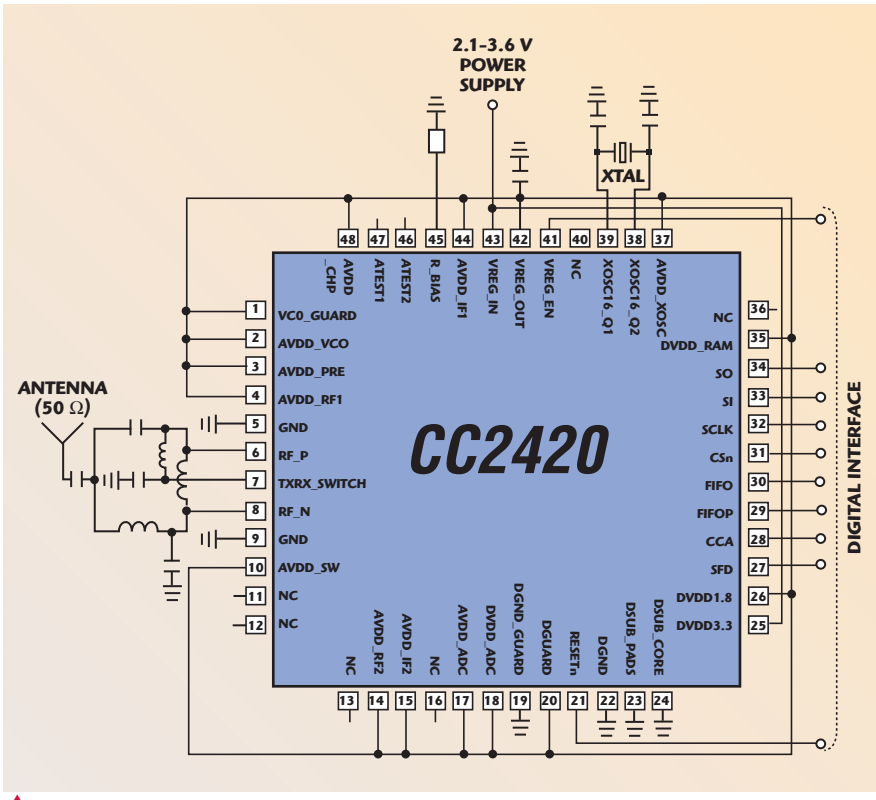

Fig. 2 A typical application circuit.

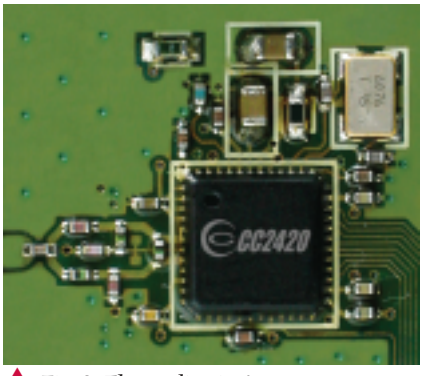

Fig. 3 The application's corresponding PCB.

receive FIFO can contain up to 128 bytes of data, accessible through the SPI; cyclic redundancy check (CRC) of the received data is performed automatically.

Furthermore, the external RF network consists of a few low cost capacitors and inductors. This network is used for input/output matching, conversion from differential to single-ended output as well as filtering. There is no need for an external RF switch as the CC2420 includes on-chip transmit/receive switch circuitry.

The frequency synthesizer is fully integrated and includes an on-chip LC-VCO operating in the 4.800 to 4.966 GHz frequency range. A 90° phase splitter is placed in the local oscillator path for generation of the I and Q signals used by the down- and up-conversion mixers.

Also significant is that the CC2420 is implemented in a 0.18 µm CMOS technology, which enables the integration of all the digital hardware features together with the RF/analog parts on a small chip area.

APPLICATION CIRCUIT

Figure 2 shows the application circuit schematic of the CC2420 transceiver, while the corresponding PCB is shown in ***Figure 3***. The only external components required are a crystal and a few passive components, and the RF transceiver is offered in a 7 by 7 mm QFN 48 package. When used in a typical system the device will interface to a microcontroller. Configuration of the chip as well as data communication is done via the SPI interface.

Only one external supply voltage of 2.1 to 3.6 V is necessary as the device has an on-chip regulator for generation of the 1.8 V core voltage. A battery monitor, accessible through the SPI interface, is included and can be used to check the status of the supply.

DEVELOPMENT TOOLS

The CC2420 is supported by comprehensive development tools for efficient and easy evaluation of the chip's performance, and designers can quickly develop their own RF application based on the reference designs. The company also provides customers with IEEE 802.15.4 MAC layer software that has been developed for an eight-bit microcontroller and is portable to other microcontroller platforms.

The most important frequency regulations for operation of RF equipment in the 2.400 to 2.4835 GHz band are ETSI EN 300 440, ETSI EN 300 328, FCC CFR Part 15 and ARIB STD-T66. The CC2420's reference designs are compliant with these standards.

CONCLUSION

The CC2420 device is the industry's first single-chip 2.4 GHz RF transceiver compliant with the IEEE 802.15.4 standard and ready to be used in ZigBee products. Home and building automation, industrial monitoring and control, and wireless sensor networks are the main applications targeted by IEEE 802.15.4/ZigBee. The most important requirement of such systems is to make secure and reliable wireless communication links with low power consumption and low costs. Due to its outstanding RF performance and all digital functions that reduce the burden of the microcontroller, the CC2420 easily fits these applications.

USEFUL RELATED WEB SITES

The following Web sites contain useful information on the relevant standards: www.ieee802.org/15/pub/TG4.html and www.zigbee.com. The IEEE 802.15.4 standard may be downloaded free on the Web at http://standards.ieee.org/getieee802/802.15.html.

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