Electrical and Computer Engineering Department

# "IEEE 802.15.4 Protocol Implementation And Measurement Of Current Consumption"

by

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# Presentation Overview

n Research Objective

n IEEE 802.15.4

n Hardware Description

n Software Development

n Setup for current measurement

n Comparison with existing results

n Limitation and future development

# Research Objective

To develop a test bench for IEEE802.15.4 wireless data transmission which can:

1. Transmit data using IEEE 802.15.4 protocol.
2. Measure the current consumption of the micro-controller and the RF chip.

# IEEE 802.15.4

## Why IEEE 802.15.4 ?

n  Designed for low-data-rate, low-power-consumption, and low-cost applications.

n  The complexity of Bluetooth makes it expensive and inappropriate for some simple applications requiring low cost and low power consumption.

n  Bluetooth also lacks flexibility in its topologies.

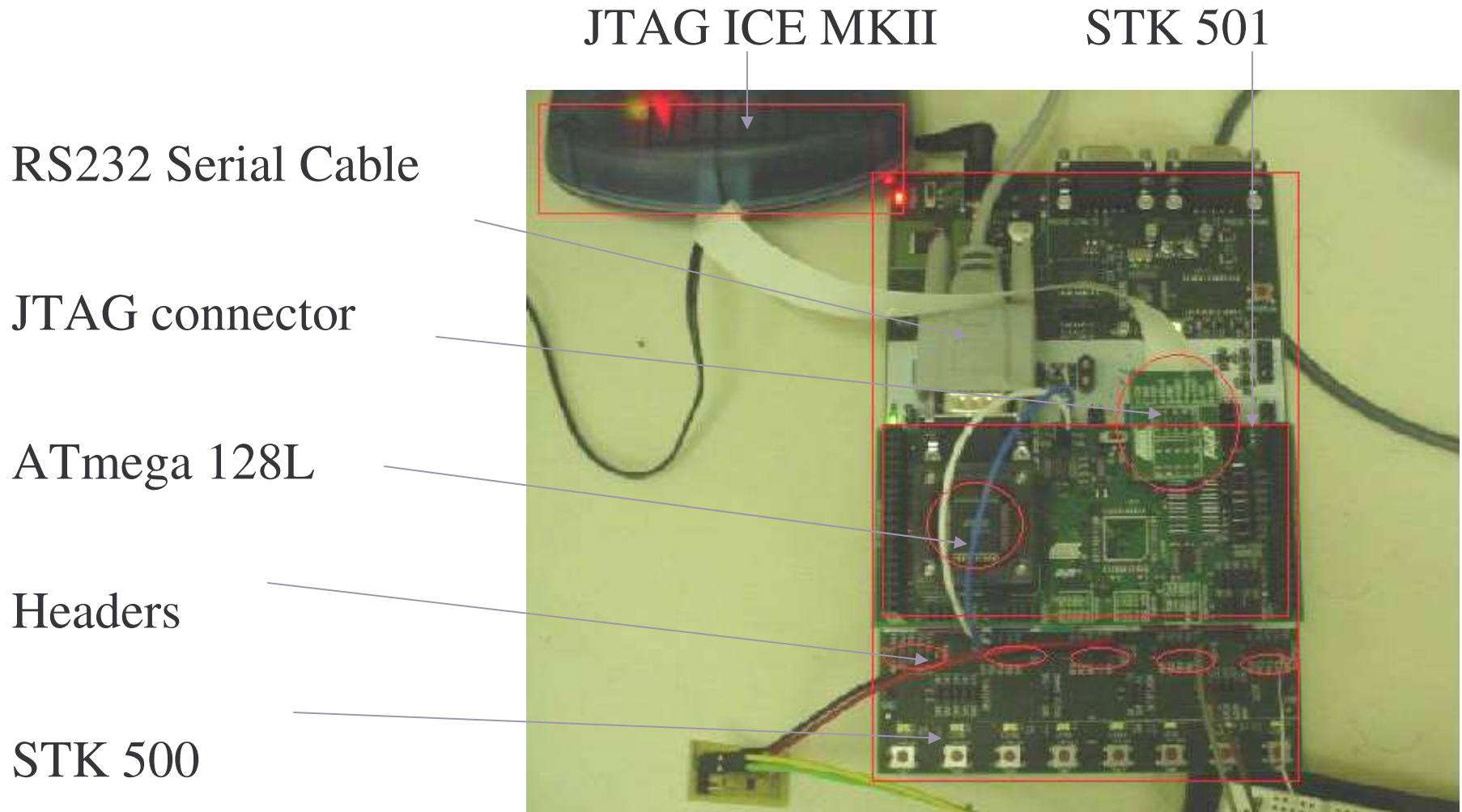n  Test bench to do an analysis recently drafted protocol.

# IEEE 802.15.4

n 16 channels in the 2450 MHz band, 10 channels in the 915 MHz band, and 1 channel in the 868 MHz band

n Over-the-air data rates of 250 kb/s, 40 kb/s, and 20 kb/s

n Star or peer-to-peer operation

n Allocation of guaranteed time slots (GTSs)

n Low power consumption

n Link quality indication (LQI)

