

Arduino Introduction

Overview

What is Arduino?

Arduino is a tool for making computers that can sense and control more of the physical world than your desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board.

Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can be communicated with software running on your computer (e.g. Flash, Processing, MaxMSP.) The boards can be assembled by hand or purchased preassembled; the open-source IDE can be downloaded for free.

The Arduino programming language is an implementation of Wiring, a similar physical computing platform, which is based on the Processing multimedia programming environment.

Feature

- Schematic design of the open source development interface free download, and also according to the needs of their own changes
- Download the program is simple and convenient.
- Simply with the sensor, a wide range of electronic components connection (such as: LED light, buzzer, keypad, photoresistor, etc.), make all sorts of interesting things.
- Using the high-speed micro-processing controller (ATMEGA328).
- The development of language and development environment is very simple, easy to understand, very suitable for beginners to learn.

Performance

- Digital I/O 0~13.
- Analog I/O 0~5.(R3 is 0~7)
- Support ISP download function.
- Input voltage: when connected to the USB without external power supply or external 5 v ~ 9 v dc voltage input. Output voltage: 5 V dc voltage output and 3.3 V dc voltage output and external power input.
- Atmel Atmega328 micro-processing controller. Because of its many supporters, the company has developed 32-bit MCU arduino platform support.
Arduino size: width of 70 mm X high 54 mm.

Special Port

1. **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can

supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

2. **AREF.** Reference voltage for the analog inputs. Used with `analogReference()`.

SainSmart UNO R3

What's UNO R3?

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

Performance

Revision 3 is the last SainSmart UNO development board version.

Parameter

- 3.3V/5V Supply Voltage and IO Voltage can be switched at the same time.
- More 3.3V modules supported, such as Xbee module, Bluetooth module, RF module, GPRS module, GPS module, LCD5110 Backlight and so on, but the original version can only support 5V IO.
- Controller uses SMD MEGA328P-AU chip. Add A6/A7 port.
- 5V Electric current : 500MA
- 3.3V Electric current : 50MA
- Input Voltage: 7-12V

Improvement of R3

- Working voltage 3.3V/5V is optional.
- Arduino can only work at 5V voltage. When it comes to 3.3V Level module, IO can't be connected to it. The Level should be changed, like the SD card, Bluetooth module and so on.
- Sainsmart UNO R3 can work at 3.3V voltage by switching on the button. At this time, IO port is 3.3V and it can work with 3.3V Level module. (R3 can directly use the electronic building blocks on I / O port and elicit G, V, S)

Arduino C Grammar

Arduino grammar is built on the basis of C/C + +, in fact is also the basic C grammar, Arduino grammar not only put some related parameters Settings are function change, we have no need to understand his bottom, let us to know AVR micro control unit (MCU) friend can also easy to fit in. So here I'll simple comment the Arduino grammar.

Control Structures

If
if...else
for
switch case
while
do... while
break
continue
return
goto

Further Syntax

;
{
/
/* */

Operators

++
--
+=
-=
*=
/=
=
+
-
*
/
%
==
!=
<
>
<=



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>=
&&
||
!

Data type

boolean
char
byte
int
unsigned int
long
unsigned long
float
double
string
array
void

Constant

HIGH | LOW Said digital IO port level, HIGH Said high level(1), LOW Said low electric flat(0).

INPUT | OUTPUT Said digital IO port direction, INPUT Said input (high impedance state)

OUTPUT Said output (AVR can provide 5 v voltage and ma current).

TURE | FALSE true(1) , false(0) .

All above are the basic c grammar words and symbols, everybody can understand, and the specific use can combine experimental procedure.

Structure

- **void setup()**

The setup() function is called when a sketch starts. Use it to initialize variables, pin modes, start using libraries, etc. The setup function will only run once, after each power up or reset of the Arduino board.

- **void loop()**

After creating a setup() function, which initializes and sets the initial values, the loop() function does precisely what its name suggests, and loops consecutively, allowing your program to change and respond. Use it to actively control the Arduino board.

Function

- **Digital I/O**

pinMode(pin, mode) pin 0~13, mode is input or output.

digitalWrite(pin, value) pin 0~13, value is HIGH or LOW.

int digitalRead(pin) pin 0~13, value is HIGH or LOW.

- **Analog I/O**

int analogRead(pin) pin 0~5.

analogWrite(pin, value) pin 3, 5, 6, 9, 10, 11, value is 0 to 255

Time

delay(ms) Pauses the program for the amount of time (in milliseconds) specified as parameter. (There are 1000 milliseconds in a second.)(unit ms).

delayMicroseconds(us)

Math

min(x, y) minimum value

max(x, y) maximum value

abs(x) absolute value

constrain(x, a, b) Constraint function, lower limit a upper limit b, x must be between a & b to be returned

map(value, fromLow, fromHigh, toLow, toHigh)

pow(base, exponent) extraction of square root

sq(x) square

sqrt(x) Square root

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Chapter 1 Hello World!

In this chapter, we will learn use Arduino IDE serial interface tools to show the contents that we want to display in the computer.

Example code:

```
void setup()
{
  Serial.begin(9600); // opens serial port, sets data rate to 9600 bps
  Serial.println("Hello World!");
}

void loop()
{
}
```

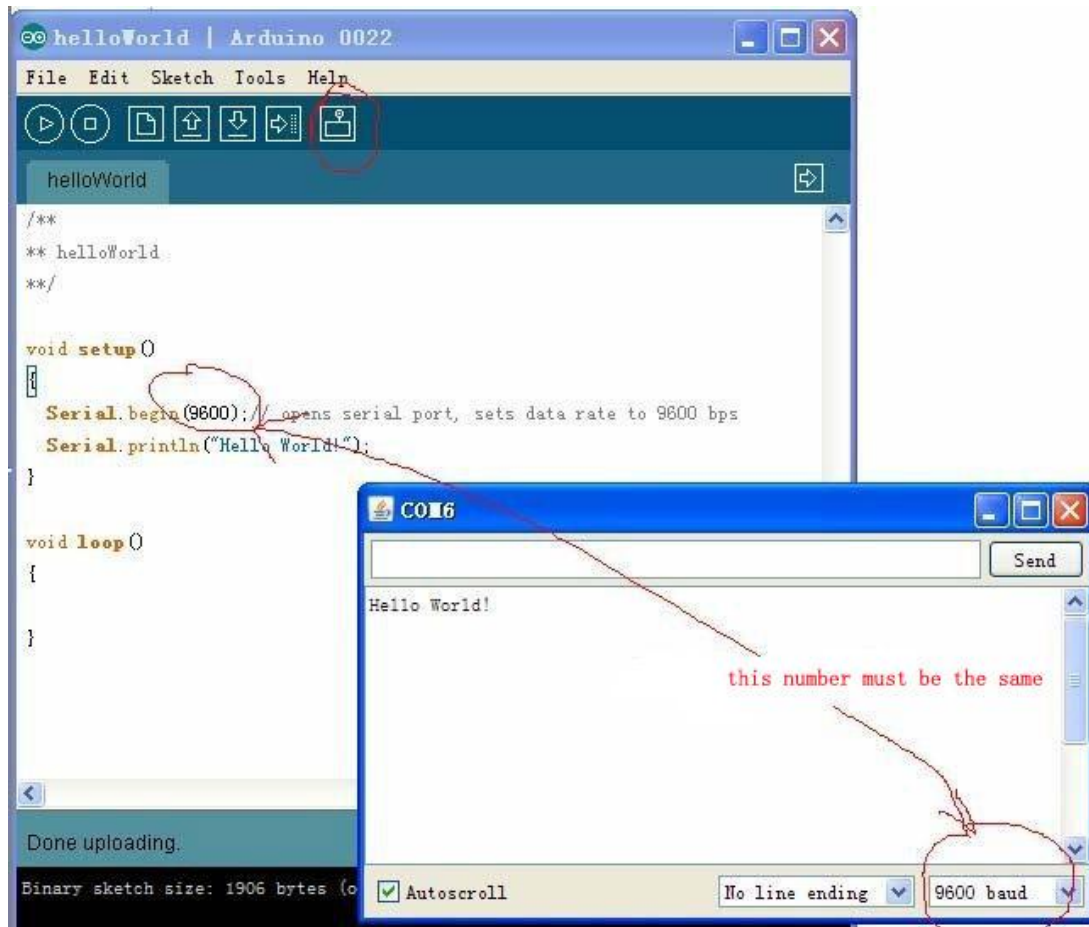
Explain:

Serial.begin(9600); The comment says 9600 bps, and just so you know bps stands for bits-per-second (we will refer to this as the baud rate). Communicate with computer, you may choose these rate "300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 38400, 57600, 115200".

Operation:

- 1) Download code to arduino.
- 2) After download, click "tool", pick up relevant arduino board, and relevant com. Then click "serial Monitor", on the new open up window's bottom right, choose the relevant rate.

