CC2430EM APPLICATION FOR MOBILE ROBOT

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Bachelor in Electrical Engineering (Control, Instrumentation and Automation)

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"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelors In Electrical Engineering (Control, Instrumentation and Automation)

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Date : ..... 13/5/09 .....

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This Report Is Submitted In Partial Fulfillment Of Requirements For The Degree of Bachelor In Electrical Engineering (Control, Instrumentation and Automation)

Faculty of Electrical Engineering
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"I declare that this report entitle "CC2430EM APPLICATION TO MOBILE ROBOT" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree."

Signature : .....

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ABSTRAK

Dengan permintaan yang semakin meningkat untuk perhubungan tanpa wayar antara peralatan, banyak aplikasi kini menggunakan Zigbee, teknologi tanpa wayar berkuasa rendah. Zigbee direka khas untuk transmisi paket kecil dengan kelajuan maksima 250Kbps, lebih rendah berbanding dengan pencabar utamanya Bluetooth yang mempunyai kelajuan maksima 1 Mbps. Ini membuat Zigbee sesuai untuk aplikasi seperti kawalan industri, system penggera kebakaran dan pencuri, automasi bangunan, automasi rumah dan lain-lain lagi. Texas Instruments telah merekacipta sebuah system dalam cip menggunakan Zigbee, iaitu CC2430 untuk mempamerkan ciri-ciri istimewa Zigbee di dalam pasaran hari ini. Laporan ini akan mengkaji bagaimana CC2430 berfungsi dan bagaimana mengawalnya dengan memberi contoh aplikasi untuk mempamerkan cirri-ciri istimewanya.

ABSTRACT

With the increasing demand of wireless communications between devices, many applications are now turning to the low-powered Zigbee wireless technology. Zigbee was designed for small packet data transmission, with only a maximum speed of 250 Kbps compared to its main rival, Bluetooth of 1 Mbps. This makes Zigbee suitable for applications such as industrial control, embedded sensing, medical data collection, smoke and intruder warning, building automation, home automation, etc. A true system-on-chip solution for Zigbee, called the CC2430 was developed by Texas Instruments to deliver the most powerful elements for ZigBee development in the market today. In this report, we will delve into the CC2430 and study its functionality, providing example application and source codes to display the unit's core features.

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LISTS OF SYMBOLS & TERMS

A/D (ADC)	Analog to Digital Converter
BCD	Binary Coded Decimal
BER	Bit Error Rate
CBC	Chiper Block Chaining
CCA	Clear Channel Assessment
CMOS	Complementary Metal Oxide Semiconductor
CPU	Central Processing Unit
CW	Continues Wave
DAC	Digital to Analog Converter
DC	Direct Current
DMA	Direct Memory Access
DNL	Differential Nonlineraity
EM	Evaluation Module
ESD	Electro Static Discharge
HAL	Hardware Abstraction Layer
HF	High Frequency
I/O	Input/ Output
I/Q	In-phase/ Quadrature-phase
IEEE	Institute of Electrical and Electronics Engineers
IF	Intermediate Frequency
KB	1024 bytes
kbps	kilo bits per second
LNA	Low-Noise Amplifier
LSB	Least Significant Byte
MAC	Medium Access Control
MAC	Message Authentication Code
MCU	Microcontroller Unit
MSB	Most Significant Byte
PCB	Printed Circuit Board

PER	Packet Error Rate
PWM	Pulse Width Modulator
RAM	Random Access Memory
RF	Radio Frequency
SFR	Special Function Register
SPI	Serial Peripheral Interface
SRAM	Static Random Access Memory
ST	Sleep Timer
WDT	Watchdog Timer

CHAPTER 1

INTRODUCTION

1.1 Project Overview

In this project, a study is conducted on using a wireless embedded system, in particular the CC 2430 System-On-Chip Solution which uses Zigbee by Texas Instruments. CC2430 is a true System-on-Chip (SoC) solution specifically tailored for IEEE 802.15.4 and Zigbee applications with integrated 8051 microcontroller and memory flash.