# Hardware Used

- STK 500
- STK 501
- ATmega 128L
- Coulomb Counter - DS2740UB
- CC2420DBK

# STK500 and STK501

JTAG ICE MKII      STK 501

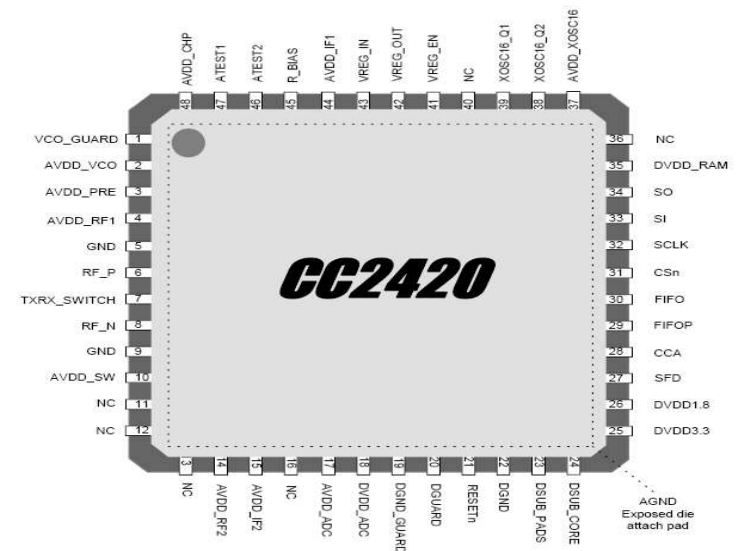RS232 Serial Cable

JTAG connector

ATmega 128L

Headers

STK 500

# Features for Atmel ATmega128L
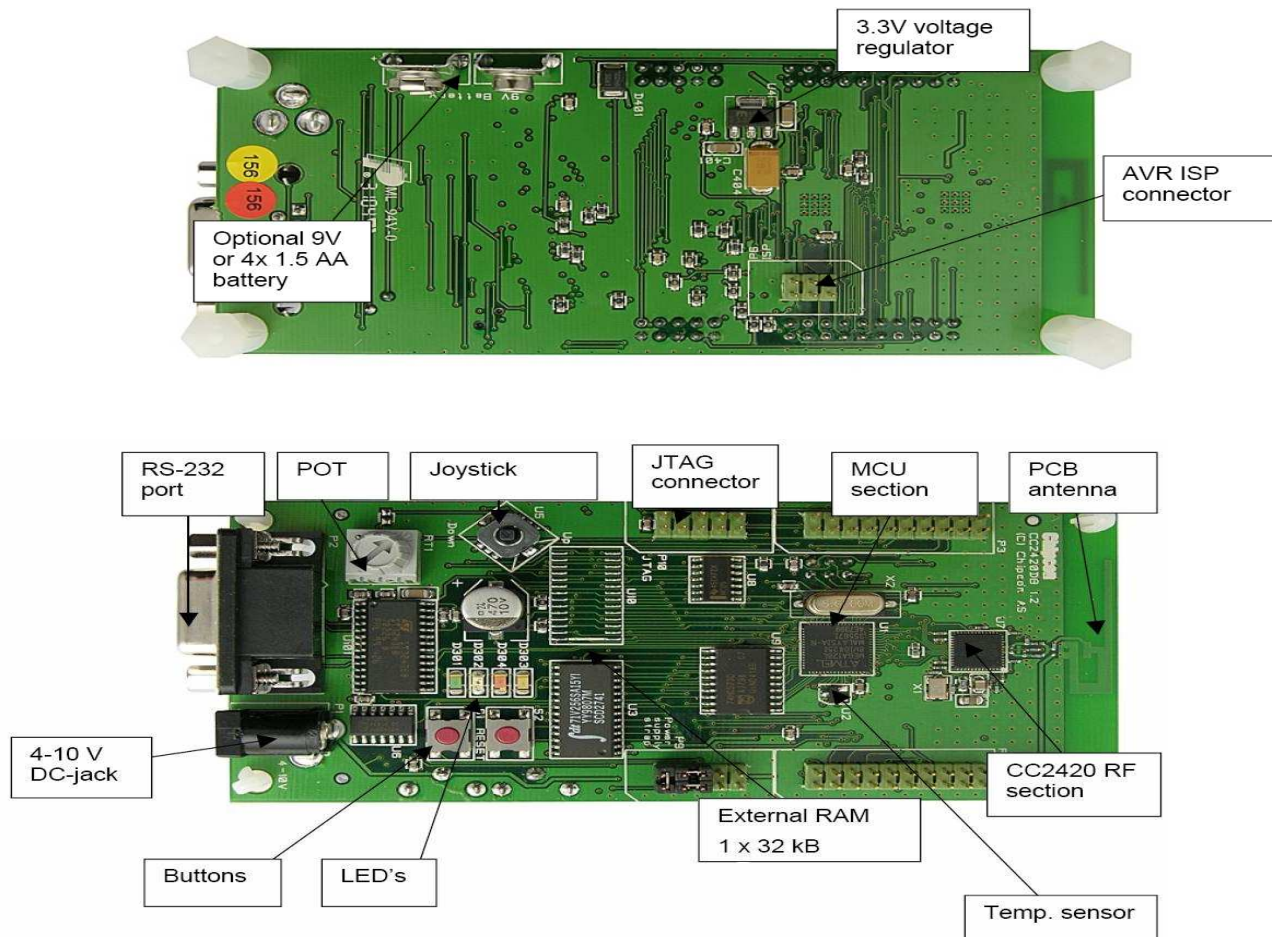
- High-performance, Low-power AVR 8-bit Microcontroller

- 128K Bytes of In-System reprogrammable flash, 4 Kbytes EEPROM and 4 Kbytes internal SRAM.