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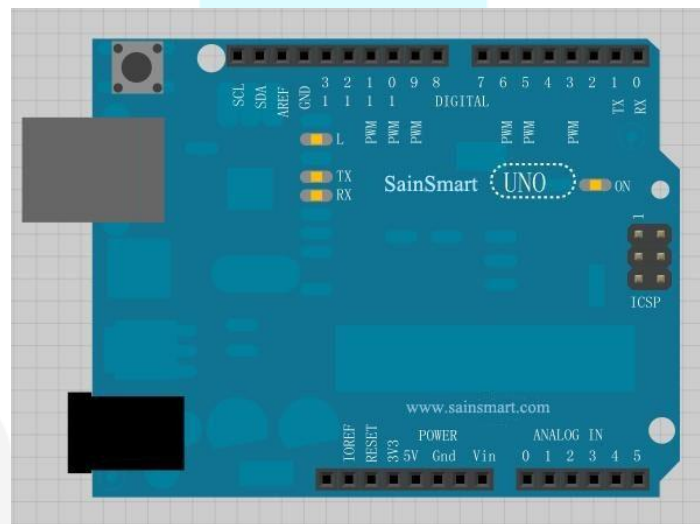
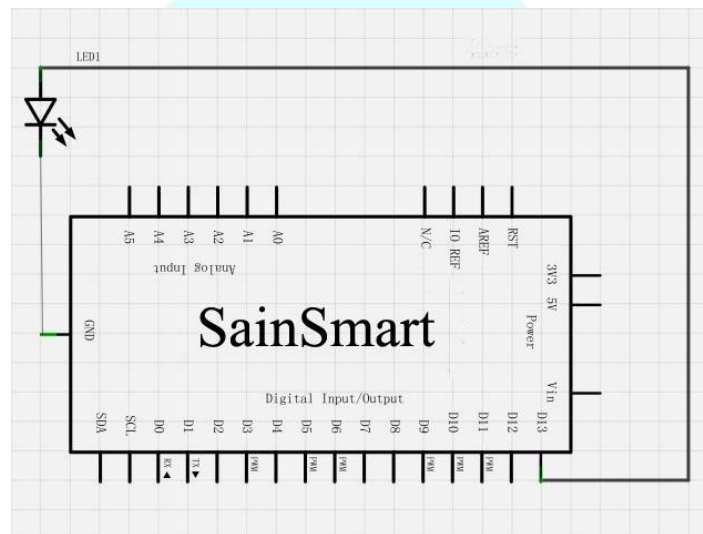


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Chapter 2 Blink LED

Small LED lamp experiment is the basis of comparison of the experimental one, this time we use the motherboard comes with 13 feet of LED lights to complete the experiment, the experimental equipment we need is the Arduino which each experiment must have and USB download cable.

Next we connect small lamp in accordance with the following experimental schematic physical map.



Accordance with the good circuit after the link above figure, you can start writing programs, and we let the small LED lights flashing. Lighting on for one second and off for one second. This program is very simple. This is Arduino own routines Blink.

Example code:

```
int ledPin = 13; // define pin 13
void setup ()
{
```



```
pinMode (ledPin, OUTPUT); // define interface is output
}
void loop ()
{
digitalWrite (ledPin, HIGH); // light up led lamp
delay (1000); // delay 1s
digitalWrite (ledPin, LOW); // go out led lamp
delay (1000); // delay 1s
}
```

After downloading the program, you can see our 13-foot LED lights flashing, so that our small lights flicker experiment is complete.



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Chapter3 LED Blink

light emitting diode

What's light emitting diode?

The light emitting diode referred to as LED. By gallium (Ga) and arsenic (AS) and phosphorus (P) made of a compound of the diode, when the electron and hole recombination can radiate visible light, and thus can be used to prepare a light-emitting diode in the circuit and the instrument as the indicator, or the composition of the text or digital display. Ga As P diode hair red, gallium phosphide diode green silicon carbide diode yellow.

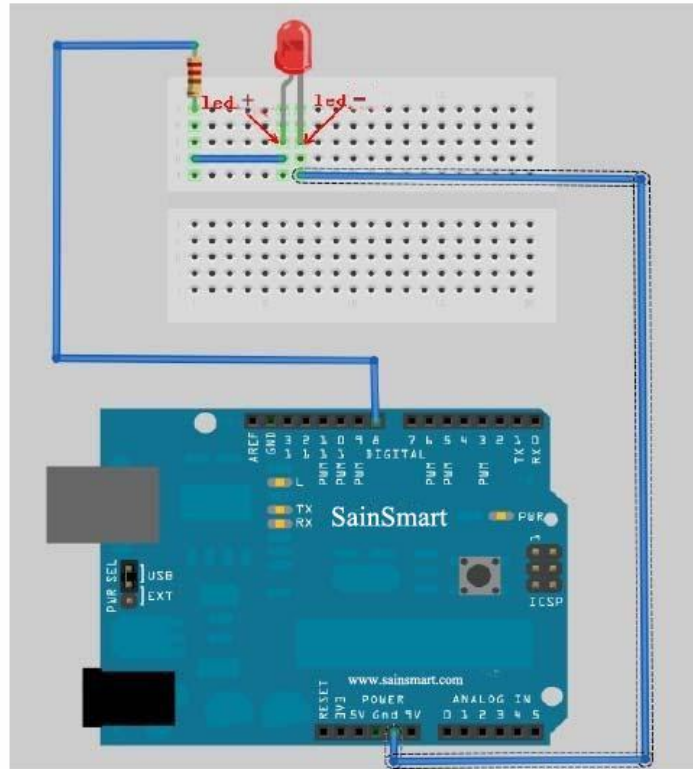


A flashing LED lights experiment

Experiment component

- LED lamp : 1
- 220 Ω resistor : 1
- Breadboard & Jumper wires

Connect your circuit as the below diagram



Example code:

```
int ledPin=8; //set IO pin of LED in control
void setup()
{
    pinMode(ledPin,OUTPUT);//set digital pin IO is OUTPUT
}
void loop()
{
    digitalWrite(ledPin,HIGH); //set PIN8 is HIGH , about 5V
    delay(1000); //delay 1000ms, 1000ms = 1s
    digitalWrite(ledPin,LOW); //set PIN8 is LOW, 0V
    delay(1000); //delay 1000ms, 1000ms = 1s
}
```

setup()

The setup() function is called when a sketch starts. Use it to initialize variables, pin modes, start using libraries, etc. The setup function will only run once, after each powerup or reset of the Arduino board.

loop()

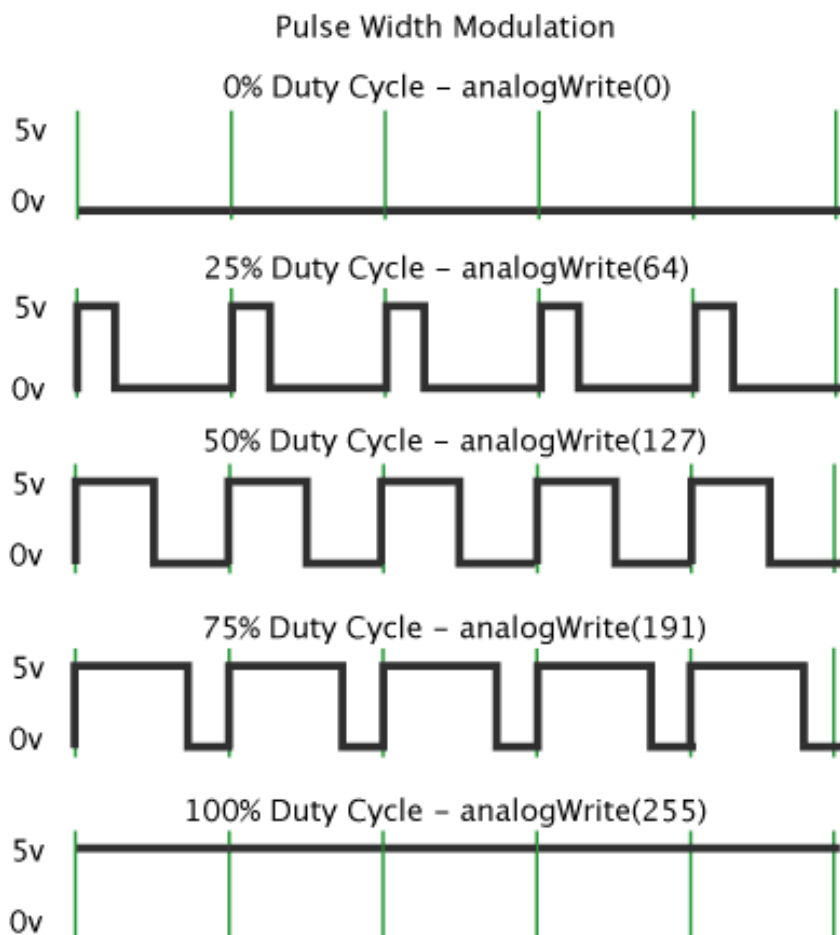
After creating a setup() function, which initializes and sets the initial values, the loop() function does precisely what its name suggests, and loops consecutively, allowing your program to change and respond. Use it to actively control the Arduino board.

Chapter4 PWM

What's PWM?

Pulse Width Modulation, or PWM, is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off. This on-off pattern can simulate voltages in between full on (5 Volts) and off (0 Volts) by changing the portion of the time the signal spends on versus the time that the signal spends off. The duration of "on time" is called the pulse width. To get varying analog values, you change, or modulate, that pulse width. If you repeat this on-off pattern fast enough with an LED for example, the result is as if the signal is a steady voltage between 0 and 5v controlling the brightness of the LED.

In the graphic below, the green lines represent a regular time period. This duration or period is the inverse of the PWM frequency. In other words, with Arduino's PWM frequency at about 500Hz, the green lines would measure 2 milliseconds each. A call to `analogWrite()` is on a scale of 0 - 255, such that `analogWrite(255)` requests a 100% duty cycle (always on), and `analogWrite(127)` is a 50% duty cycle (on half the time) for example.



For the Arduino, you write a value from 0 to 255 on a PWM pin, and the Arduino library will cause the pin to output a PWM signal whose on time is in proportion to the value written.

When it comes time for us to actually write an output voltage, the 0-255 value lacks meaning. What we want in many cases is a voltage. For our purposes, we will assume the Arduino is

running at $V_{cc} = 5$ volts. In that case, a value of 255 will also be 5 volts. We can then easily convert the desired voltage to the digital value needed using simple division. We first divide the voltage we want by the 5 volts maximum. That gives us the percentage of our PWM signal. We then multiply this percentage by 255 to give us our pin value. Here is the formula:

Pin Value (0-255) = $255 * (\text{AnalogWrite} / 5)$;

Arduino use analogWrite()

analogWrite() : Writes an analog value (PWM wave) to a pin. Can be used to light a LED at varying brightnesses or drive a motor at various speeds. After a call to analogWrite(), the pin will generate a steady square wave of the specified duty cycle until the next call to analogWrite() (or a call to digitalRead() or digitalWrite() on the same pin). The frequency of the PWM signal is approximately 490 Hz.

