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The Design of Key Finder by Using Bluetooth Low Energy Technology

Information Technology
2016

FOREWORD

This thesis was done during my bachelor study time in Vaasa University of Applied Sciences. I would like to express my gratitude to all those who helped me during my studies and the writing of this thesis.

My deepest gratitude goes first and foremost to my supervisor Mr Jani Ahvonen for his constant encouragement and guidance. He has walked me through all the stages of the writing of this thesis. Thanks to Dr Chao Gao and Mr Jukka Matila who have instructed and helped me a lot during my project.

In addition I would like to thank my boyfriend, dear parents and all my friends, they give me so much care and support all through my study time.

Last I would also like to thank all my teachers and staff members in Vaasa University of Applied Sciences.

Vaasa, Finland, 14.05.2016

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ABSTRACT

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Title	The Design of Key A Finder by Using Bluetooth Low Energy Technology
Year	2016
Language	English
Pages	Appendices
Name of Supervisor	Jani Ahvonen

I can not always find my keys or my wallet, but in fact I did not loose them, I merely put them randomly somewhere I can not remember. However, this randomly loosing things behavior bothers me quit much, I suppose many people are annoyed by not finding their keys. In this thesis, a small PCB was designed that can be hung on key and when the keys are lost, the owner can trigger a buzz on a mobile app and the key finder will start to buzz.

The key finder is a small PCB design that can be wirelessly remotely controlled via A mobile app.

Keywords: Wireless Remote Control, Bluetooth Low Energy, PCB and UART.

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LIST OF ABBREVIATIONS

PCB	Printed Circuit Board
L2CAP	Logical Link Control
ACL	Asynchronous Connection-Less
I/O	Input/Output
IEEE	Institute of Electrical and Electronics Engineers
LMP	Link Manager Protocol
PCM	Pulse Code Modulation
PPP	Point to Point
RTS	Request to Send
RAM	Random Access Memory
SPI	Serial Peripheral Interface
SIG	Special Interest Group
UASRT	Synchronous Asynchronous Receiver and Transmitter
USR	UASRT Status Register
UCR	UASRT Control Register
UDR	UASRT I/O Data Register
UBRR	UASRT Baud Rate Register

1 INTRODUCTION

The introduction chapter includes THE aim and scope, The background and the structure of THE thesis.

1.1 Project Aim And Scope

The aims of this thesis project are:

- Becoming familiar with an AVR micro-controller
- Understanding Bluetooth protocols
- Understanding the communication between a micro-controller and a Bluetooth module
- Understanding the knowledge of programming a micro-controller
- Understanding the design of PCB

This thesis project covers:

- The designing of a PCB board
- Programming AVR micro-controller ATtiny 2313
- Controlling key finder with A mobile app
- Controlling a Bluetooth module with a micro-controller, ATtiny 2313

1.2 Background

With the development of Bluetooth technology, wireless control becomes possible for daily life. A tiny AVR micro-controller is very powerful now, it can easily control a Bluetooth module, and an AVR micro-controller has a flash memory that can only BE needed to be programmed once.

Bluetooth low energy (LE) (also called Bluetooth Smart or Version 4.0+ of the Bluetooth specification) is the power and application-friendly version of Bluetooth that was built for the Internet of Things (IoT).

Bluetooth is a recently conceived communication standard that allows wireless connectivity between Bluetooth enabled computing devices. Bluetooth allows devices to communicate via short range radio links, removing the restrictions of wires, cables, and line of sight requirements. The desirable features of Bluetooth include robustness, low complexity, low power and low cost.

Cite from: https://www.bluetooth.com/what-is-bluetooth-technology/bluetooth-technology-basics/low-energy

The advantages of Bluetooth technology:

- Wireless control
- Easy to use
- Globally accepted specification
- Communication protocol

Atmel tiny AVR micro-controllers (MCUs) are optimized for applications that require performance, power efficiency, and ease of use in a small package. All tiny AVR devices are based on the same architecture and are compatible with other AVR devices. Integrated ADC, an EEPROM memory and A brown-out detector lets you build applications without adding external components.Tiny AVR devices also offer Flash memory and on-chip debug for fast, secure, cost-effective in-circuit upgrades that significantly cut your time to market.

The devices are supported by the Atmel Studio development platform which enables code development in C or Assembly, provides cycle-accurate simulation, and integrates seamlessly with starter kits, programmers, debuggers, evaluation kits, and reference designs. This results in faster development, a more-production development team, and rapid entrance to the market .

cite from: http://www.atmel.com/products/microcontrollers/avr/tinyavr.aspx

The advantages of an ATtiny AVR micro-controller are:

- Small size
- High integration
- Fast and code efficient
- Flash memory

1.3 The Structure of Thesis

Chapter one gives an overall introduction of the whole project with background. In chapter 2 Bluetooth communication is introduced, including Bluetooth low energy technology. Chapter 3 focuses on the project application, The PCB schematic is explained, hardware requirements are also included with the connection between all the components. In Chapter 4 software development is interpreted and how source code is written to make a key finder function is explained. Future work is demonstrated in Chapter 5 and Chapter 6 contains a summary and a conclusion. References and Appendices are included at the end of the thesis.

2 BLUETOOTH TECHNOLOGY OVERVIEW

2.1 Description of Bluetooth

Bluetooth is a recently conceived communication standard that allows wireless connectivity between Bluetooth enabled computing devices. Bluetooth now is organized by SIG Group (Bluetooth Special Interest). IEEE lists Bluetooth specifications on many aspects of IEEE 802.15.1 standard. The range of Bluetooth is between 10 meters to 100 meters.

Bluetooth allows multiple devices to interact simultaneously in wireless networks called piconets. Every piconet contains one master and one or more slave devices. Figure 2-1 is an example of A Bluetooth piconet with one master and three slaves. A scatternet is the term that describes a network with devices belonging to more than one NETWORK simultaneously. Figure 2-2 is an example of A scatternet.