1.2 Problem Statement

In order to meet the increasing demand of low powered wireless systems on chip solutions, many leading companies have rolled out their own line of solutions. One example is the CC2430 System-on-Chip Solution using Zigbee technology developed by Texas Instruments. Although being a complete system-on-chip solution, these systems maybe complex to user who wants to use it for simpler applications. Users must spend a lot of time studying the basics of microcontrollers and programming in either C or assembly language. Therefore, I propose to research on the CC2430 by Texas Instruments and compile a detailed but simple to understand report for users who wishes to spent less time on studying the unit and apply this knowledge to develop a simple mobile robot.

1.3 Objectives

The objectives of this project are:

- To study and understand the functions on CC2430.
- To demonstrate the function of CC2430.
- To build a simple mobile robot using CC2430 as its controller

1.4 Scope

Based on preliminary research, only one programming language will be covered in this project, which is either C language or assembly languages.

1.5 Literature Review

The demand for wireless embedded systems from both home and industry sectors are is only at its beginning. In the next few years, the market will be filled with wireless products, making engineers a highly needed resource. Many researches have been conducted in applying wireless embedded systems to a vast array of applications.

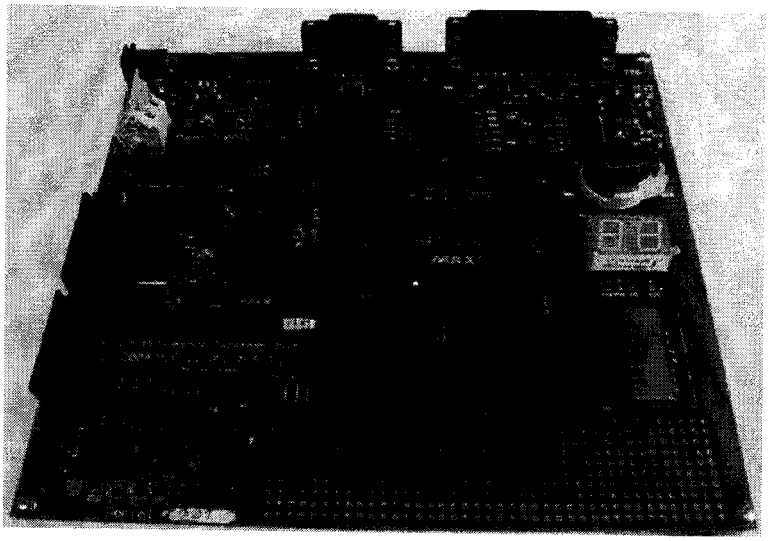

Figure 1.0: McGumps McGill University Microprocessor Systems Board User Manual

Work by Z. Zilic and his team for his department in McGill University, Montreal, Quebec implies that students need exposure to this technology, seeing that this field is growing [5]. He and his team designed and developed a laboratory kit to help train

future engineers based on their earlier McGill University Microprocessor System kit called *McGumps* which is based on Texas Instruments MSP430 microcontroller. The outcome of this lab setup is that students get exposure to physical design and embedded software development for wireless embedded systems.

The applications of wireless embedded systems are wide, ranging from home application to industrial applications. One such application is wireless sensor network (WSN). Due to their remote environment monitoring capability, WSN has become an increasing important technology, but has its drawback. Most WSN consist of large number short lived and unreliable sensors. Jang-Ping Sheu and colleagues developed a smart robot that can detect and replace weak nodes in a wireless sensor network [3]. The smart robot uses Texas Instruments/Chipcon's CC1000 single chip RF transceiver for wireless communication. The robot detects the weak node and then determines a path base on packet sending between nodes.

From these articles, it can be concluded that there is much more that can be done with wireless embedded system, such as remote control mobile robots, but one must be well equipped with the knowledge of using this powerful technology in the first place. Texas Instruments/Chipcon's products are used in both articles, suggesting that their product is highly capable to satisfy the need for wireless embedded system.