On most Arduino boards (those with the ATmega168 or ATmega328), this function works on pins 3, 5, 6, 9, 10, and 11. On the Arduino Mega, it works on pins 2 through 13. Older Arduino boards with an ATmega8 only support analogWrite() on pins 9, 10, and 11. The Arduino Due supports analogWrite() on pins 2 through 13, plus pins DAC0 and DAC1. Unlike the PWM pins, DAC0 and DAC1 are Digital to Analog converters, and act as true analog outputs. You do not need to call pinMode() to set the pin as an output before calling analogWrite(). The analogWrite function has nothing to do with the analog pins or the analogRead function.

Syntax

analogWrite(pin, value)

Parameters

pin: the pin to write to.

value: the duty cycle: between 0 (always off) and 255 (always on).

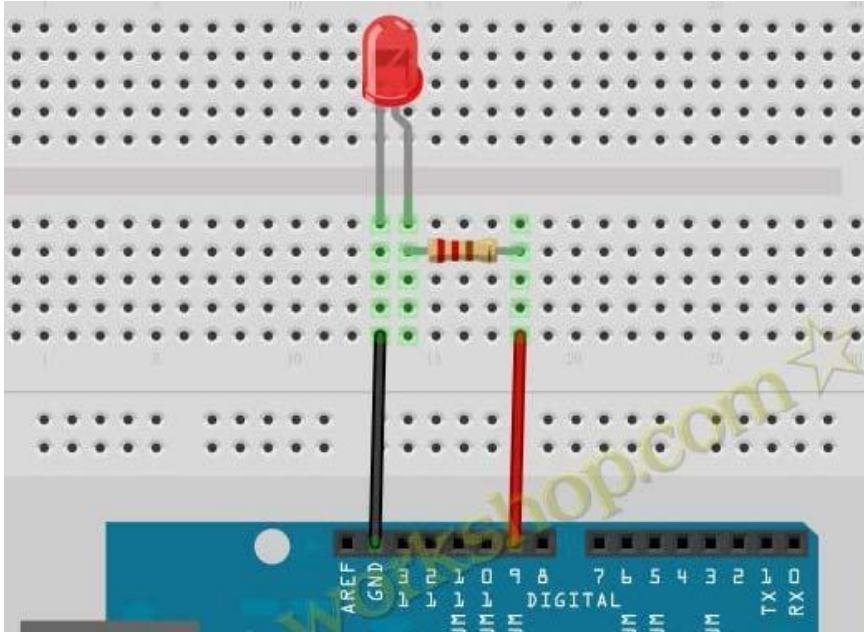
Notes and Known Issues

The PWM outputs generated on pins 5 and 6 will have higher-than-expected duty cycles. This is because of interactions with the millis() and delay() functions, which share the same internal timer used to generate those PWM outputs. This will be noticed mostly on low duty-cycle settings (e.g 0 - 10) and may result in a value of 0 not fully turning off the output on pins 5 and 6.

Experiment component:

1. 1 x 220Ω resistor
2. 1 x LED
3. 1 x Breadboard

Connect your circuit as the below diagram.



Example code:

```
int brightness = 0;    //define original value of brightness, the value is brightness of LED.
int fadeAmount = 5;   //define fadeAmount, the value is the amount of brightness variations'
change.

void setup() {
  pinMode(9, OUTPUT); // set pin9 is output
}

void loop() {

  analogWrite(9, brightness); //write the value of brightness in pin9

  brightness = brightness + fadeAmount; //change the value of brightness

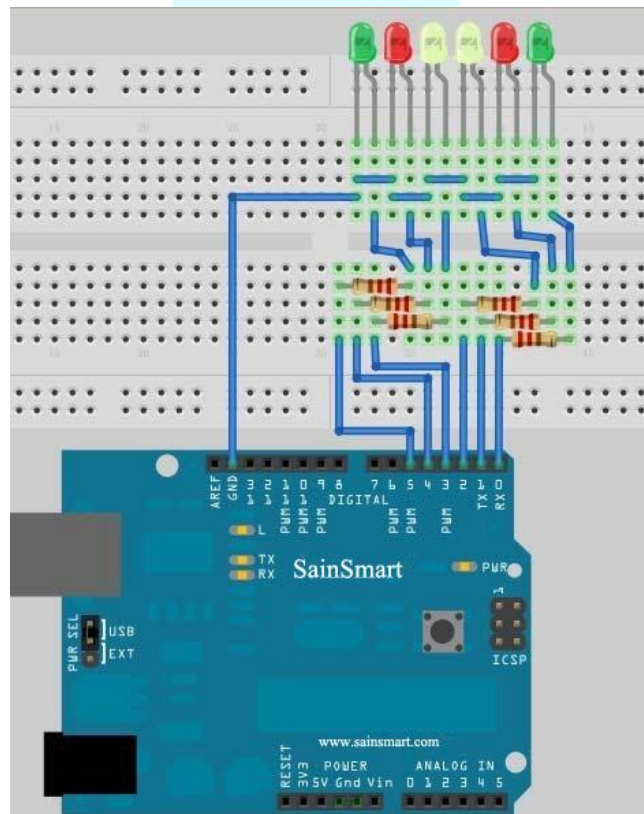
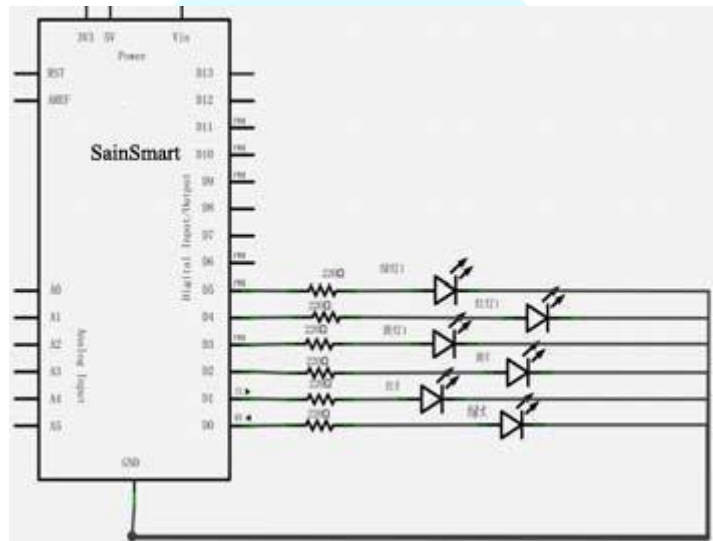
  if (brightness == 0 || brightness == 255) {
    fadeAmount = -fadeAmount ; // roll over the brightness between the highest and
lowest
  }
  delay(30); //delay 30ms
}
```

Chapter5 Advertising LED

Experiment component:

- LED lamp: 6
- 220Ω resistors: 6
- Breadboard & Jumper wires

Connect your circuit as the below diagram.



Example code

Program code is in the advertising lights program folder. Double-click to open and you will see a led2 folder, open it, you will find out a led2.pde file. Double-click the icon to open it. Then you will see that it is the arduino programming software window with the experimental program code.

```
//set in Led's digital IO pin control
int Led1 = 1;
int Led2 = 2;
int Led3 = 3;
int Led4 = 4;
int Led5 = 5;
int Led6 = 6;
//led lamp run the example 1 program
void style_1(void)
{
  unsigned char j;
  for(j=1;j<=6;j++)//every 200ms light up one of led lamps with 1~6 pin in turn
  {
    digitalWrite(j,HIGH);//light up the led lamps with j pin
    delay(200);//delay 200ms
  }
  for(j=6;j>=1;j--)//every 200ms got out one of led lamps with 6~1 pin in turn
  {
    digitalWrite(j,LOW);//go out the led lamps with j pin
    delay(200);//delay 200ms
  }
}
//led lamp blink example program
void flash(void)
{
  unsigned char j,k;
  for(k=0;k<=1;k++)//blink twice
  {
    for(j=1;j<=6;j++)//light up led lamps with 1~6 pin
    {
      digitalWrite(j,HIGH);//light up led lamp with j pin
      delay(200);//delay 200ms
    }
    for(j=1;j<=6;j++)//go out the led lamp with 1~6 pin
    {
      digitalWrite(j,LOW);//go out the led lamp with j pin
      delay(200);//delay 200ms
    }
  }
}
//led lamp run the example 2 program
void style_2(void)
{
  unsigned char j,k;
```



```
k=1;//set k is 1
for(j=3;j>=1;j--)
{
    digitalWrite(j,HIGH);//light up
    digitalWrite(j+k,HIGH);//light up
    delay(400);//delay 400ms
    k +=2;//k plus 2
}
k=5;//set k is 5
for(j=1;j<=3;j++)
{
    digitalWrite(j,LOW);//go out
    digitalWrite(j+k,LOW);//go out
    delay(400);//delay 400ms
    k -=2;//k sub 2
}
}
// led lamp run the example 3 program
void style_3(void)
{
    unsigned char j,k;//led lamp run the example 3 program
    k=5;//set k is 5
    for(j=1;j<=3;j++)
    {
        digitalWrite(j,HIGH);//light up
        digitalWrite(j+k,HIGH);//light up
        delay(400);//delay 400ms
        digitalWrite(j,LOW);//go out
        digitalWrite(j+k,LOW);//go out
        k -=2;//k sub 2
    }
    k=3;//set k is 3
    for(j=2;j>=1;j--)
    {
        digitalWrite(j,HIGH);//light up
        digitalWrite(j+k,HIGH);//light up
        delay(400);//delay 400ms
        digitalWrite(j,LOW);//go out
        digitalWrite(j+k,LOW);//go out
        k +=2;//k plus 2
    }
}
void setup()
{
```

```
unsigned char i;
for(i=1;i<=6;i++)//set 1~6 pin output in turn
  pinMode(i,OUTPUT);//set i pin output
}
void loop()
{
  style_1();//example 1
  flash();//blink
  style_2();//example 2
  flash();//blink
  style_3();//example 3
  flash();//blink
}
```