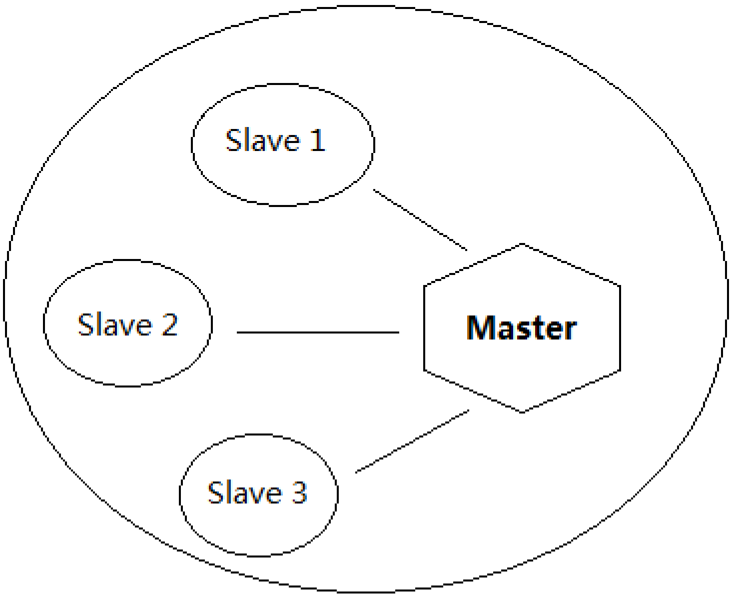

Figure 2-1: Piconet with one master and three slaves

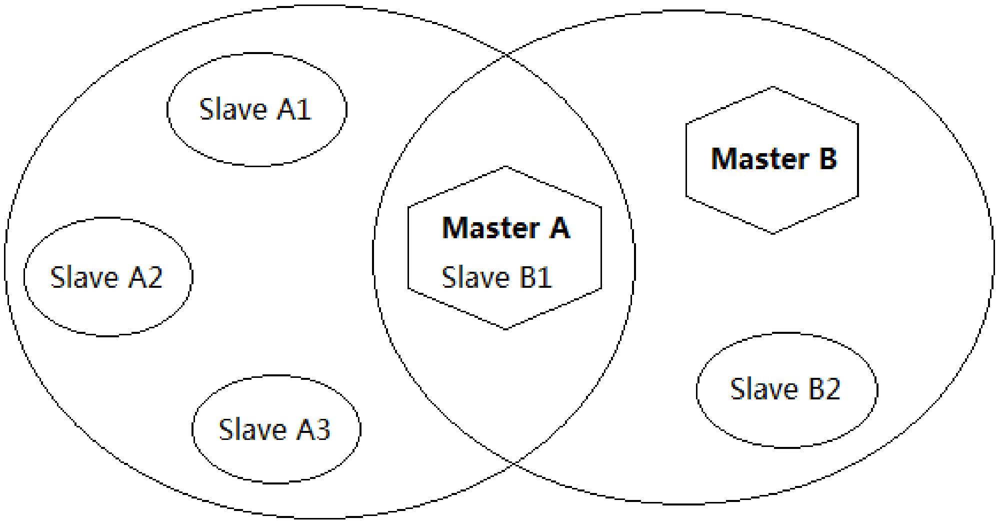

Figure 2-2: Scatternet with two piconets

2.2 Bluetooth Architecture

The Bluetooth architecture is cut up into multiple layers. In this Chapter, every layer's function will be described. Figure 2-3 shows the Bluetooth system architecture.

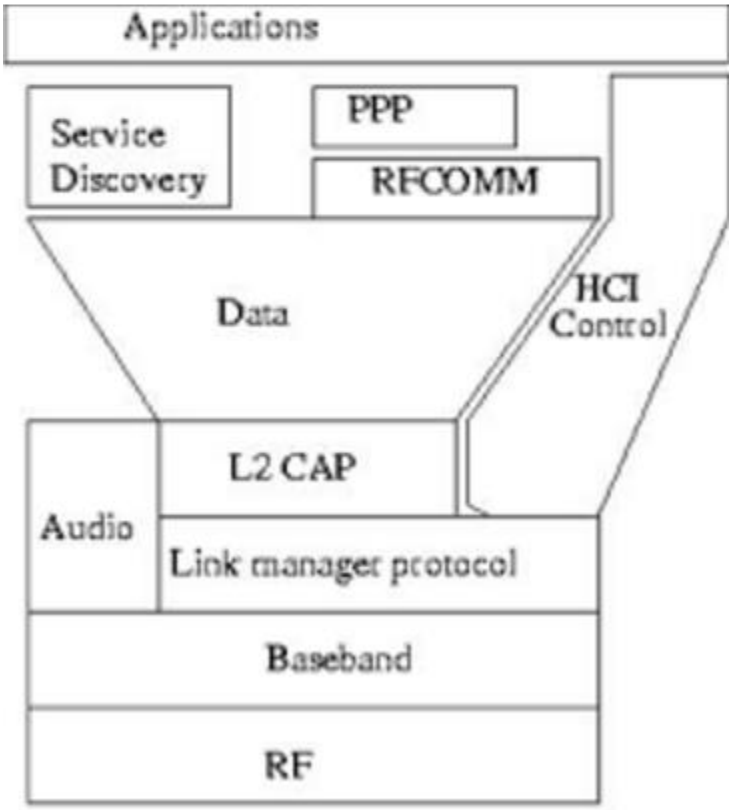

Figure 2-3: Bluetooth system architecture

2.2.1 Radio Layer

The Bluetooth air interface is based on a nominal antenna power of 0 dBm with extensions for operating at up to 20 dBm. The air interface compiles with most countries' ISM (Industrial Scientific Medical) band rules up to 20 dBm. The radio uses Frequency Hopping in spreading of the energy through the ISM spectrum in 79 hops displaced by 1 MHz, beginning at 2.402 GHz and stopping at 2.480 GHz.

The nominal link range is 10 cm to 10 m, but this range can be expanded to more than 100 m by increasing the transmit power.

2.2.2 Baseband Layer

The baseband layer is also called physical layer. The baseband layer manages physical channels and links other services for example error correction, hop selection, data whitening and Bluetooth security. It lies above the radio layer. The baseband protocol is accomplished as a link controller, it works with the link manager to carry out link level routines such as link connection and power control. The baseband also manages synchronous and asynchronous links, handles packets, does paging and inquiry to access and inquires Bluetooth devices. The baseband transceiver applies a TDD scheme. Apart from different hopping frequency, the time is slotted.

2.2.3 Link Manager Layer

The link manager layer controls the baseband layer state machine. The responsibilities of the link manager are: service quality monitoring, security services, authentication and baseband state control. This layer also controls the power modes, duty cycles of the Bluetooth radio device and connection states of a Bluetooth unit in a piconet.

2.2.4 Logic Link Control and Adaption Protocol

The Bluetooth logical link control and adaptation protocol (L2CAP) adapts upper layer protocols over the baseband. L2CAP provides services to upper layer when the payload data is never sent at LMP messages. Both connection-oriented and connectionless data services are provided in this layer and the key duties of L2CAP layer is multiplexing capability, segmentation and reassembly operation.

2.2.5 Service Discovery Protocol

The Bluetooth SDP provides a means by which service applications running on different Bluetooth enabled devices may discover each other's existence, and exchange information to determine their characteristics.

2.2.6 RFCOMM

The RFCOMM protocol emulates the serial cable line settings and status of an RS-232 serial port and is used for providing serial data transfer. RFCOMM connects to the lower layers of the *Bluetooth* protocol stack through the L2CAP layer.

The last 2 protocols, SDP and RFCOMM, are belong to middleware protocol when others are belong to transport protocol.

2.3 The Bluetooth Transmission Theory

In this section, some basic theories, characteristics and ways of using in Bluetooth transmission will be introduced.

2.3.1 Radio

The radio layer defines the technical characteristics of Bluetooth radios. A Bluetooth radio operates on the license-free 2.4 GHz ISM band. It uses a fast frequency hoping spread spectrum technique. The channel is represented by a pseudo-random hopping sequence hopping through the 79 or 23 RF channels. The frequencies are located at (2.402+k) MHz, k=0, 1… 78.

2.3.2 Baseband

The baseband defines the key procedures that enable devices to communicate with each other using the Bluetooth wireless technology which includes how the piconets creating, Bluetooth links and also show how the transmit resources are to be shared among several devices in a piconet as well as the low level packet types.