- SPI Interface

- JTAG Interface

- 8 bit ,16 bit Timer/Counters and Watchdog Timer

- ISP Interface

# Features of Chipcon CC2420

n   2.4 GHz IEEE 802.15.4 compliant RF transceiver with PHY and MAC support

n   Low current consumption (RX: 19.7 mA, TX: 17.4 mA)

n   Low supply voltage (2.1 – 3.6 V) with integrated voltage regulator

n   Low supply voltage (1.6 – 2.0 V) with external voltage regulator

n   Very few external components

n   128(RX) + 128(TX) byte data buffering

n   Digital RSSI / LQI support

# CC2420DBK Evaluation board



3.3V voltage regulator

Optional 9V or 4x 1.5 AA battery

AVR ISP connector

RS-232 port

POT

Joystick

JTAG connector

MCU section

PCB antenna

4-10 V DC-jack

Buttons

LED's

External RAM 1 x 32 kB

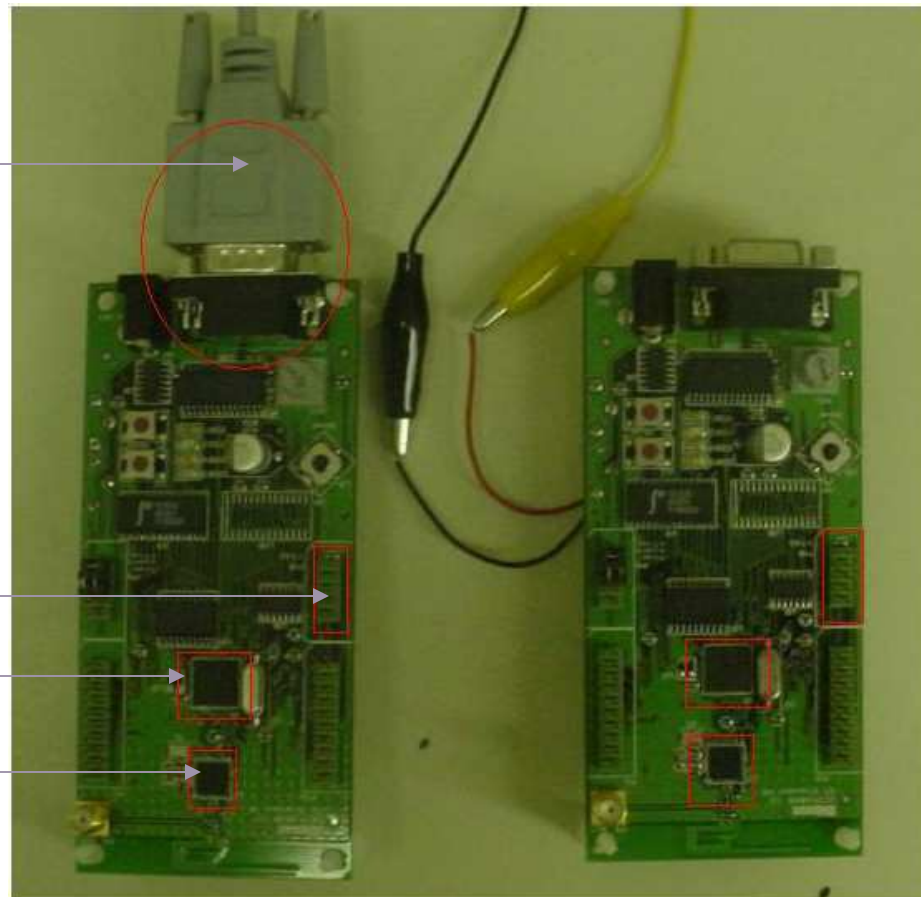CC2420 RF section

Temp. sensor

# CC2420DBK Evaluation board

RS-232 Serial Cable

JTAG

ATmega 128 L

CHIPCON CC2420

# Coulomb Counter - DS2740UB

n  15-Bit or 13-bit Bidirectional Current Measurement

n  Analog Input Filter (IS1,IS2)Extends Dynamic Range for Pulse-Load Applications

n  Current Accumulation Register

n  Dallas 1 Wire Interface

n  Low Power Consumption
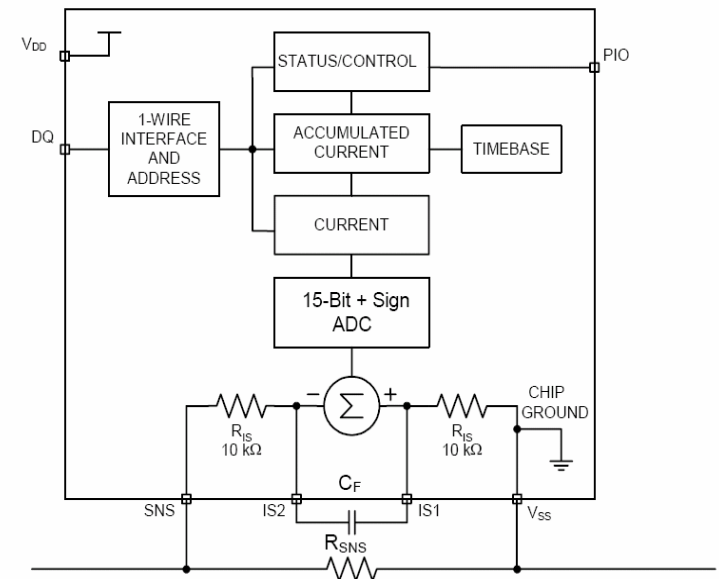
# Coulomb-Counter - Prototype

n    DS2740 Coulomb Counter evaluation board based on George Sandler's design.