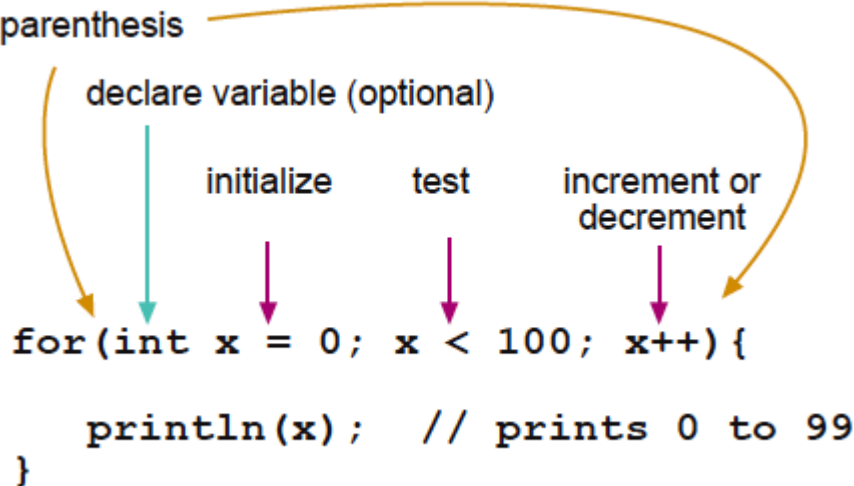
Example code used: `for(i=1;i<=6;i++)//set 1~6 pin output in turn
pinMode(i,OUTPUT);//set i pin output`

The “for” statement is used to repeat a block of statements enclosed in curly braces. An increment counter is usually used to increment and terminate the loop. The for statement is useful for any repetitive operation, and is often used in combination with arrays to operate on collections of data/pins.

There are three parts to the for loop header:

```
for (initialization; condition; increment) {  
  //statement(s);  
}
```

parenthesis



```
for(int x = 0; x < 100; x++) {  
  println(x); // prints 0 to 99  
}
```

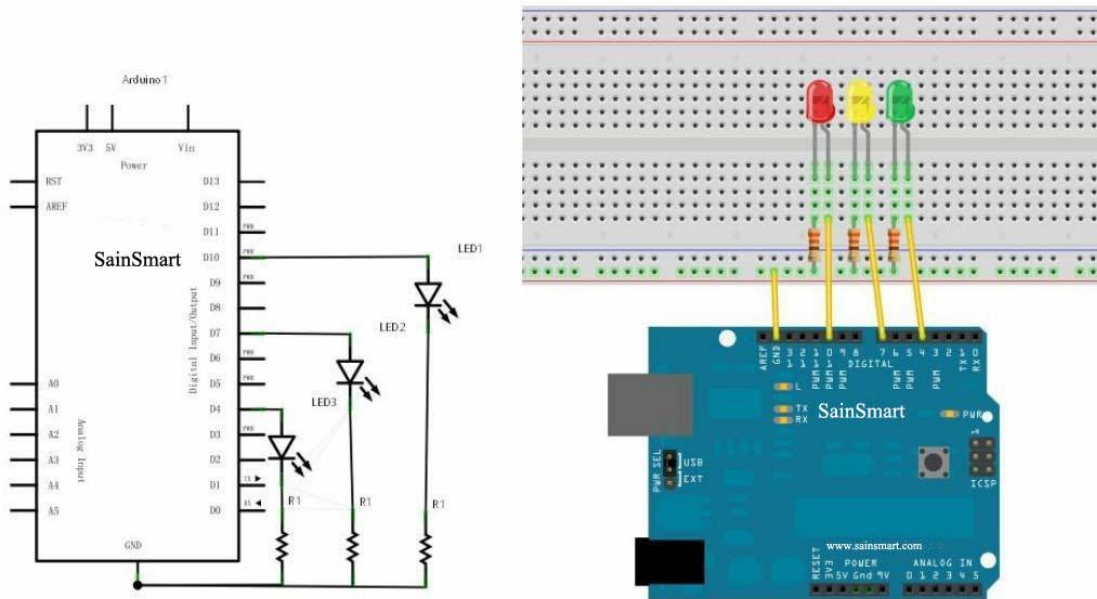
The initialization happens first and exactly once. Each time through the loop, the condition is tested; if it's true, the statement block, and the increment is executed, then the condition is tested again. When the condition becomes false, the loop ends.

Chapter6 Traffic light

Experiment component:

- Red , Green , Yellow led lamp: 3
- 220Ω resistor: 3
- Breadboard & Jumper wires

Connect your circuit as the below diagram.

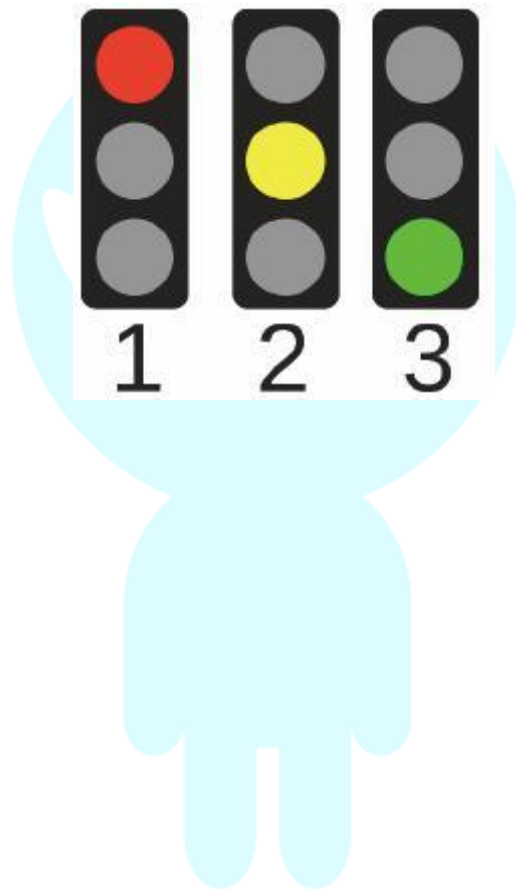


Example code:

Program code is in the traffic lights program folder. Double-click to open and you will find out a trafficLed.pde file. Double-click the icon to open it. Then you will see that it is the arduino programming software window with the experimental program code.

```
int ledred=10; //define digital pin10 red
int ledyellow=7; //define digital pin7 yellow
int ledgreen=4; //define digital pin4 green
void setup()
{
  pinMode(ledred,OUTPUT);//set red pin output
  pinMode(ledyellow,OUTPUT);// set yellow pin output
  pinMode(ledgreen,OUTPUT);// set green pin output
}
void loop()
{
  digitalWrite(ledred,HIGH);//light up red lamp
  delay(1000);//delay 1000 ms = 1 s
  digitalWrite(ledred,LOW);//go out red lamp
```

```
digitalWrite(ledyellow,HIGH);//light up yellow lamp  
delay(200);//delay 200 ms//  
digitalWrite(ledyellow,LOW);//go out  
digitalWrite(ledgreen,HIGH);//light up green lamp  
delay(1000);//delay 1000 ms  
digitalWrite(ledgreen,LOW);//go out  
}
```



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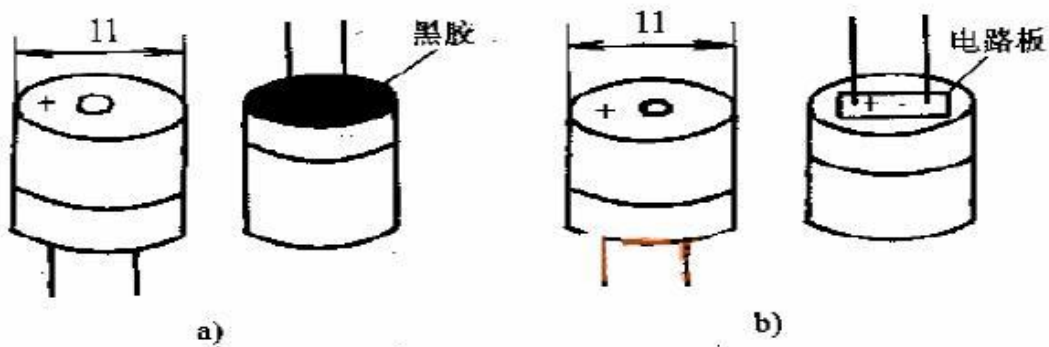
Chapter7 Buzzer

What's buzzer?

The buzzer is one integrated electronic transducers, DC voltage supply, widely used in computers, printers, copiers, alarm, electronic toys, automotive electronic equipment, telephones, timers and other electronic products for sound devices.



They can be divided into the: active buzzer (containing driver line) and passive buzzer (external drive) in their drive different way, teach you to distinguish between active buzzer and passive buzzer. A small buzzer for sale on the market now because of its small size (diameter is only 11mm), light weight, low price, solid structure, while widely used in various electrical equipment with sound, electronic production and microcontroller circuits. Appearance of active the buzzer and passive buzzer like a, b shown. a) active b) passive.