2.3.3 Bluetooth Addressing and Clock

Each Bluetooth device has two parameters that are involved in practically all aspects of Bluetooth communications. The first parameter is a unique IEEE type 48 bit address which is assigned to each radio when it was manufactured. The Bluetooth device address is engraved on Bluetooth and it is not permitted for modification. The second parameter is a free running 28 bit clock which ticks one time for every 312.5μs. It corresponds to half of the residence time in a frequency when the radio hops at the nominal rate of 1,600 hops/s. Bluetooth devices can communicate with each other, by acquiring each other's Bluetooth addresses and clocks.

2.3.4 Piconet

How Bluetooth works to connect with other devices in its proximity, is through a networking architecture called a Piconet which allows up to 8 devices (1 master and 7 slaves) to participate in an ad-hoc connection.

A Bluetooth piconet is considered to be personal area network due to limited range of generally a few meters used commonly for linking personally owned devices to nearby equipment in a brief exchange of information or establishing a connection to the Internet through another Bluetooth access point.

Bluetooth drivers are used only for controlling by what method a Bluetooth radio transceiver communicates with an operating system of connected devices to the piconet, and is not actually needed for how Bluetooth works.

Master devices such a laptop with Bluetooth can store up to 255 slave devices in its piconet database as paired inactive devices, and will activate and bring into service any Bluetooth radio which is discovered within its signal range until the limit of 7 slave devices is reached.

A Bluetooth access point operates on the 2.4GHz frequency band between 2.4 to 2.485GHz and taking advantage of this spread spectrum by a using a technique called adaptive frequency hopping.

As electronic devices are discovered operating within the vicinity of a Bluetooth access point, the adaptive technology switches or hops to an available unused frequency within the spectrum avoiding interference.

Frequency hopping is how Bluetooth works to maintain greater throughput as less packet resends are needed, and provides electronic interference protection for all Bluetooth devices operating in the piconet.

3 PROJECT APPLICATION OVERVIEW

This Chapter describes the components used on the PCB, also the circuit design.

3.1 AVR Micro-controller

3.1.1 Overview of Atmel ATtiny 2313 Board

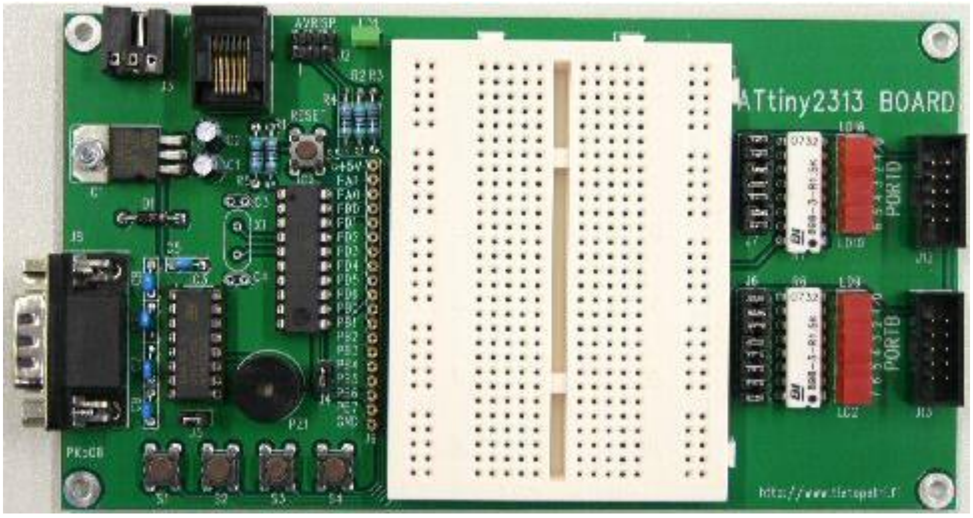

Figure 3-1: Atmel ATtiny 2313 Board

cite from: http://www.tietopetri.fi/tuotteet.html

The main features of the ATtiny 2313 Board are:

- Atmel AVR micro-controller ATtiny 2313
- Programmable via AVR SPI port
- Power supply voltage can be from 9 to 18 volts DC
- All PORTB and PORTD are freely available for the user

- 15 LEDs, 4push buttons and piezo-buzzer
- Serial interface

3.1.2 Micro-controller ATtiny 2313

The ATtiny2313 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATtiny2313 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The ATtiny2313 provides the following features: 2K bytes of In-System Programmable Flash, 128 bytes EEPROM, 128 bytes SRAM, 18 general purpose I/O lines, 32 general purpose working registers, a single-wire Interface for On-chip Debugging, two flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, Universal Serial Interface with Start Condition Detector, a programmable Watchdog Timer with internal Oscillator, and three software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or hardware reset. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low-power consumption.

The device is manufactured using Atmel's high density non-volatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, or by a conventional non-volatile memory programmer. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATtiny2313 is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATtiny2313 AVR is supported with a full suite of program and system development tools including: C Compilers, Macro Assemblers, Program Debugger/Simulators, In-Circuit Emulators, and Evaluation kits.