JTAG

ATmega 128L

Pull up resistor
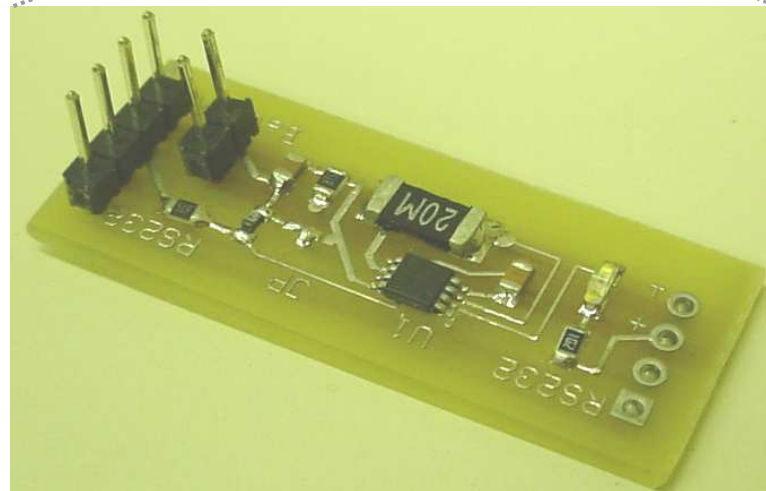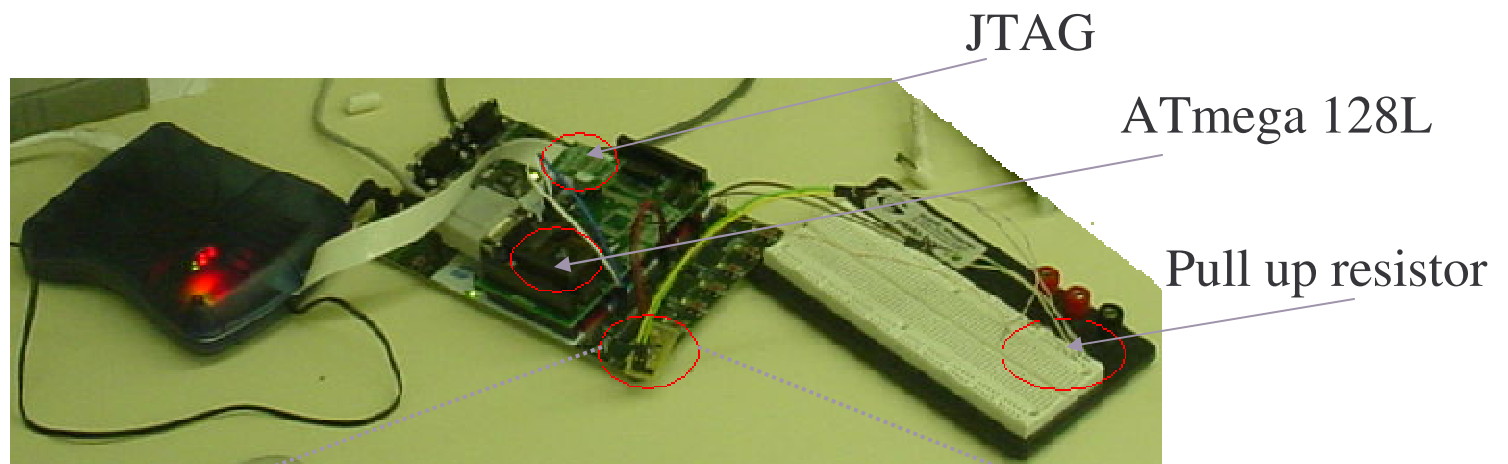
# Software Development