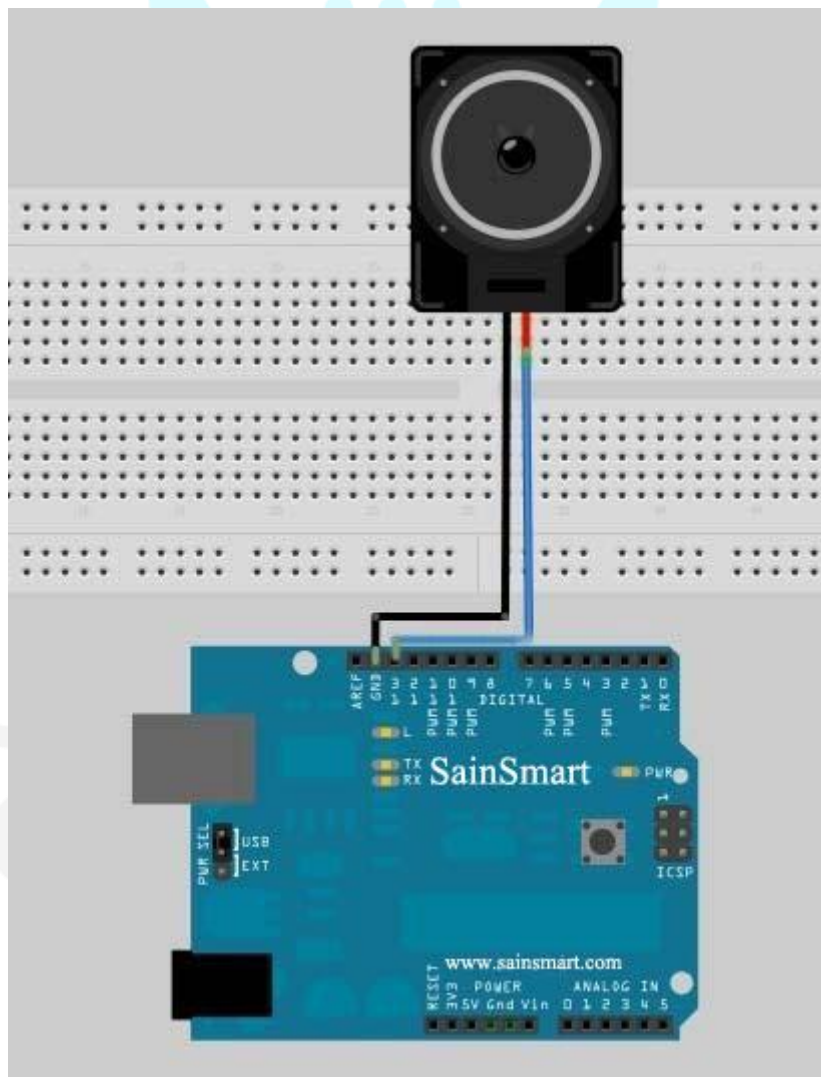
From the figure a, b appearance watching, the two buzzers seems to the same, but a closer look, the height of the two slight difference active buzzer a height of 9mm, passive buzzer b, a height

of 8 mm. As facing up to two buzzers' pin County it can be seen that there are a green circuit board is passive buzzer, no circuit board using vinyl enclosed one is active buzzer. Further determine the active and passive buzzer multimeter resistance profile Rxl file test: use a black pen touch buzzer's pin "+", red pen touch in the other pin back and forth, If you feel a click, cracking sound and resistance is only 8Ω

(Or 16Ω) which is a passive buzzer; continuing sound can issue, and the resistance is more than hundreds of Europe that is active buzzer. Active buzzer directly connected to the rated power (indicate on the new buzzer's label) can be continuous sound; rather passive buzzer and electromagnetic speaker needs to be connected to the audio output circuit can vocalization. Buzzer also can be divided into according to the constructed different,: the electromagnetic buzzer and piezoelectric buzzer;

Connect your circuit as the below diagram.

The buzzer used in this experiment with the internal drive. Circuit the buzzer positive connect directly into the digital port 13. GND socket connected to the negative terminal of the buzzer.



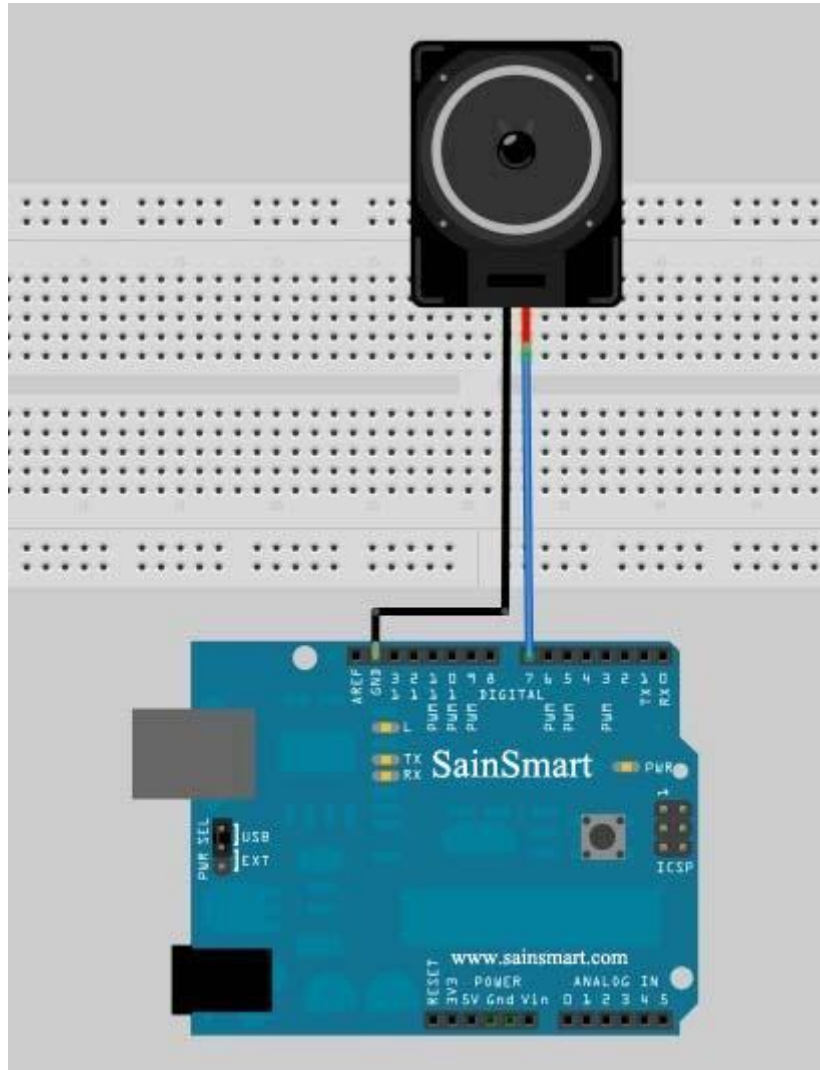
Buzzer analog ambulance siren sound experiment

Experiment component:

Buzzer : 1

Breadboard & Jumper wires

Connect your circuit as the below diagram.



Example code

```
int buzzer=7;//set buzzer's digital pin IO in control
void setup()
{
  pinMode(buzzer,OUTPUT);//set digital pin IO OUTPUT
}
void loop()
{
  unsigned char i,j;//define i j
  while(1)
  {
    for(i=0;i<80;i++)// Output a frequency of sound
```

```
    {
    digitalWrite(buzzer,HIGH);//sound
    delay(1);//delay 1ms
    digitalWrite(buzzer,LOW);//mute
    delay(1);//delay 1ms
    }
    for(i=0;i<100;i++)// Output the other frequency of sound
    {
    digitalWrite(buzzer,HIGH);//sound
    delay(2);//delay 2ms
    digitalWrite(buzzer,LOW);//mute
    delay(2);//delay 2ms
    }
}
```

while loops

Description

while loops will loop continuously, and infinitely, until the expression inside the parenthesis, () becomes false. Something must change the tested variable, or the while loop will never exit. This could be in your code, such as an incremented variable, or an external condition, such as testing a sensor.

Syntax

```
while(expression){
    // statement(s)
}
```

Parameters

expression - a (boolean) C statement that evaluates to true or false

Example

```
var = 0;
while(var < 200){
    // do something repetitive 200 times
    var++;
}
```


Chapter8 Tilt switch

What's Tilt Sensor?

The tilt sensor is a component that can detect the tilting of an object. However it is only the equivalent to a pushbutton activated through a different physical mechanism. This type of sensor is the environmental-friendly version of a mercury-switch. It contains a metallic ball inside that will commute the two pins of the device from on to off and viceversa if the sensor reaches a certain angle.



Tilt switch controls led lamp light & out

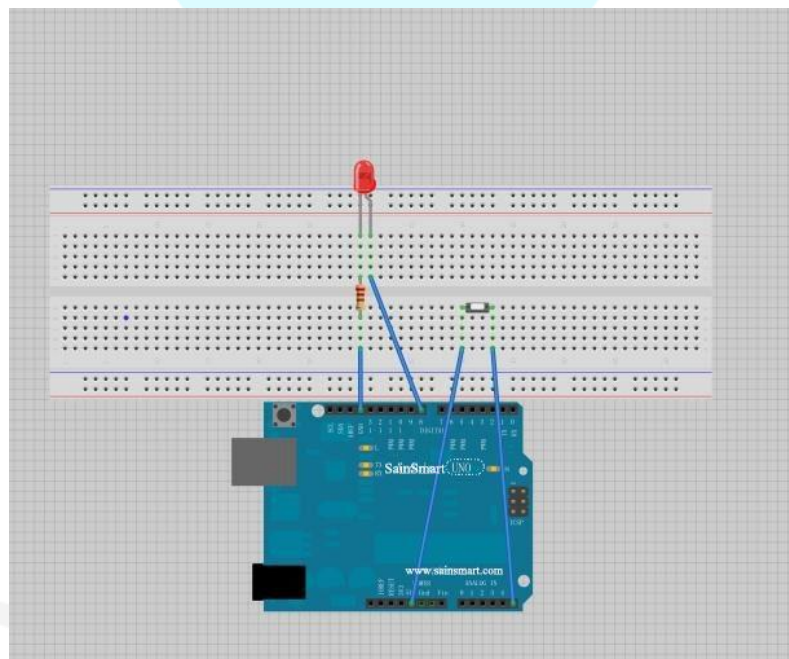
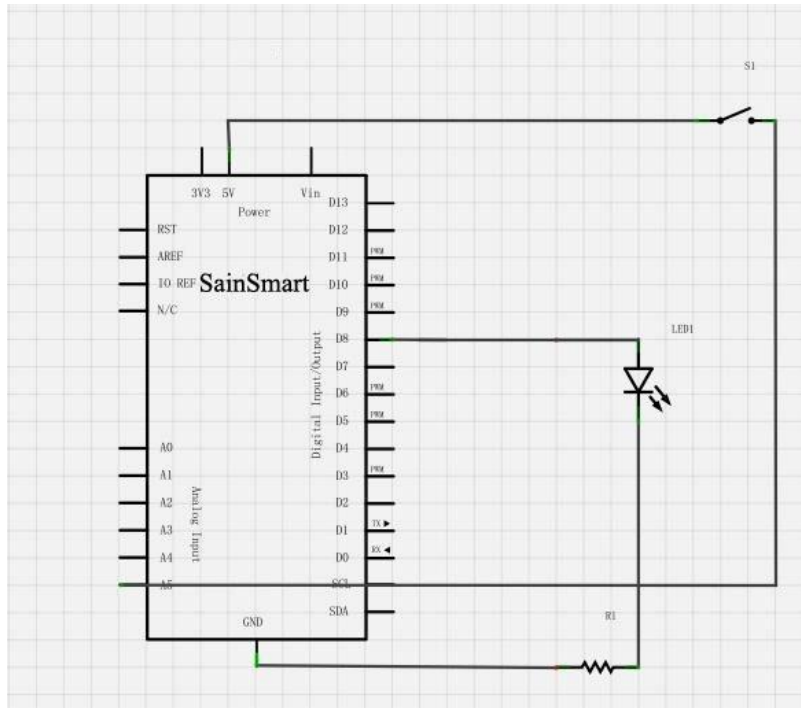
Experiment component:

Tilt sensor : 1

Breadboard & Jumper wires

Connect your circuit as the below diagram.

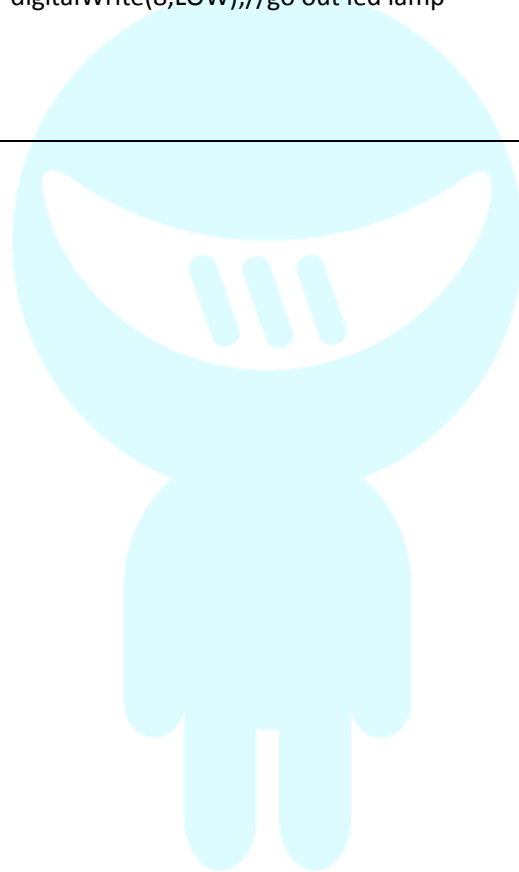
Tilt switch connect to analog pin.



Example code

```
void setup()
{
    pinMode(8,OUTPUT);//set pin8 output
}
void loop()
{
    int i;//define i
    while(1)
```

```
{
    i=analogRead(5);//read voltage values of pin5
    if(i>200)//if more than 512 ( 2.5V)
    {
        digitalWrite(8,HIGH);//light up led lamp
    }
    else
    {
        digitalWrite(8,LOW);//go out led lamp
    }
}
```



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Chapter9 Potentiometer

What's Analog Pins?

1. A/D converter

The Atmega168 contains an onboard 6 channel analog-to-digital (A/D) converter. The converter has 10 bit resolution, returning integers from 0 to 1023. While the main function of the analog pins for most Arduino users is to read analog sensors, the analog pins also have all the functionality of general purpose input/output (GPIO) pins (the same as digital pins 0 - 13).

Consequently, if a user needs more general purpose input output pins, and all the analog pins are not in use, the analog pins may be used for GPIO.

2. Pin mapping

The Arduino pin numbers corresponding to the analog pins are 14 through 19. Note that these are Arduino pin numbers, and do not correspond to the physical pin numbers on the Atmega168 chip. The analog pins can be used identically to the digital pins, so for example, to set analog pin 0 to an output, and to set it HIGH, the code would look like this:

```
pinMode(14, OUTPUT);  
digitalWrite(14, HIGH);
```

3. Pullup resistors

The analog pins also have pullup resistors, which work identically to pullup resistors on the digital pins. They are enabled by issuing a command such as

```
digitalWrite(14, HIGH); // set pullup on analog pin 0
```

while the pin is an input.

Be aware however that turning on a pullup will affect the value reported by `analogRead()` when using some sensors if done inadvertently. Most users will want to use the pullup resistors only when using an analog pin in its digital mode.

4. Details and Caveats

The `analogRead` command will not work correctly if a pin has been previously set to an output, so if this is the case, set it back to an input before using `analogRead`. Similarly if the pin has been set to HIGH as an output, the pullup resistor will be on, after setting it back to an INPUT with `pinMode`.

The Atmega168 datasheet also cautions against switching digital pins in close temporal proximity to making A/D readings (`analogRead`) on other analog pins. This can cause electrical noise and introduce jitter in the analog system. It may be desirable, after manipulating analog pins (in digital mode), to add a short delay before using `analogRead()` to read other analog pins.

`analogRead()`

- **Description**

Reads the value from the specified analog pin. The Arduino board contains a 6 channel (8 channels on the Mini and Nano, 16 on the Mega), 10-bit analog to digital converter. This means that it will map input voltages between 0 and 5 volts into integer values between 0 and 1023. This yields a resolution between readings of: 5 volts / 1024 units or, .0049 volts (4.9 mV) per unit. The input range and resolution can be changed using `analogReference()`.

It takes about 100 microseconds (0.0001 s) to read an analog input, so the maximum reading rate is about 10,000 times a second.

- **Syntax**

`analogRead(pin)`

- **Parameters**

pin: the number of the analog input pin to read from (0 to 5 on most boards, 0 to 7 on the Mini and Nano, 0 to 15 on the Mega)

- **Returns**

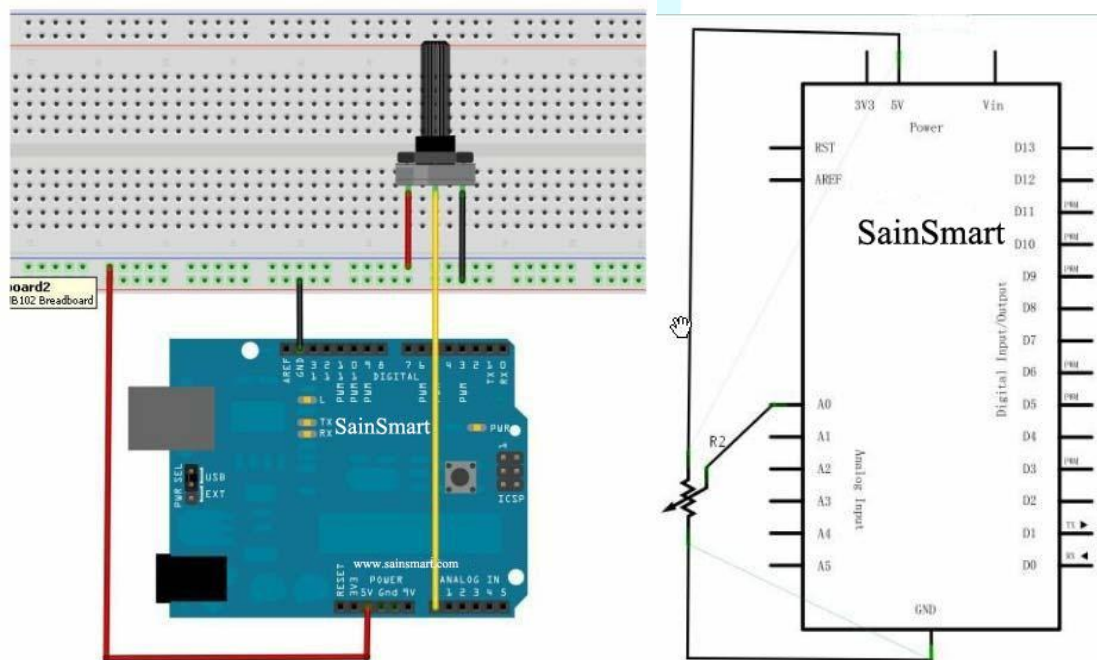
int (0 to 1023)

What's Potentiometer?

A potentiometer is a simple knob that provides a variable resistance, which we can read into the Arduino board as an analog value. In this example, that value controls the rate at which an LED blinks.

We connect three wires to the Arduino board. The first goes to ground from one of the outer pins of the potentiometer. The second goes from 5 volts to the other outer pin of the potentiometer. The third goes from analog input 2 to the middle pin of the potentiometer.

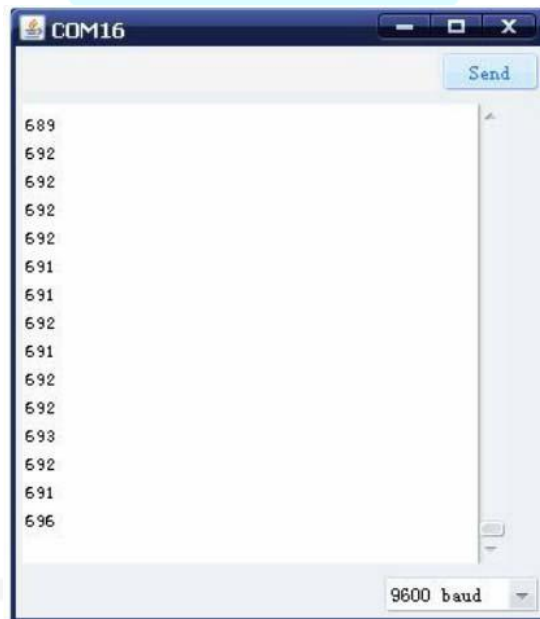
By turning the shaft of the potentiometer, we change the amount of resistance on either side of the wiper which is connected to the center pin of the potentiometer. This changes the relative "closeness" of that pin to 5 volts and ground, giving us a different analog input. When the shaft is turned all the way in one direction, there are 0 volts going to the pin, and we read 0. When the shaft is turned all the way in the other direction, there are 5 volts going to the pin and we read 1023. In between, `analogRead()` returns a number between 0 and 1023 that is proportional to the amount of voltage being applied to the pin.