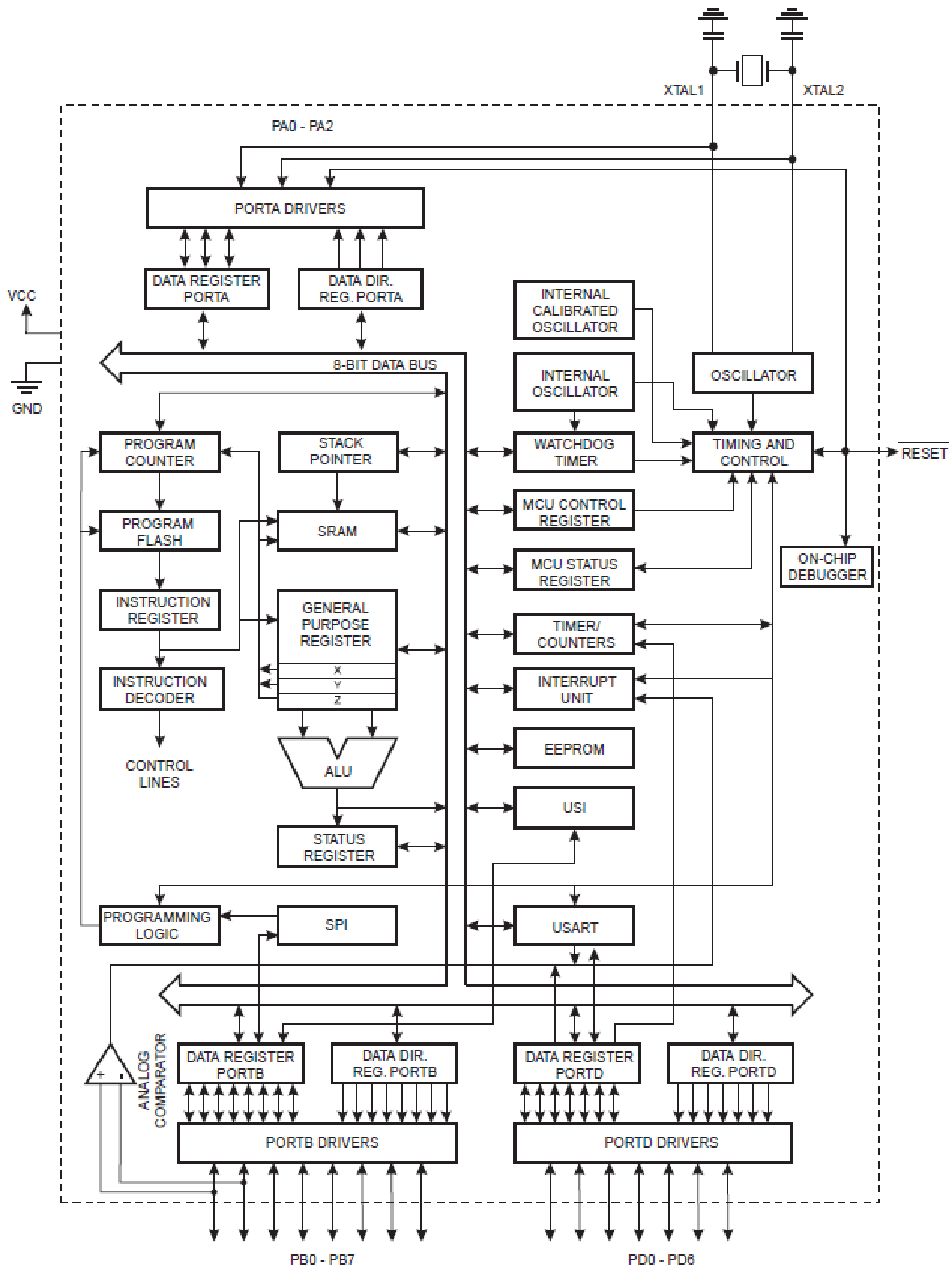

Figure 3-2: ATtiny 2313 Block Diagram

3.1.3 UART Control

USART I/O Data Register – UDR:

Bit	7	6	5	4	3	2	1	0	
	RXB[7:0]								UDR (Read)
	TXB[7:0]								UDR (Write)
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

The USART Transmit Data Buffer Register and USART Receive Data Buffer Registers share the same I/O address referred to as UDR. The TXB will be written according to UDR Register location and RXB will be read.

USART Status Register-USR:

Bit	7	6	5	4	3	2	1	0	
	RXC	TXC	UDRE	FE	DOR	UPE	U2X	MPCM	UCSRA
Read/Write	R	R/W	R	R	R	R	R/W	R/W	
Initial Value	0	0	1	0	0	0	0	0	

The USR Register is a read-only register providing information on the UART status.

• Bit 7 – RXC: USART Receive Complete

• Bit 6 – TXC: USART Transmit Complete

• Bit 5 – UDRE: USART Data Register Empty

• Bit 4 – FE: Frame Error

• Bit 3 – DOR: Data OverRun

• Bit 2 – UPE: USART Parity Error

USART Control Register-UCR:

Bit	7	6	5	4	3	2	1	0	
	RXCIE	TXCIE	UDRIE	RXEN	TXEN	UCSZ2	RXB8	TXB8	UCSRB
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R	R/W	
Initial Value	0	0	0	0	0	0	0	0	

• Bit 7 – RXCIE: RX Complete Interrupt Enable

• Bit 6 – TXCIE: TX Complete Interrupt Enable

• Bit 5 – UDRIE: USART Data Register Empty Interrupt Enable

• Bit 4 – RXEN: Receiver Enable

• Bit 3 – TXEN: Transmitter Enable

• Bit 2 – UCSZ2: Character Size

• Bit 1 – RXB8: Receive Data Bit 8

• Bit 0 – TXB8: Transmit Data Bit 8

USART Baud Rate Registers – UBRRL and UBRRH:

Bit	15	14	13	12	11	10	9	8	
	–	–	–	–	UBRR[11:8]				UBRRH
	UBRR[7:0]								UBRRL
	7	6	5	4	3	2	1	0	
Read/Write	R	R	R	R	R/W	R/W	R/W	R/W	
	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	

$$BAUD = \frac{fck}{16\times(UBRR+1)}$$

BAUD=Baud Rate

fck=Crystal Clock Frequency

UBRR=Contents of the UASRT Baud Rate Register(0-255)

cite from: http://www.atmel.com/images/doc2543.pdf

3.2 Bluetooth Module

3.2.1 BLE Mini Overview

Figure 3-3: BLE Mini Bluetooth Module

BLE Mini is a Bluetooth module that can be used on embedded systems. It supports Bluetooth 4.0 Low Energy (BLE) technology.

The features of BLE Mini are:

- Bluetooth SIG certified with on-board chip antenna
- Texas Instruments CC2540 2.4 GHz Bluetooth System-on-Chip (SoC)
- Dimension - (L)39mm x (W)18.5mm x (H)3.8mm
- On-board programmable components
- 512Kb EEPROM, 2 LEDs (Blue & Green), Push Button
- Baud rate is 57600, 8 data bits, no parity, one stop bit & no flow control
- 0.1mA power consumption
- Accessories included - Coin Cell Battery holder & 3 connectors
- Powering options - 3.7V Li-ion

3.2.2 Pin Configuration

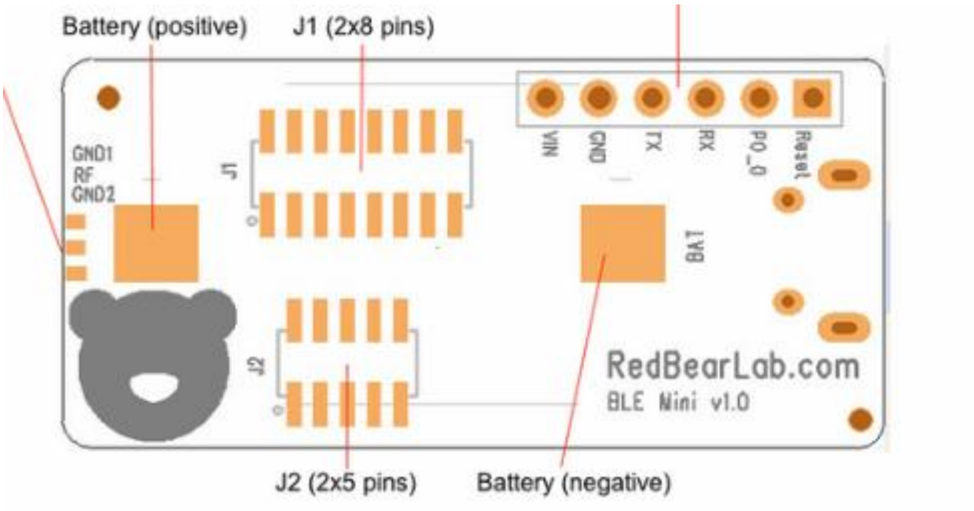

Figure 3-4: BLE Mini Bluetooth module schematic

- VIN > Power
- GND > GND
- TX > RX (PD0)
- RX > TX (PD1)

3.3 Button Battery

3.3.1 CR 2032 Overview

Figure 3-5: CR 2032 Coin Battery

The CR 2032 battery is a button cell lithium battery rated at 3 volts. It is commonly used on an embedded system.