1.6 Background Theory

CC2430 is integrated with others electronic system into a single integrated circuit. Therefore, all the main functions of the CC2430 will be studies and discuss in this chapter. Besides, there are two available programs that can develop the software for the CC2430, the IAR Embedded WorkBench for 8051 from IAR Systems and SmartRF Studio for Texas Instruments also will be discussed in this chapter.

1.6.1 CC2430

The CC2430 is the first single chip IEEE 802.15.4 compliant and ZigBee TM SoC (System on Chip) RF Transceiver with integrated 8051 microcontroller and 32kB, 64kB or 128kB memory flash.

The CC2430 is highly suited for systems where ultra low power consumption is required. This is ensured by various operating modes. Short transition times between operating modes further ensure low power consumption.

There are many specifications for CC2430. The CC2430 has a excellent RF performance, including receiver sensitivity and receiver robustness (selectivity and blocking). It is very fast transition time from low power modes to active modes enables ultra low average power consumption in low duty cycle system.

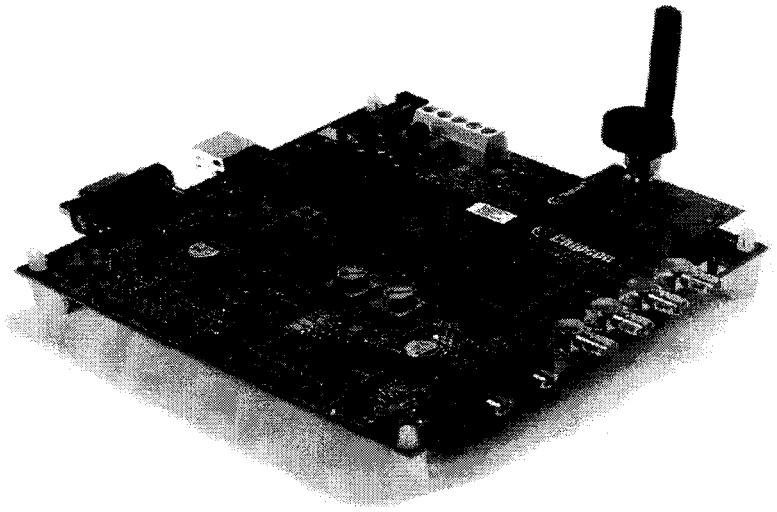

Figure 1.1: SmartRF04EB with CC2430

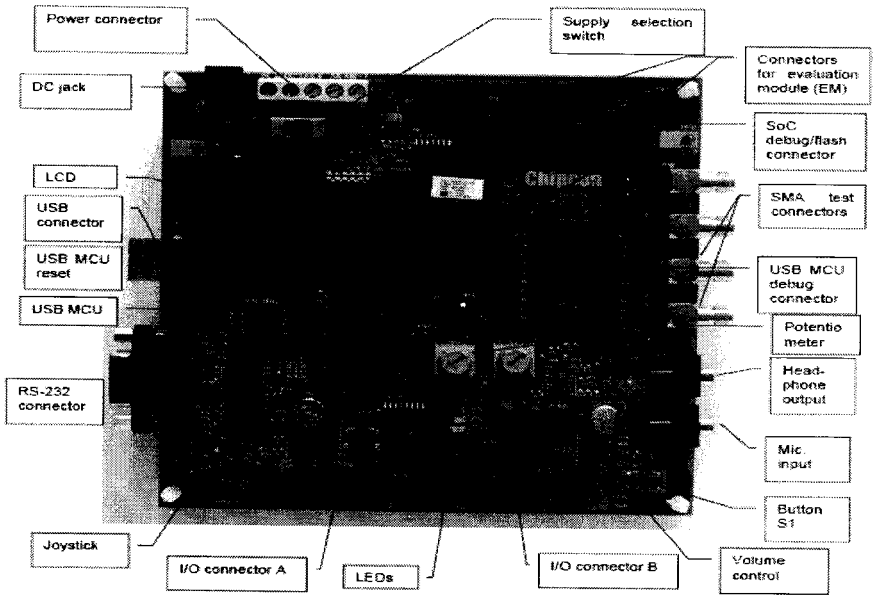

Figure 1.2: SmartRF04EB overview

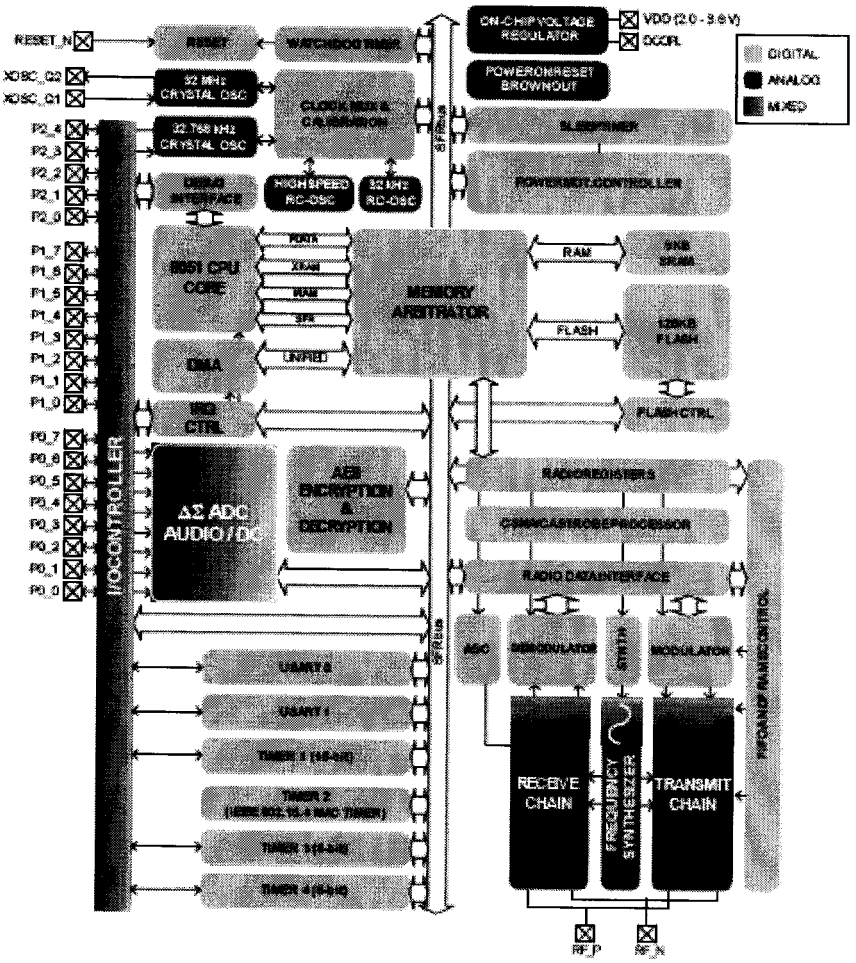

Figure 1.3: CC2430 overview

The CC2430 is playing important role in the current stage and in future time. It has many applications. It can be used as 2.4 GHz IEEE 802.15.4 systems, ZigBee systems, Home/building automation, Industrial Control and Monitoring, Low power wireless sensor networks, PC peripherals, Set-top boxes and remote controls and so on.

1.6.2 ZigBee system

ZigBee is the name of a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4-2006 standard for wireless personal area networks (WPANs), such as wireless headphones connecting with cell phones via short-range radio. The technology is intended to be simpler and cheaper than other WPANs, such as Bluetooth. ZigBee is targeted at radio-frequency (RF) applications that require a low data rate, long battery life, and secure networking.