n   Compiler - WinAVR

n   Debugger - AVR Studio 4.0

n   JTAG MK II Connector

Trace Disabled

## Workspace

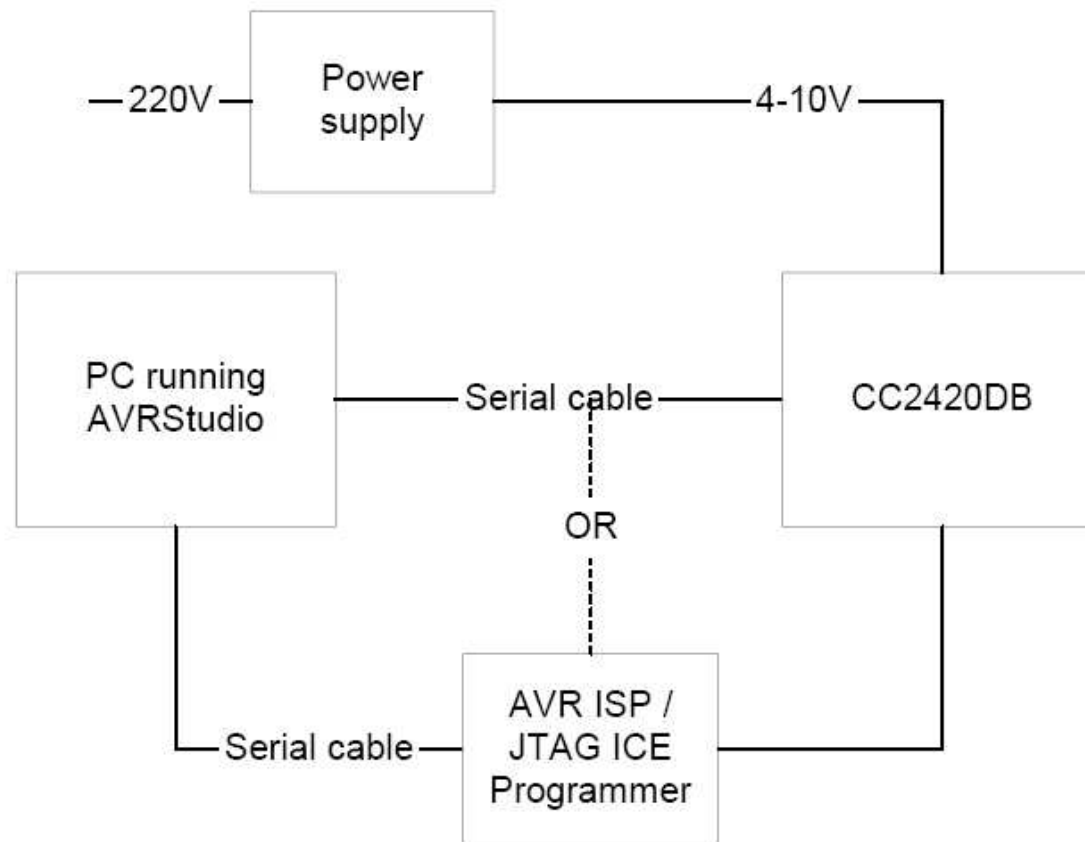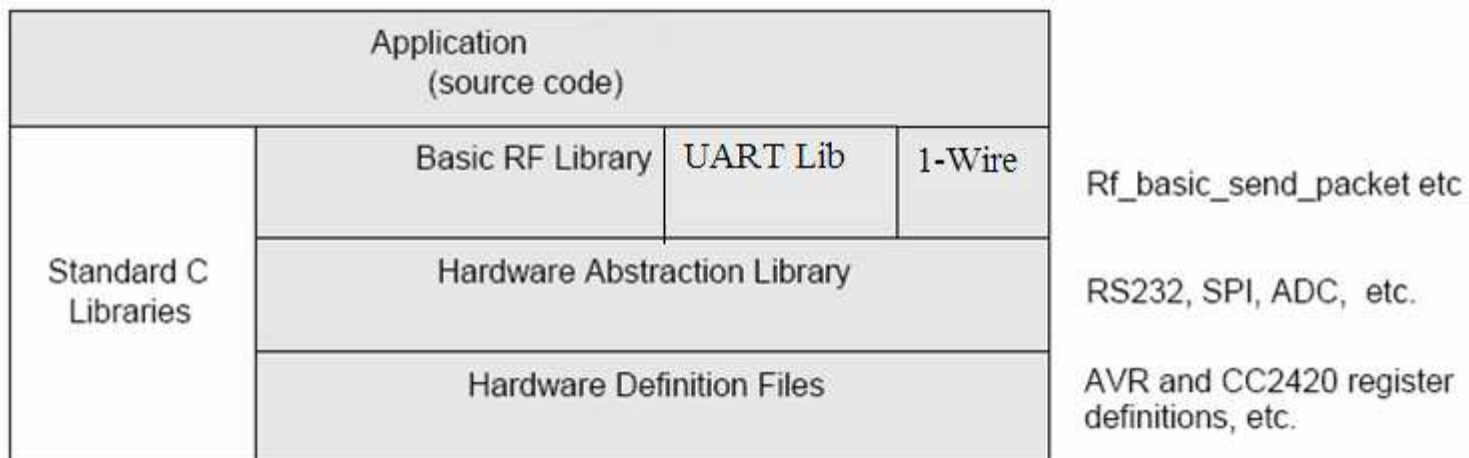| Name | Value | Bits | Address |
|---|---|---|---|
| I/O ATmega128 | | | |
| AD_CONVERTER | | | |
| ANALOG_COMPARATOR | | | |
| BOOT_LOAD | | | |
| CPU | | | |
| SREG | 0xA3 | 7 6 5 4 3 2 1 0 | 0X3F (0X5F) |
| SPH | 0x10 | 7 6 5 4 3 2 1 0 | 0X3E (0X5E) |
| SPL | 0xF2 | 7 6 5 4 3 2 1 0 | 0X3D (0X5D) |
| MCUCR | 0x00 | 7 6 5 4 3 2 1 0 | 0X35 (0X55) |
| XMCRA | 0x00 | 7 6 5 4 3 2 1 0 | na (0X6D) |
| XMCRB | 0x00 | 7 6 5 4 3 2 1 0 | na (0X6C) |
| OSCCAL | 0x9F | 7 6 5 4 3 2 1 0 | na (0X6F) |
| XDIV | 0x00 | 7 6 5 4 3 2 1 0 | 0X3C (0X5C) |
| MCUCSR | 0x17 | 7 6 5 4 3 2 1 0 | 0X34 (0X54) |
| RAMPZ | 0x00 | 7 6 5 4 3 2 1 0 | 0X3B (0X5B) |
| EEPROM | | | |
| EXTERNAL_INTERRUPT | | | |
| JTAG | | | |
| MISC | | | |
| PORTA | | | |
| PORTB | | | |
| PORTC | | | |
| PORTD | | | |
| PORTE | | | |
| PORTF | | | |
| PORTG | | | |
| SPI | | | |
| SPDR | 0x00 | 7 6 5 4 3 2 1 0 | 0X0F (0X2F) |
| SPSR | 0x01 | 7 6 5 4 3 2 1 0 | 0X0E (0X2E) |
| SPCR | 0x50 | 7 6 5 4 3 2 1 0 | 0X0D (0X2D) |
| TIMER_COUNTER_0 | | | |
| TIMER_COUNTER_1 | | | |
| TIMER_COUNTER_2 | | | |
| TIMER_COUNTER_3 | | | |

Project   I/O   Info

```c
void main (void) {
    UINT16 ledDutyCycle, dimmerDifference;
    UINT8 n;

    // Initalize ports for communication with CC2420 and other peripheral units
    PORT_INIT();
    SPI_INIT();

    // Initialize PWM0 with a period of CLK/1024
    PWM0_
```

### c:\murari_rf\lib\hal\hal_rf_wait_for_crystal_oscillator.c

```c
        BYTE spiStatusByte;

        // Poll the SPI status byte until the crystal oscillator is stable
        do {
            DISABLE_GLOBAL_INT();
            FASTSPI_UPD_STATUS(spiStatusByte);
            ENABLE_GLOBAL_INT();
        } while (!(spiStatusByte & (BM(CC2420_XOSC16M_STABLE))));

    } // halRfWaitForCrystalOscillator
```

```c
    // In
    ADC_I
    ADC_S
    ADC_E

    // Wa
    while

        }

    }

    // In
    rfTxI
    rfTxI
    rfTxI
    rfRxI

    for (
        P
    }

    // Tu
    basicRfReceiveOn();

    // The main loop:
```

c:\murari_rf\lib\hal\atmega128\hal_wait.c | c:\murari_rf\apps\basic_rf\rf_blink_led\rf_blink_led.c | c:\murari_rf\lib\hal\hal_rf_wait_for_crystal_osc