The features of CR 2032 are:

- Capacity of 225 mAh
- Nominal voltage of 3.0 V
- Usable temperature range between -20 °C to 70 °C

3.3.2 Power Consumption Calculation

Capacity of battery : 250 mAh

Consumption of BLE : 0.1 mA

Consumption of micro-controller : < 0.1 µA

$$
\begin{aligned}
Month &= Battery\ Capacity \div BLE\ Consumption \div 24h \div 30days \\
&= 250\ mAh \div 0.1\ mA \div 24h \div 30days = 3.5months
\end{aligned}
$$

3.4 Buzzer

Figure 3-6: Buzzer

- Rated frequency of 4.1KHz
- Operating voltage range from 3VDC to 16VD
- Maximum current consumption of 7mA at 12VDC
- Minimum sound pressure level of 70dB at 30cm/12VDC
- Continuous tone
- Operating temperature range from -20°C to 70°C
- Dimension of 13.7mm x 7.6mm

3.5 AVRISP mkII

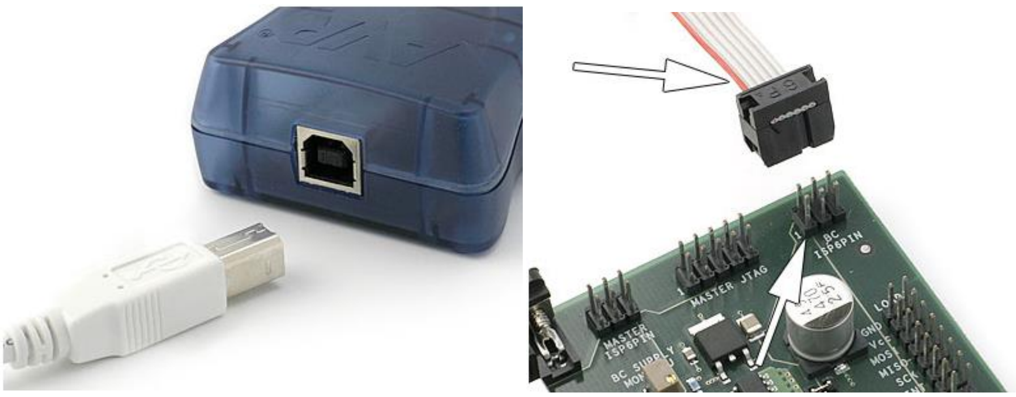

Figure 3-7: AVRISP mkII

The Atmel AVRISP mkII combined with Atmel Studio can program all Atmel AVR 8-bit RISC microcontrollers with ISP, PDI or TPI Interface

3.6 Circuit Design

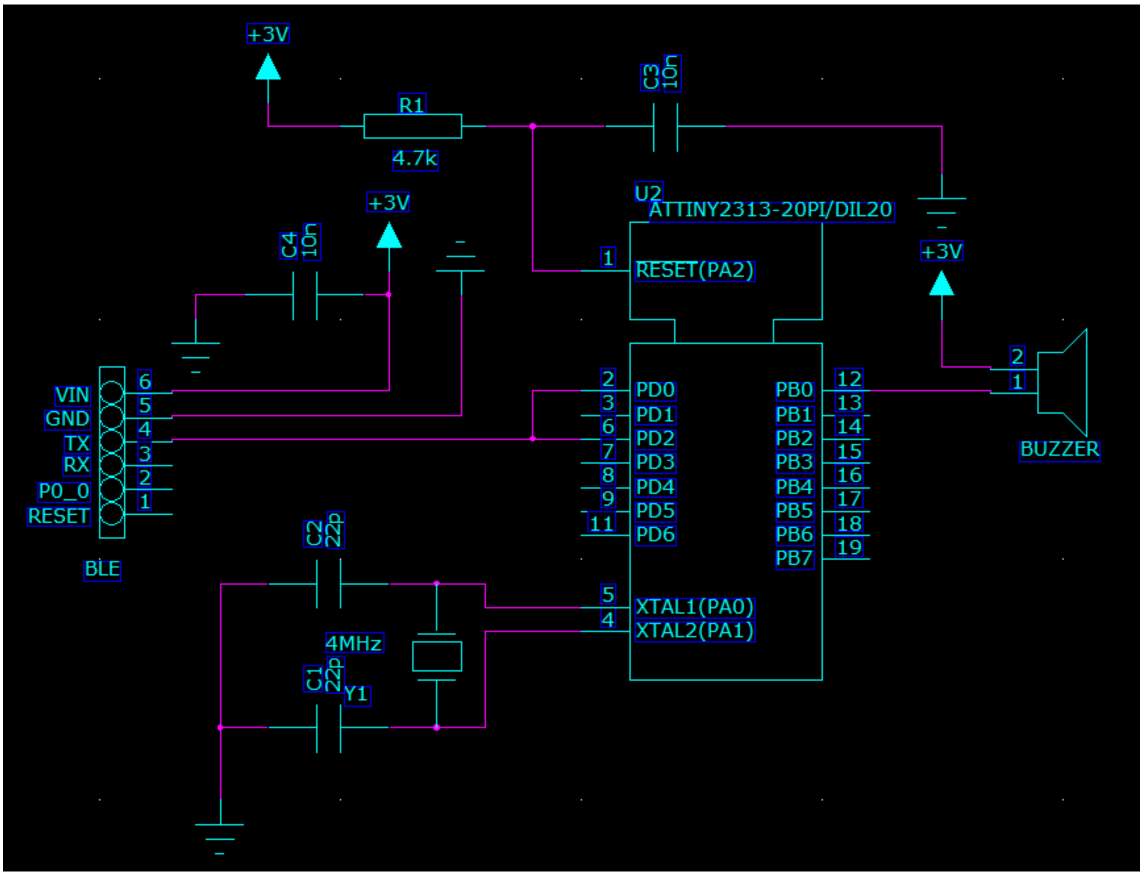

Figure 3-8: circuit design

The real PCB board looks like this:

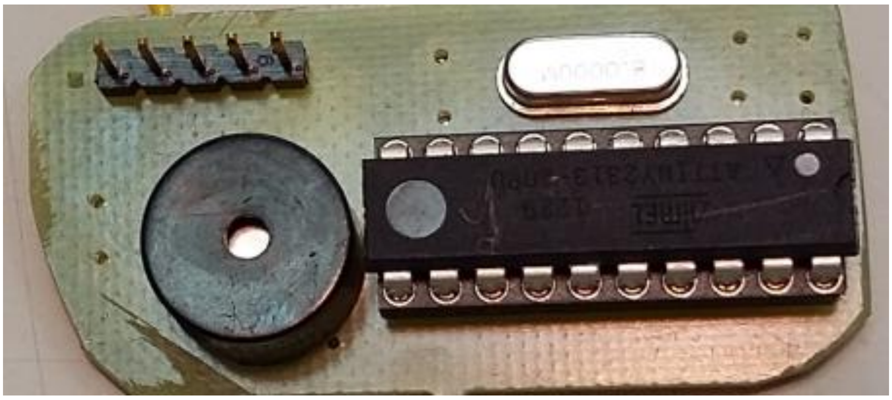

Figure 3-9: the key finder

The circuit is designed according to above introduction. The specific PCD design schematic and layout are in the appendices at the end of the essay.

4 APPLICATION DEVELOPMENT

This Chapter describes how the micro-controller was programmed to control Bluetooth module, and how to remotely control key finder with mobile App.

4.1 Programming Micro-controller

The software I used was Atmel Studio 6.2. Atmel Studio is released by Atmel company to program all Atmel AVR micro-controller. It is completely free for download.

First create a new file.