Example code:

```
int potpin = 0 ; //define analog pin0
int ledpin = 13 ; //define analog pin13
int val = 0 ; //set val is0.

void setup()
{
    pinMode(ledpin,OUTPUT);//set analog pin13 output
    Serial.begin(9600);//set baud rate 9600
}
void loop()
{
    digitalWrite(ledpin,HIGH);//light up led in pin13
    delay(50);//delay 0.05s
    digitalWrite(ledpin,LOW);//go out led in pin13
    delay(50);//delay 0.05s
    val = analogRead(potpin);//give the value of pin0 to val
    Serial.println(val) ; //print val's value
}
```



Chapter10 Photoresistor

What's photoresistor?

Photoresistor, also known as light pipes, common production materials is cadmium sulfide, There are also selenium, aluminum sulfide, lead sulfide and bismuth sulfide material. these production materials having characteristics in light of a specific wavelength, its resistance decreases rapidly. This is due to the light generated carriers are involved in the electrical conductivity, under the applied electric field drift motion, so that the photosensitive resistor rapid decline.

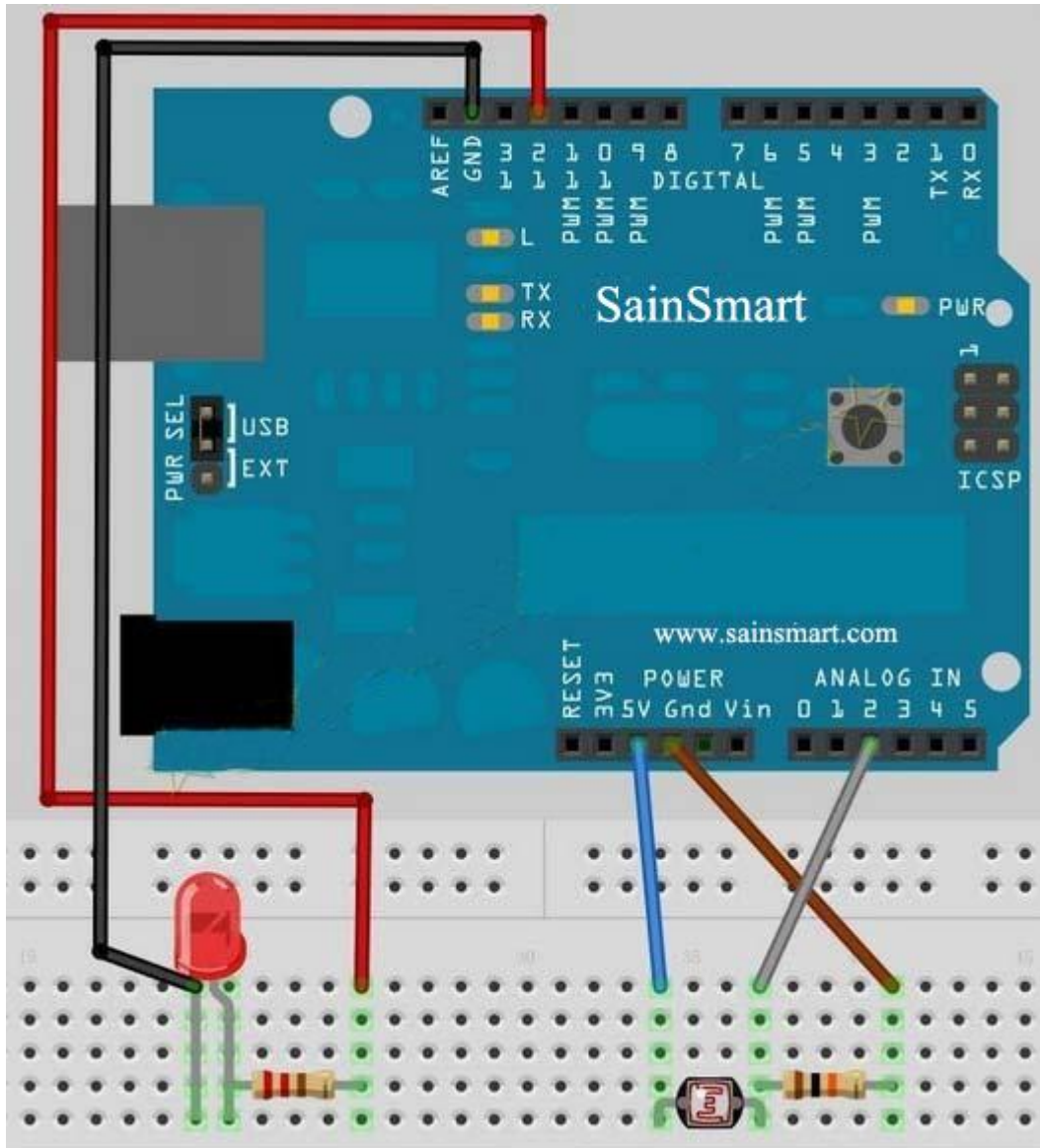


Experiment component

- Photoresistor : 1
- Buzzer : 1
- 10K resistor : 1
- 220 Ω resistor : 1
- Breadboard & Jumper wires

Connect your circuit as the below diagram.

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Example code:

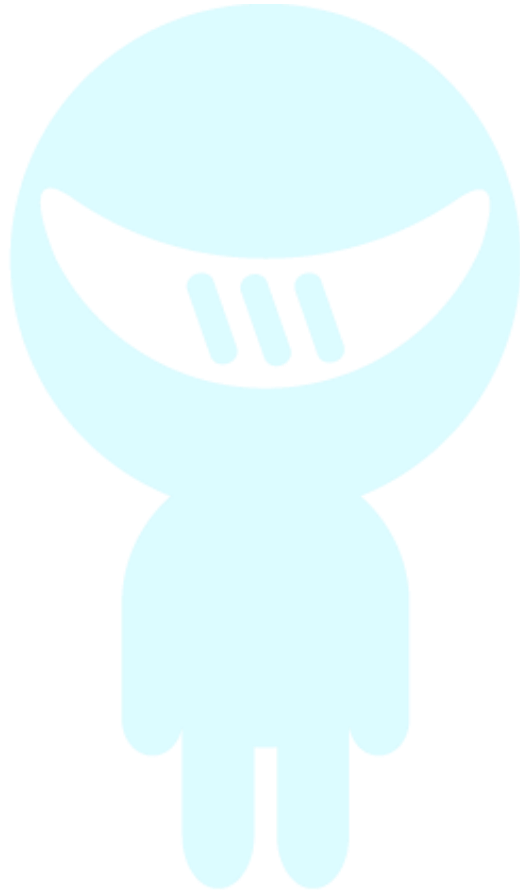
```
int photocellPin = 2;          //define photocellsh=2, read the value of voltage.
int ledPin = 12;              //define ledPin12 is the output port of led's level.
int val = 0;                  //define original of val.

void setup() {
  pinMode(ledPin, OUTPUT);    //set ledPin output
}

void loop() {
  val = analogRead(photocellPin); //get the value from sensor
  if(val<=512){
    //512=2.5V, if want the sensor be more sensitive, increase the number, or lese low the number.
  }
}
```



```
digitalWrite(ledPin, HIGH); //when the value of val is less than 512(2.5V), light up led lamp
}
else{
digitalWrite(ledPin, LOW);
}
}
```



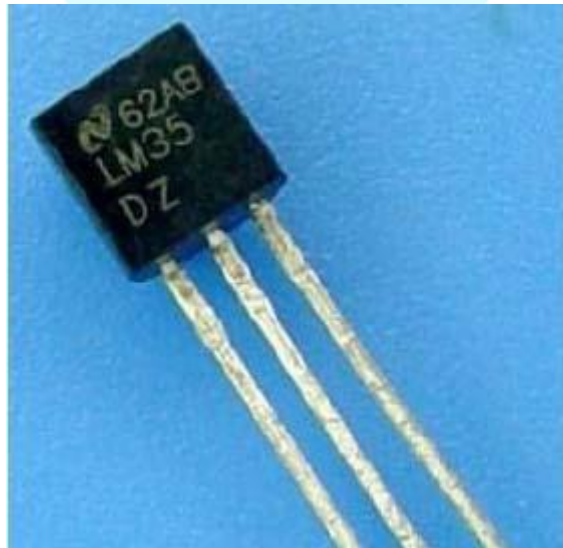
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Chapter11 LM35 temperature sensor

Temperature sensor

What's temperature sensor?

The temperature sensor is that use substances of various physical properties with temperature variation of the sensor and let the temperature converted to electricity. These regularly change the physical properties of the main body temperature sensor is a core part of the temperature measuring instruments, and a wide variety. In accordance with the measurement method is divided into contact and non-contact two major categories, In accordance with the characteristics of sensor materials and electronic components into the thermal resistance and thermocouple. Used in this experiment is the LM35 temperature sensor.