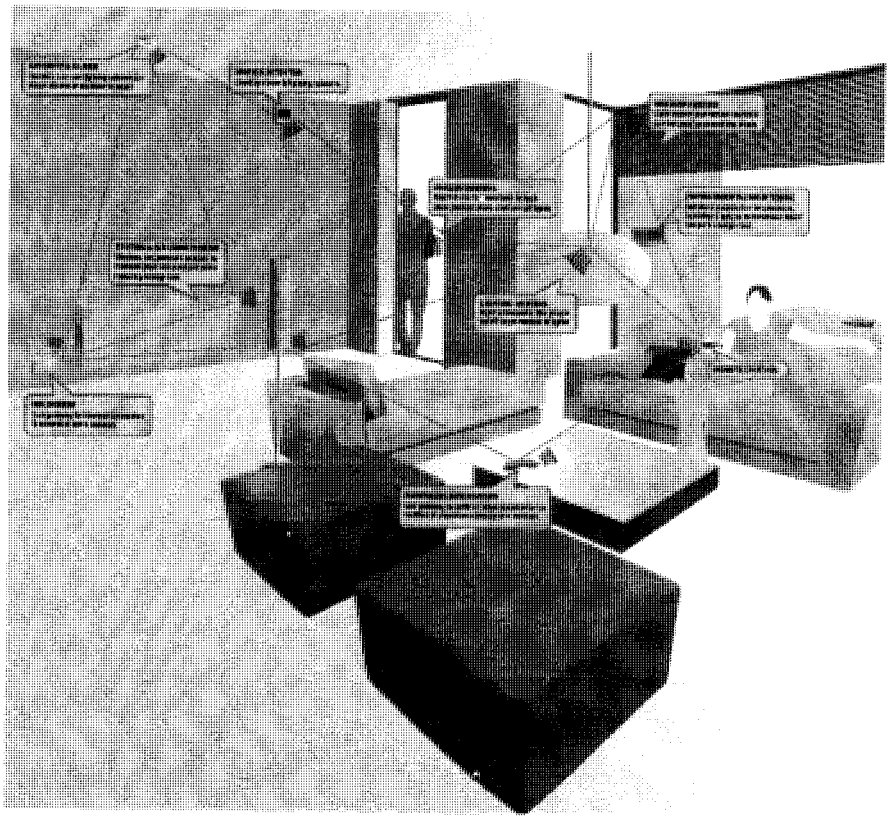

Figure 1.4: ZigBee wireless network overview

ZigBee's current focus is to define a general-purpose, inexpensive, self-organizing mesh network that can be used for industrial control, embedded sensing, medical data collection, smoke and intruder warning, building automation, home automation, etc. The resulting network will use very small amounts of power so individual devices might run for a year or two using the originally installed battery.

Typical application areas include

- **Home Entertainment and Control** — Smart lighting, advanced temperature control, safety and security, movies and music
- **Home Awareness** — Water sensors, power sensors, smoke and fire detectors, smart appliances and access sensors
- **Mobile Services** — m-payment, m-monitoring and control, m-security and access control, m-healthcare and tele-assist
- **Commercial Building** — Energy monitoring, HVAC, lighting, access control
- **Industrial Plant** — Process control, asset management, environmental management, energy management, industrial device control

1.6.3 Radio Frequency (RF)

Radio frequency (RF) also is a main function of CC2430. Radio frequency (RF) is a frequency or rate of oscillation within the range of about 3 Hz to 300 GHz. This range corresponds to frequency of alternating current electrical signals used to produce and detect radio waves. Most of this range is beyond the vibration rate that most mechanical systems can respond to; RF usually refers to oscillations in electrical circuits or electromagnetic radiation.

Electrical currents that oscillate at RF have special properties not shared by direct current signals. The first special property is the ease with

which it can ionize air to create a conductive path through air. This property is exploited by 'high frequency' units used in electric arc welding. Another special property is an electromagnetic force that drives the RF current to the surface of conductors, known as the skin effect. Another property is the ability to appear to flow through paths that contain insulating material, like the dielectric insulator of a capacitor. The degree of effect of these properties depends on the frequency of the signals.

For the wireless networking, the name of the frequency is called super high frequency (SHF). The length of the frequency is between 3Hz to 30 GHz and the wavelength is 1-10cm.

1.6.4 8051 MCU

CC2430 combine with an industry-standard enhanced 8051 microcontroller unit (MCU). The prime use of a microcontroller is to control the operation of a machine using a fixed program that is stored in ROM and that does not change over the lifetime of the system.