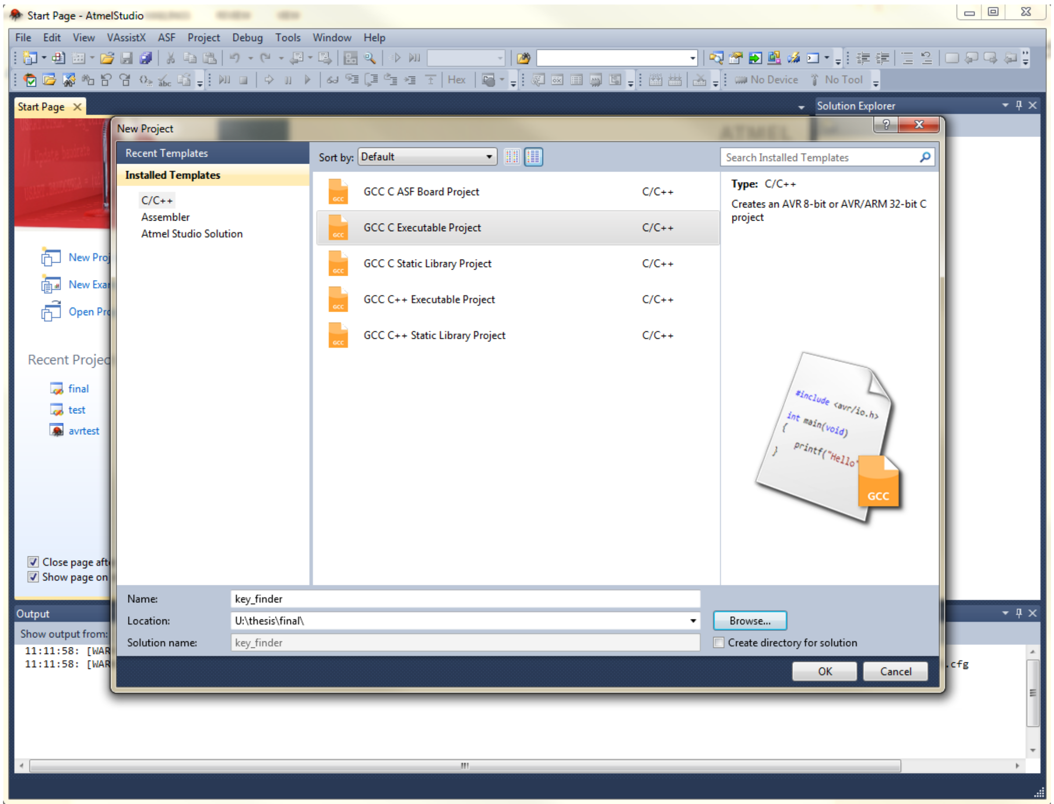

Figure 4-1: Atmel Studio create new file

Secondly choose the micro-controller type.

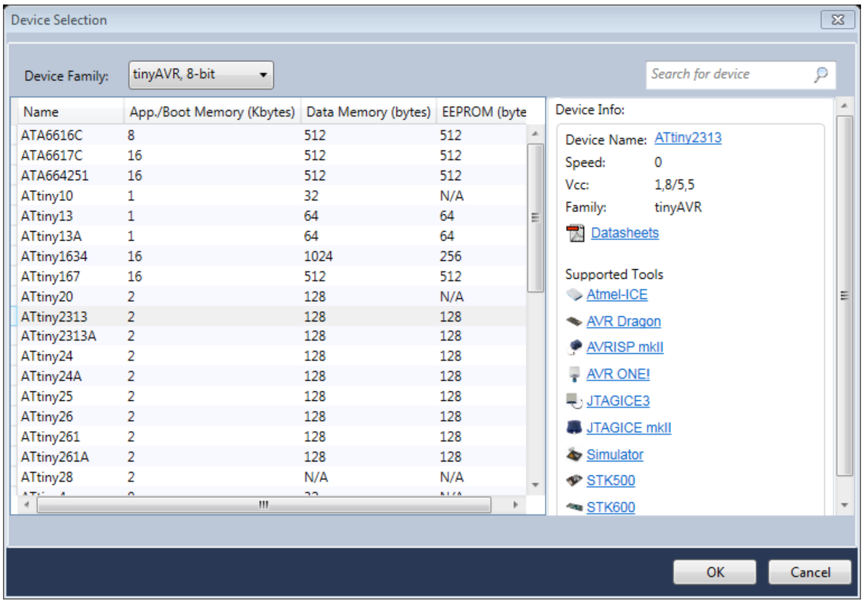

Figure 4-2: Atmel Studio Setup

Setup micro-controller parameters.

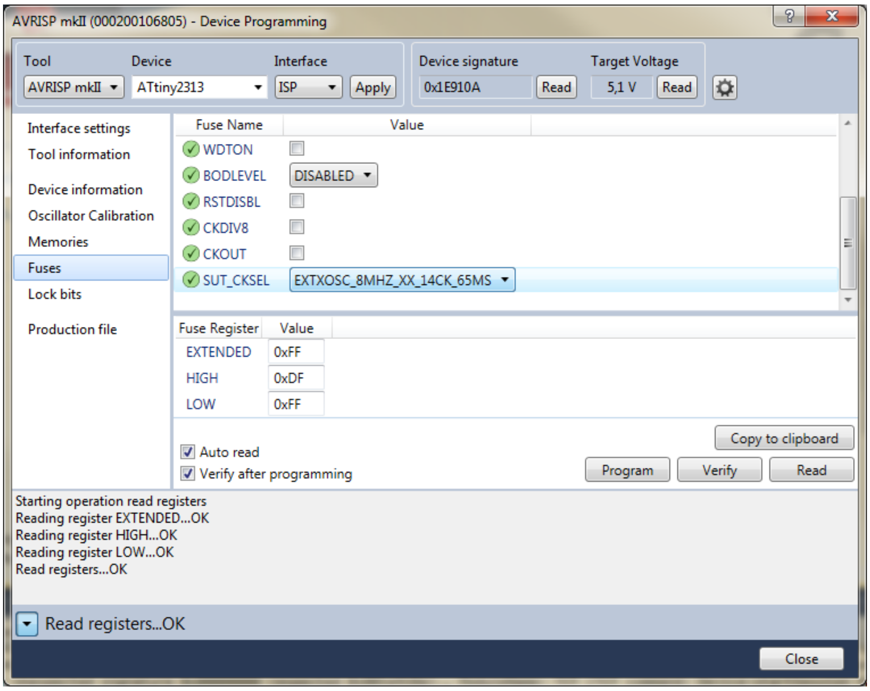

Figure 4-3: Atmel Studio setup micro-controller parameters

Thirdly configure Device Programming for debugging.