Output

| Name | Value | Type | Location |
|---|---|---|---|
| | | | |

Watch

Build

Watch 1  Watch 2  Watch 3  Watch 4

ATmega128   JTAGICE mkII   Auto   Stopped   Ln 64, Col 27

# Library Stack

n Chipcon RF Communication Library
n One Wire Library
n UART Library

| Application (source code) | | | | |
|---|---|---|---|---|
| Standard C Libraries | Basic RF Library | UART Lib | 1-Wire | Rf_basic_send_packet etc |
| | Hardware Abstraction Library | | | RS232, SPI, ADC, etc. |
| | Hardware Definition Files | | | AVR and CC2420 register definitions, etc. |

# Library Stack - RF Communication

n   Association, scanning, beacons is not implemented

n   No defined coordinator/device roles (peer-to-peer, all nodes are equal)

n   Waits for the channel to become ready, but does not check CCA twice (802.15.4 CSMA-CA)

n   Does not retransmit packets

n   Can not communicate with other networks (using a different PAN identifier)
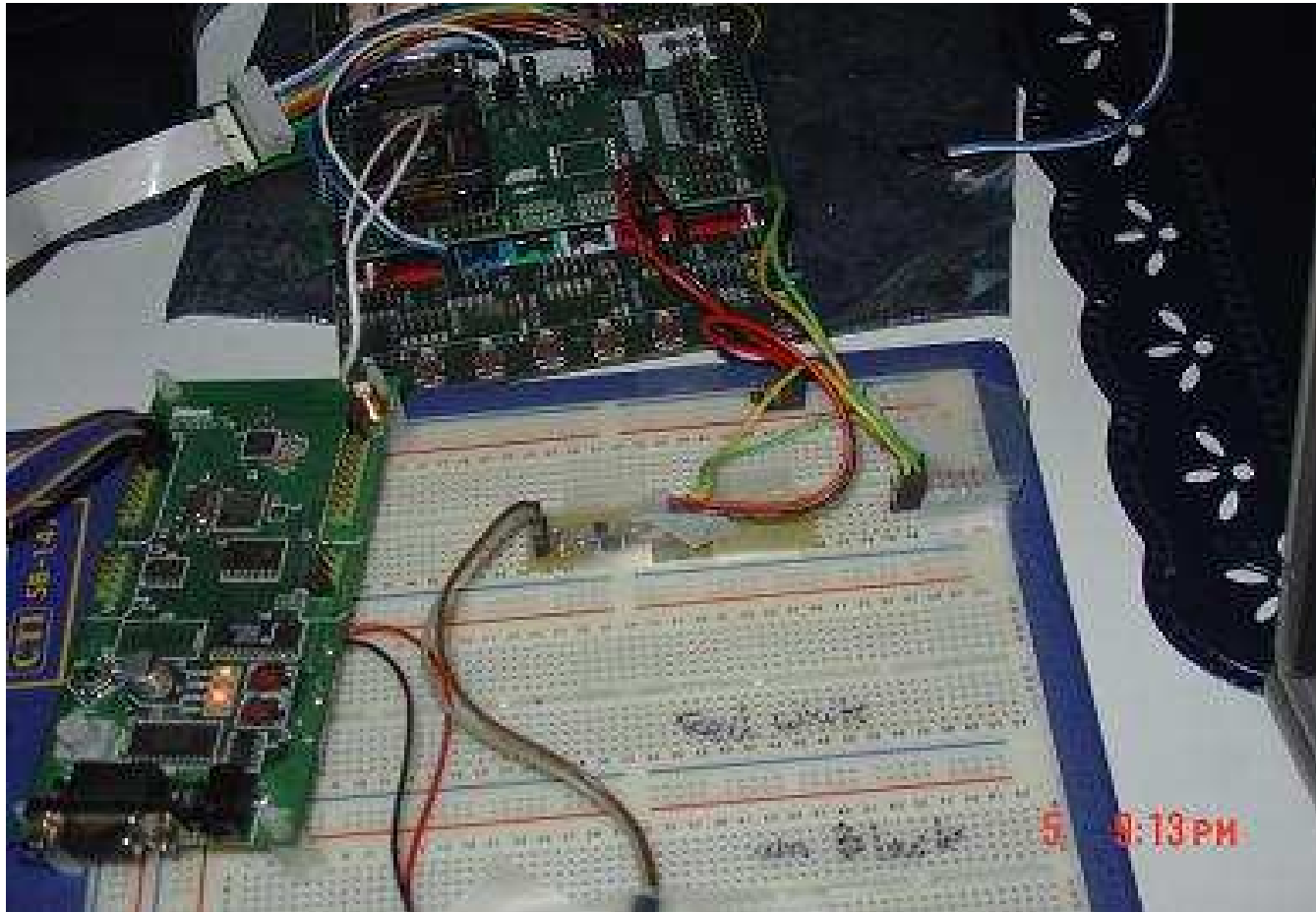
n   Short addresses only