The CC2430 includes an 8-bit CPU core which is an enhanced version of the industry standard 8051 core. The enhanced 8051 core uses the standard 8051 instruction set. Instruction execute faster than the standard 8051 due to the following:

- One clock per instruction cycle is use as opposed to 12 clocks per instruction cycle in the standard 8051.
- Wasted bus states are eliminated.

Since an instruction cycle is aligned with memory fetch when possible, most of the single byte instructions are performed in a single clock cycle. In addition to the speed improvement, the enhanced 8051 core also includes architectural enhancement:-

- A second data pointer.

- Extended 18-source interrupt unit

1.6.5 Memory

The 8051 CPU architecture has four different spaces. The 8051 has separate memory spaces for program memory and data memory. The four different memory spaces are:

- CODE. A read-only memory space for program memory, it memory space addresses 64kB.
- DATA. A read/write data memory space, which can be directly or indirectly, accessed by a single cycle CPU instruction, thus allowing fast access. This memory space addresses 256 bytes.
- XDATA. A read/write data memory space access to which usually requires 4-5 CPU instruction cycle, thus giving slow access. The memory space addresses 64kB.
- SFR. A read/ write register memory space which can be directly accessed by a single CPU instruction. The memory space consists of 128 bytes. For SFR registers whose address is visible by eight, each bit is also individually addressable.

1.6.6 Features Emphasized

1.6.6.1 High-Performance and Low-Power 8051-Compatible Microcontroller

- Optimized 8051 core, which typically gives 8x the performance of a standard 8051
- Dual data pointers
- In-circuit interactive debugging is supported for the IAR Embedded Workbench through a simple two-wire serial interface

1.6.6.2 Up to 128 KB Non-volatile Program Memory and 2 x 4 KB Data Memory

- 32/64/128 KB of non-volatile flash memory in-system programmable through a simple two-wire interface or by the 8051 core
- Worst-case flash memory endurance: 1000 write/erase cycles
- Programmable read and write lock of portions of Flash memory for software security
- 4096 bytes of internal SRAM with data retention in all power modes
- Additional 4096 bytes of internal SRAM with data retention in power modes 0 and 1

1.6.6.3 Hardware AES Encryption/Decryption

- AES supported in hardware coprocessor

1.6.6.4 Peripheral Features

- Powerful DMA Controller
- Power On Reset/Brown-Out Detection
- Eight channel ADC with configurable resolution
- Programmable watchdog timer
- Real time clock with 32.768 kHz crystal oscillator
- Four timers: one general 16-bit timer, two general 8-bit timers, one MAC timer
- Two programmable USARTs for master/slave SPI or UART operation
- 21 configurable general-purpose digital I/O-pins
- True random number generator

1.6.6.5 Low Power

- Four flexible power modes for reduced power consumption
- System can wake up on external interrupt or real-time counter event
- Low-power fully static CMOS design

- System clock source can be 16 MHz RC oscillator or 32 MHz crystal oscillator.
- The 32 MHz oscillator is used when radio is active
- Optional clock source for ultra-low power operation can be either low-power RC oscillator or an optional 32.768 kHz crystal oscillator

1.6.6.6 IEEE 802.15.4 MAC hardware support

- Automatic preamble generator
- Synchronization word insertion/detection
- CRC-16 computation and checking over the MAC payload
- Clear Channel Assessment
- Energy detection / digital RSSI
- Link Quality Indication
- CSMA/CA Coprocessor

1.6.6.7 Integrated 2.4GHz DSSS Digital Radio

- 2.4 GHz IEEE 802.15.4 compliant RF transceiver (based on industry leading CC2420 radio core).
- Excellent receiver sensitivity and robustness to interferers
- 250 kbps data rate, 2 MChip/s chip rate
- Reference designs comply with worldwide radio frequency regulations covered by ETSI EN 300 328 and EN 300 440 class 2 (Europe), FCC CFR47 Part 15 (US) and ARIB STD-T66 (Japan). Transmit on 2480MHz under FCC is supported by duty-cycling, or by reducing output power.