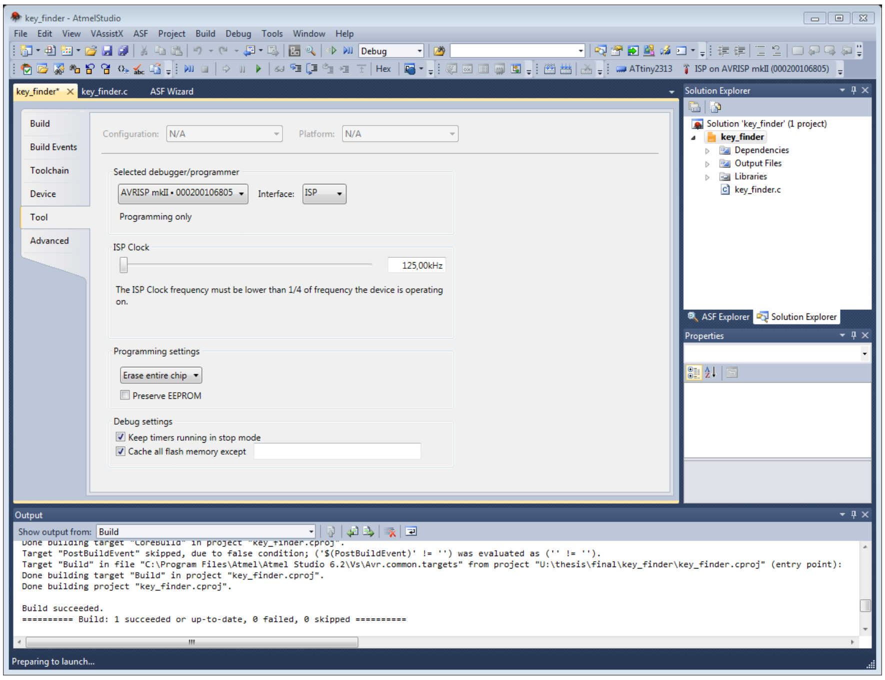

Figure 4-4:Atmel Studio set up Device Programming

Then the micro-controller is ready for programming.

Declare header file, clock frequency and baud rate.

```
#include <avr/io.h>
#define F_CPU 20000000UL
#include <util/delay.h>
#include <avr/sleep.h>
#include <avr/interrupt.h>
#define BAUD_RATE 57600
```

Declare all registers that need to be used.

```
int main(void)
{
    DDRB=0x01;  //enable PB0 as output
    PORTB=0xff;

    UCSRA=0x00;
    UCSRB = (1<<RXEN);
    UCSRC=0x06;
    UBRRH = (((F_CPU/BAUD_RATE)/16)-1)>>8;
    UBRRL = (((F_CPU/BAUD_RATE)/16)-1);

    DDRD &= ~(1 << PD2);     // INT0: input...
    PORTD |= (1 << PD2);     // ...with pullup.


    MCUCR &= ~((1 << ISC01) | (1 << ISC00));
    GIMSK = (1 << INT0); //INT0: External Interrupt Request 0 Enable
    sei();
```

Enable PORTB0 to control buzzer, turned the micro-controller in sleep mode in the beginning to save power. Then set password to ‘a’, when receiving ‘a’ from mobile App, the micro-controller will trigger buzzer.

```
    unsigned char ch=0;
    while (1)
    {

        sei();
        PORTB=0xff;
        GIMSK |= (1 << INT0);
        set_sleep_mode(SLEEP_MODE_PWR_DOWN);
        sleep_mode();

        GIMSK &= ~(1 << INT0);
        cli();
        PORTB=0xFF;

            while (!(UCSRA & (1<<RXC)));
            ch=UDR;

            if(ch=='a')
            {
                PORTB=0;
                _delay_ms(1000);
            }
    }

}
```

4.2 Mobile App

The mobile used is called BLE Controller which is released by RedBearLab the same manufacture of Bluetooth module. It can be freely download from Apple store, Google play and Windows store.

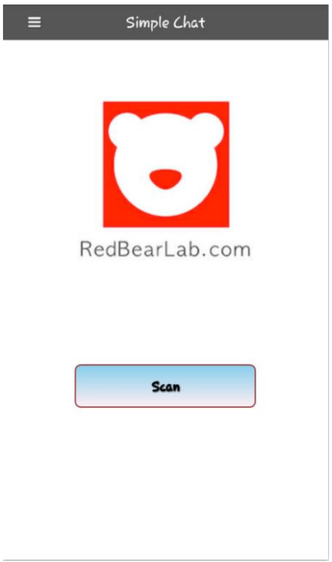

Figure 4-5: BLE Controller

Connect to key finder and choose Simple Chat mode.

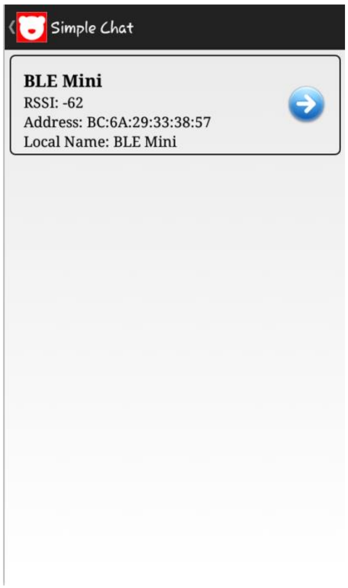

Figure 4-6: BLE Controller Simple Chat mode

Send password for communication.

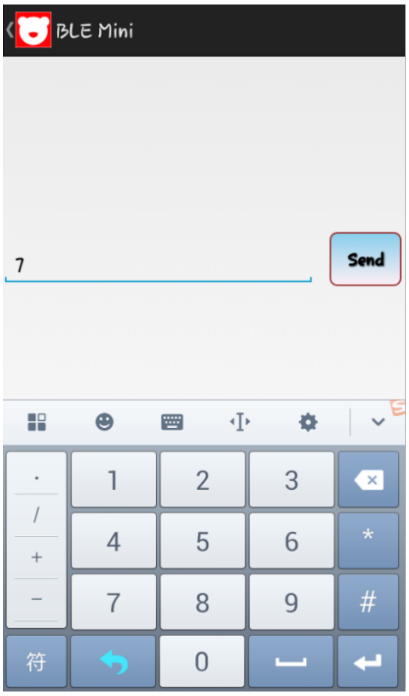

Figure 4-7: BLE Controller send password to key finder

5 FUTURE WORK

In this project, I designed a PCD using micro-controller and Bluetooth module, to build a remotely wirelessly controlled embedded system. It is a nonchargeable device.

In the future, this technology can be expanded to other fields. Since it is a small embedded system, it can be easily used on other IoT (Internet of Things) for remote controlling. Any collected data can be sent through Bluetooth technology, Bluetooth technology is very advanced nowadays and really power saving.

6 SUMMARY AND CONCLUSION

The key finder is a small PCB board using Bluetooth technology and micro-controller control. The key components are Bluetooth module and micro-controller. The AVR micro-controller is a very powerful component, it can drive many other components. This technology can be expanded to many other devices.

For the PCB design part, proper pin configuration should be very careful. In order for the micro-controller to work, a crystal should be added to the circuit. And the PCB board should be designed as small as possible for easy use.

For the key finder hardware, it is powered by a button battery and nonchargeable. The micro-controller should be in sleep mode for all the time in the purpose of power saving. But when password is received by Bluetooth module, the micro-controller should wake up and trigger the buzzer.

For mobile controlling part, only the owner of the key finder should know the password. When no password is sent to the key finder, the key finder should remain silence, it only buzz when receive the right password.