# Setup for current measurement
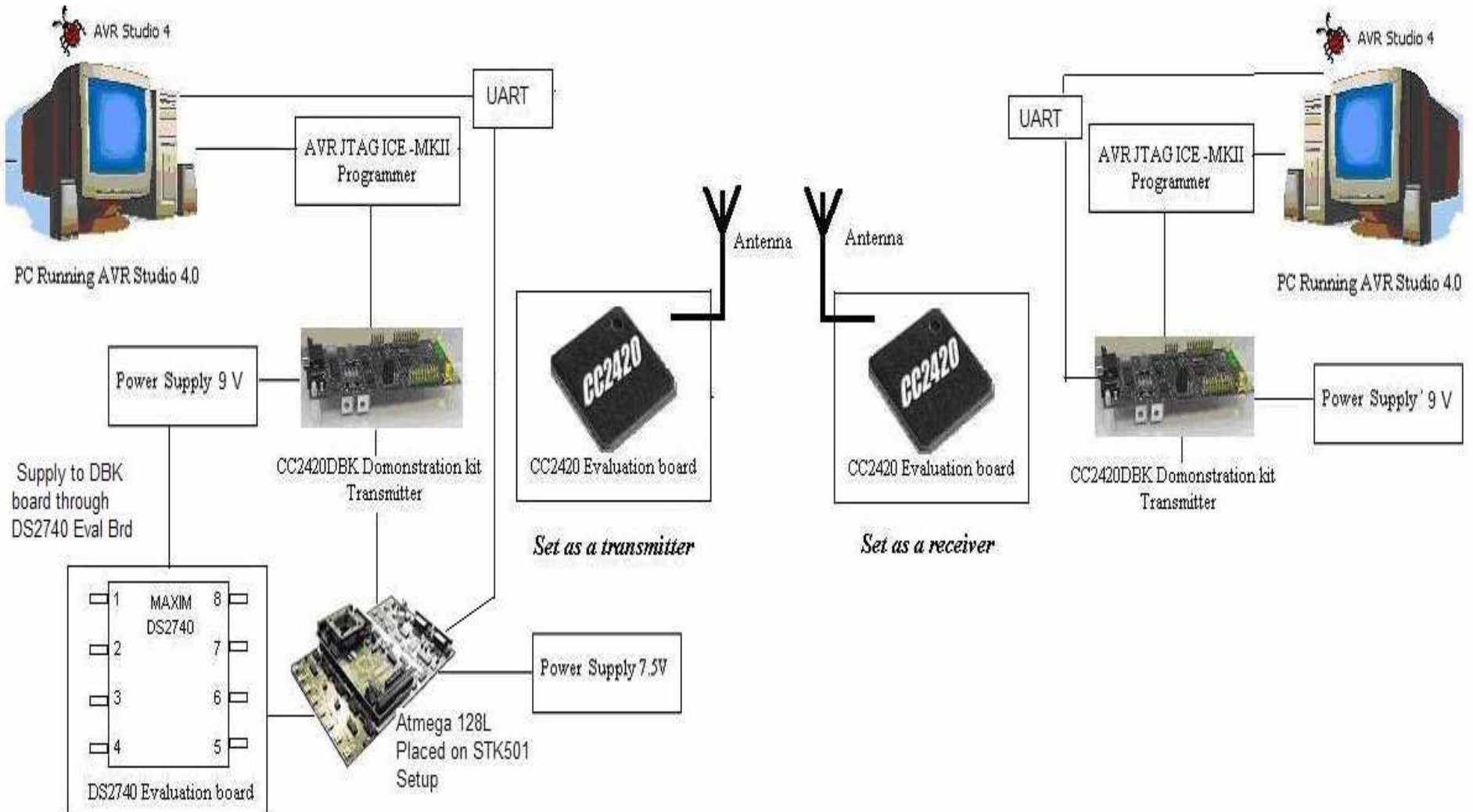
# Setup for current measurement
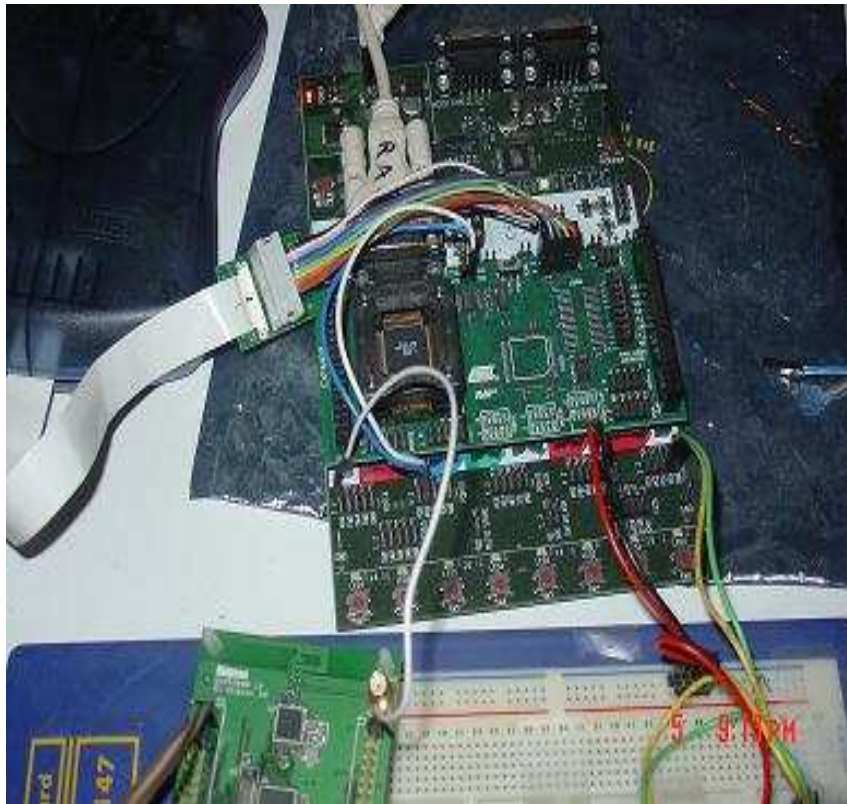
# Setup for current measurement