REFERENCES

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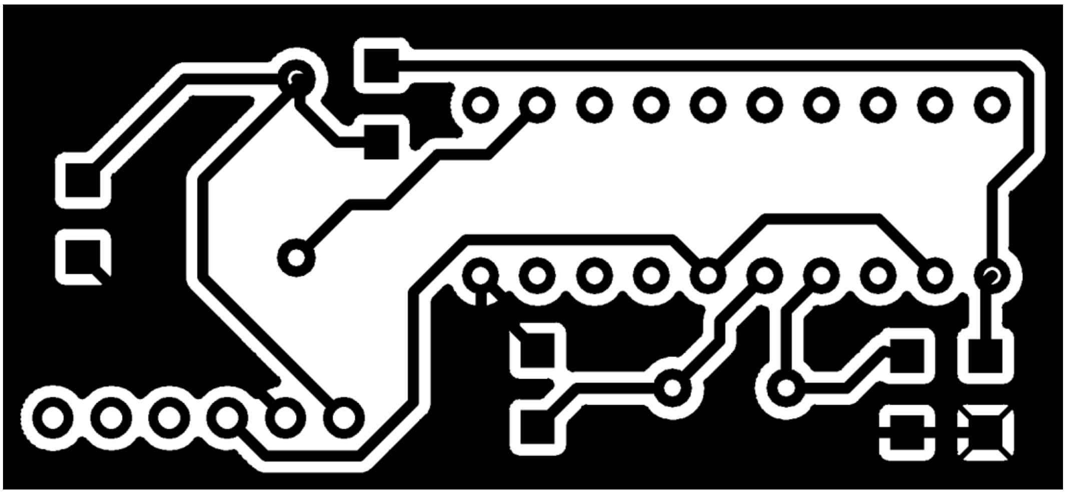
/3/http://www.tietopetri.fi/tuotteet.html

/4/http://www.atmel.com/images/doc2543.pdf

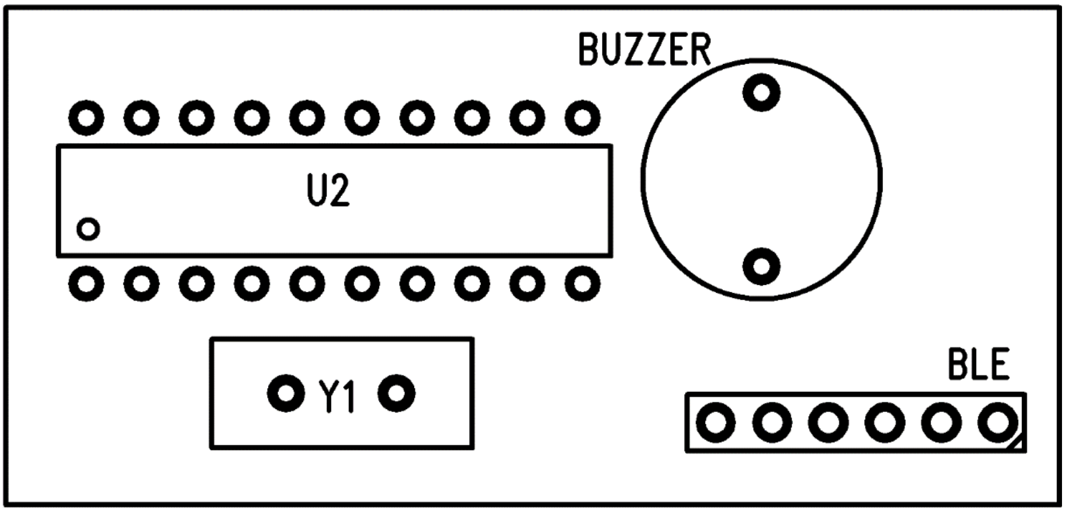
/5/http://homepages.inf.ed.ac.uk/group/sli_archive/slip0304_b/resources/com/karl/sdp/sdp_intro.html

/6/https://developer.bluetooth.org/TechnologyOverview/Pages/RFCOMM.aspx

APPENDICES



Top layer



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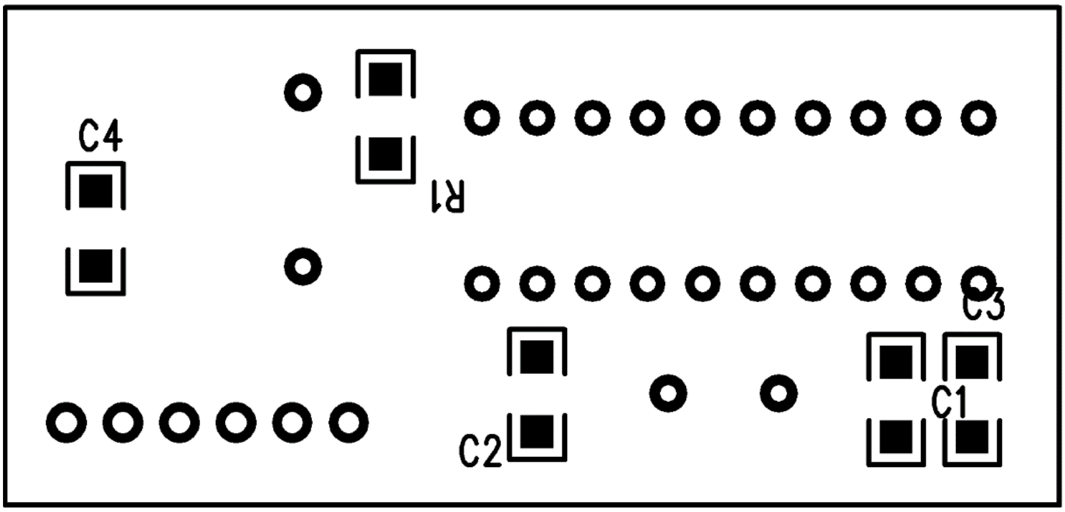

Source Code

```
/*

  * key finder.c

  *

  * Created: 18.5.2016 10:21:58

  * Author : e1301322

  */



#include <avr/io.h>

#define F_CPU 20000000UL  // clock frequency 20 MHz

#include <util/delay.h>

#include <avr/sleep.h>

#include <avr/interrupt.h>       // interrupt header
```

```
#define BAUD_RATE 57600        //bluetooth baud rate


int main(void)

{

    DDRB=0x01;            // enable pb0 to control buzzer

    PORTB=0xff;


    UCSRA=0x00;

    UCSRB = (1<<RXEN);   // enable receiver

    UCSRC=0x06;          //set fram format: 8data, 2 stop bit

    UBRRH = (((F_CPU/BAUD_RATE)/16)-1)>>8; // set baud rate

    UBRRL = (((F_CPU/BAUD_RATE)/16)-1);    //solve the value loaded into
UBRR register


    DDRD &= ~(1 << PD2);        // INT0: input...

    PORTD |= (1 << PD2);        // ...with pullup.




    MCUCR &= ~((1 << ISC01) | (1 << ISC00));

    GIMSK = (1 << INT0); //INT0: External Interrupt Request 0 Enable

    sei();
```

```
unsigned char ch=0;

 while (1)
 {
   sei();
   PORTB=0xff;
   GIMSK |= (1 << INT0);

   set_sleep_mode(SLEEP_MODE_PWR_DOWN);  //  set  microcontroller
to sleep mode

   sleep_mode();

   GIMSK &= ~(1 << INT0);
   cli();
   PORTB=0xFF;

   while (!(UCSRA & (1<<RXC)));
   ch=UDR;     //put data into buffer, sends the data
```

```
        if(ch=='a') //set password as 'a'
        {
            PORTB=0; // trigger buzzer for 1 second
            _delay_ms(1000);
        }
    }

}

    ISR(INT0_vect)
    {
    }
```