# Comparison with existing work

**Current consumption measurement using Coulomb Counter**

| Reading Number | Current ( µA) | Packet Size (no. of bytes) | Transmit Power, $P_t(i)$, dBm |
|---|---|---|---|
| 1. | 21474 | 116 | 0 |
| 2. | 21474 | 116 | 0 |
| 3. | 21474 | 116 | 0 |
| 4. | 21474 | 116 | 0 |
| 5. | 20849 | 116 | 0 |
| 6. | 21474 | 116 | 0 |
| 7. | 21474 | 116 | 0 |
| 8. | 21474 | 116 | 0 |
| 9. | 20849 | 116 | 0 |
| 10. | 21474 | 116 | 0 |
| 11. | 21161 | 116 | 0 |
| 12. | 21474 | 116 | 0 |
| 13. | 21474 | 116 | 0 |
| 14. | 21474 | 116 | 0 |
| 15. | 21474 | 116 | 0 |
| **Average** | **21369.8** | **116** | **0** |

**Typical Current Consumption of CC2420 and Mr. Neto's measurements**

| Index, i | Transmit Power, $P_t(i)$, dBm | Transmit Current, $I_t(i)$, mA | Measured Current, $I_t(i)$, mA |
|---|---|---|---|
| **1** | **0** | **17.4** | **16.24** |
| 2 | -1 | 16.5 | 15.07 |
| 3 | -3 | 15.2 | 14.09 |
| 4 | -5 | 13.9 | 13.11 |
| 5 | -7 | 12.5 | 11.86 |
| 6 | -10 | 11.2 | 10.68 |
| 7 | -15 | 9.9 | 9.64 |
| 8 | -25 | 8.5 | 8.53 |

# Analysis

n   Average current consumption reading 21.3698 mA

n   Current consumption of the ATmega128L at 3.3 V is approximately 4.5mA.

n   According to the CC2420 data sheet , the maximum current consumption while transmitting data is 17.4mA.

n   Results observed using the coulomb counter is slightly less than the theoretical result.

n   If Mr. Neto's results are used as a reference, the Coulomb counter reading should be sum of 4.5mA and 16.24mA, or 20.7mA which is very close to the results noted using the Coulomb Counter.



IDLE SUPPLY CURRENT vs. $V_{CC}$
INTERNAL RC OSCILLATOR, 8 MHz



Jumper J1

Jumper J2

Jumper J3
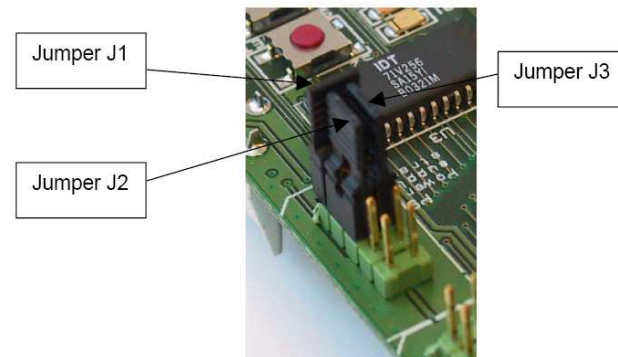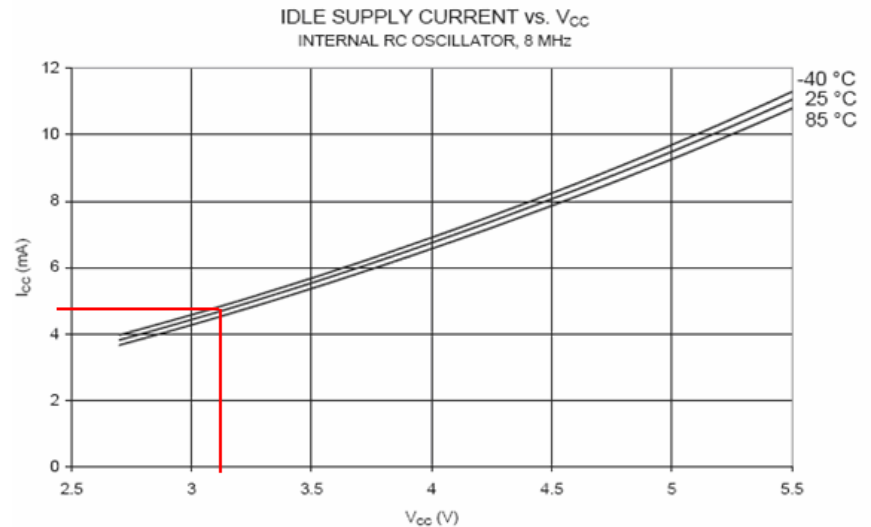
# Limitation and Future Development

Ø    Conversion period for 13 bit resolution is
      0.875s.


Ø    Implementation of full fledge IEEE 802.15.4
      protocol.


Ø    Efficient code Implementation.

# References

[1]     E. Callaway, P. Gorday, L. Hester, J.A.Gutierrez, M. Naeve, B. Heile, V.Bahl "Home Networking with IEEE 802.15.4:  A Developing Standard for Low-Rate Wireless Personal Area Networks", IEEE Communication Magazine, August 2002.

[2]     IEEE Standards Publications  IEEE Std 802.15.4™-2003 Part 15.4:  Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)
        http://standards.ieee.org/getieee802/download/802.15.4-2003.pdf

[3]     Chipcon, "SmartRF® CC2420:  2.4GHz IEEE802.15.4/Zigbee RF Transceiver,"
        http://www.chipcon.com/files/CC2420_Data_Sheet_1_2.pdf.

[4]     Chipcon, "User Manual Rev1.3 SmartRF ® CC2420DBK Demonstration Board Kit "
        http://www.chipcon.com/files/CC2420DBK_User_Manual_1_3.pdf

[5]     Chipcon, CC2420DBK Libraries. It's the basic RF library
        http://www.chipcon.com/files/CC2420DBK_Libraries_Release_1_1.zip.

# Acknowledgements

- Dr.James M. Conrad
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Thank you!

# Questions?