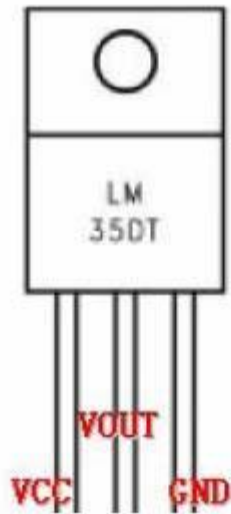
Working principle

LM35 temperature sensor output voltage linear relationship between the Celsius temperature scale. 0 °C, output is 0V, for every 1°C increases in output voltage of 10mV.

$$V_{\text{out_LM35}}(T) = 10 \text{ mV}/^{\circ}\text{C} \times T^{\circ}\text{C}$$

LM35 pin diagram is as follows

Plastic Package*



TO-92 Plastic Package



Out can be seen from experimental cartridge of the temperature sensor, temperature sensor side is flat, and the other side is semicircular. Flat face of our own, the leftmost VCC pin (connected to +5 v), the middle of the GND pin VOUT (voltage value output pin, then the analog pins on the board), and the rightmost pin (connected board GND). Three pins, respectively, then you can use.

Temperature alarm experiment

Experiment component

- LM35 temperature sensor module*1
- Breadboard & jumper wire few

Connection

First ready experimental board; Follow the LM35 temperature sensor connection connected to VOUT is connected to an analog 0. Such temperature alarm experimental circuit connected.

Experimental principle

LM35 temperature sensor works shows that the temperature is increased by 1 ° C vout the mouth output voltage increases 10MV.

According to this principle procedures in real time reading out the analog voltage value of 0, since the analog port reads out a voltage value of 0 to 1023, i.e. 0V corresponding 0,5 V corresponds to 1023.

Application, we only need to LM35 module, analog interface, the read analog value is converted to the actual temperature.

Example code

```
int potPin = 0 ;//define pin0 connect with LM35
void setup()
```

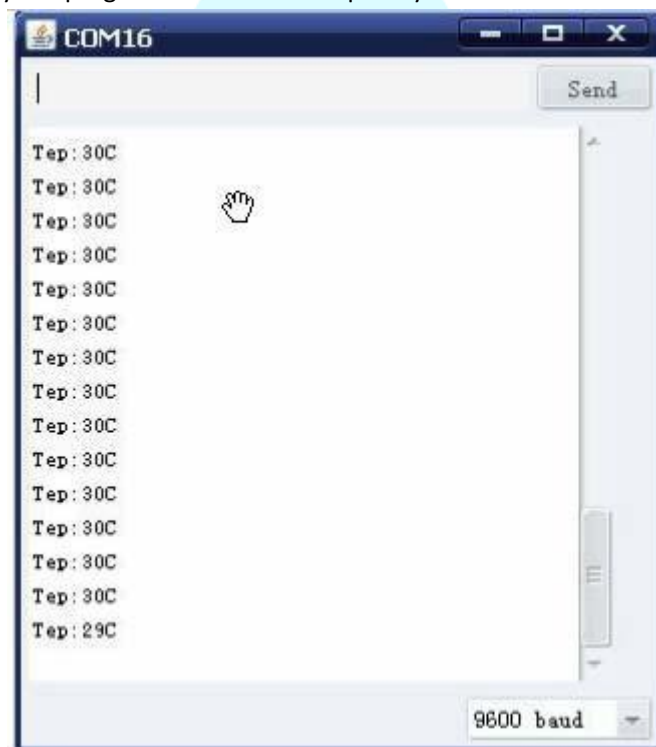
```
{
  Serial.begin(9600);
}
void loop()
{
  int val;
  int dat;

  val = analogRead(potPin);

  dat = (125*val)>>8 ; // Temperature calculation formula
  Serial.print("Tep : "); //print "Tep" means temperature
  Serial.print(dat) ; // print the value of dat
  Serial.println("C"); //print "C" means degree
  delay(500); //delay 0.5s
}
```

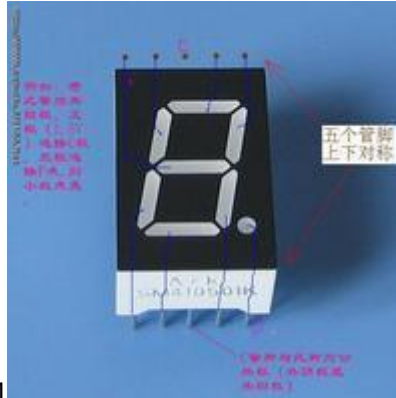
Program function

Download the program to the experimental board, open the monitor, you can see the current ambient temperature. (In fact, the temperature value a little deviation, according to the ambient temperature modify the program so that it is completely consistent with their own environment.)



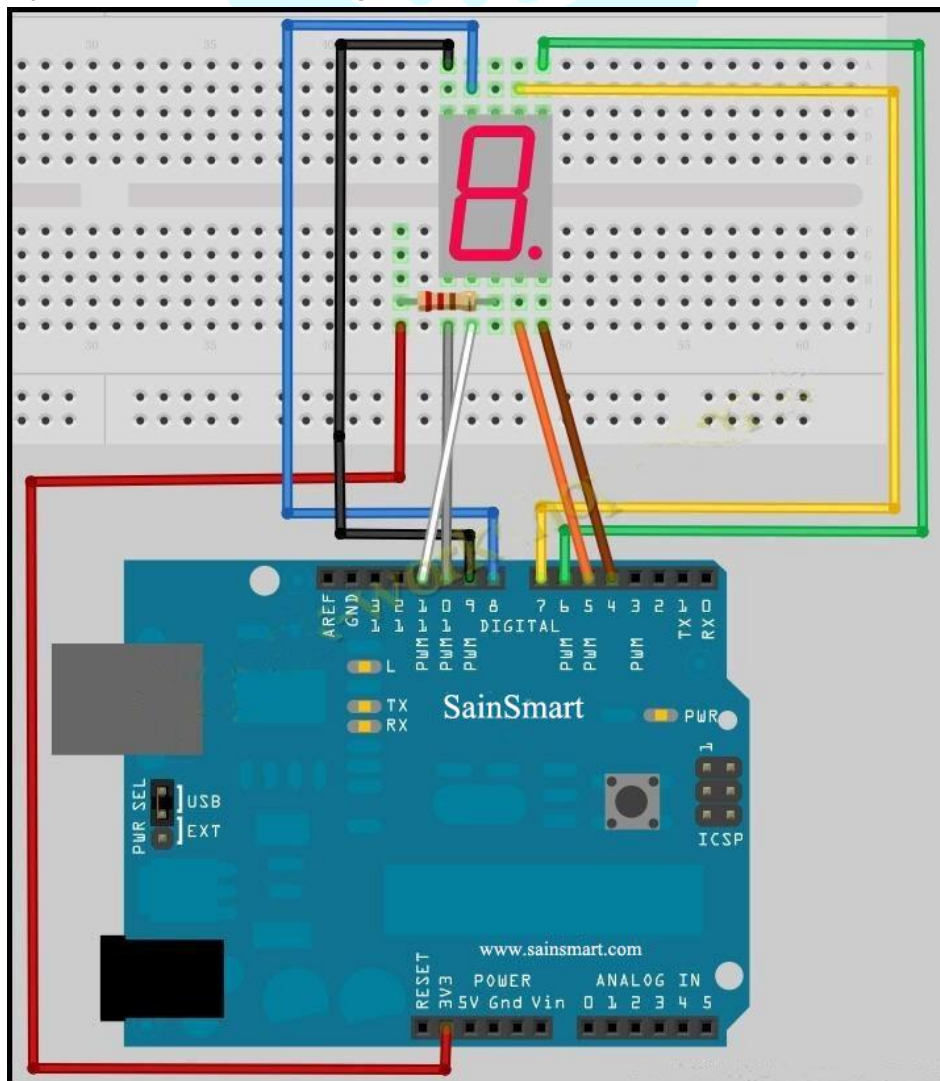
Chapter12 Nixie tube

Experiment component



- digital tube x1
- 220 Ω resistance x4
- Breadboard & jumper wire

Connect your circuit as the below diagram.



Example code

```
int a=7;
int b=6;
int c=5;
int d=11;
int e=10;
int f=8;
int g=9;
int dp=4;
//display number 1
void digital_1(void)
{
    unsigned char j;
    digitalWrite(c,LOW);// pin5 low, light up c
    digitalWrite(b,LOW);//light up b
    for(j=7;j<=11;j++)//go out else
        digitalWrite(j,HIGH);
    digitalWrite(dp,HIGH);//go out decimal point dp
}
//display number2
void digital_2(void)
{
    unsigned char j;
    digitalWrite(b,LOW);
    digitalWrite(a,LOW);
    for(j=9;j<=11;j++)
        digitalWrite(j,LOW);
    digitalWrite(dp,HIGH);
    digitalWrite(c,HIGH);
    digitalWrite(f,HIGH);
}
// display number3
void digital_3(void)
{
    unsigned char j;
    digitalWrite(g,LOW);
    digitalWrite(d,LOW);
    for(j=5;j<=7;j++)
        digitalWrite(j,LOW);
    digitalWrite(dp,HIGH);
    digitalWrite(f,HIGH);
    digitalWrite(e,HIGH);
}
```

```
// display number4
void digital_4(void)
{
    digitalWrite(c,LOW);
    digitalWrite(b,LOW);
    digitalWrite(f,LOW);
    digitalWrite(g,LOW);
    digitalWrite(dp,HIGH);
    digitalWrite(a,HIGH);
    digitalWrite(e,HIGH);
    digitalWrite(d,HIGH);
}

// display number5
void digital_5(void)
{
    unsigned char j;
    for(j=7;j<=9;j++)
        digitalWrite(j,LOW);
    digitalWrite(c,LOW);
    digitalWrite(d,LOW);
    digitalWrite(dp,HIGH);
    digitalWrite(b,HIGH);
    digitalWrite(e,HIGH);
}

// display number6
void digital_6(void)
{
    unsigned char j;
    for(j=7;j<=11;j++)
        digitalWrite(j,LOW);
    digitalWrite(c,LOW);
    digitalWrite(dp,HIGH);
    digitalWrite(b,HIGH);
}

// display number7
void digital_7(void)
{
    unsigned char j;
    for(j=5;j<=7;j++)
        digitalWrite(j,LOW);
    digitalWrite(dp,HIGH);
    for(j=8;j<=11;j++)
        digitalWrite(j,HIGH);
}
}
```

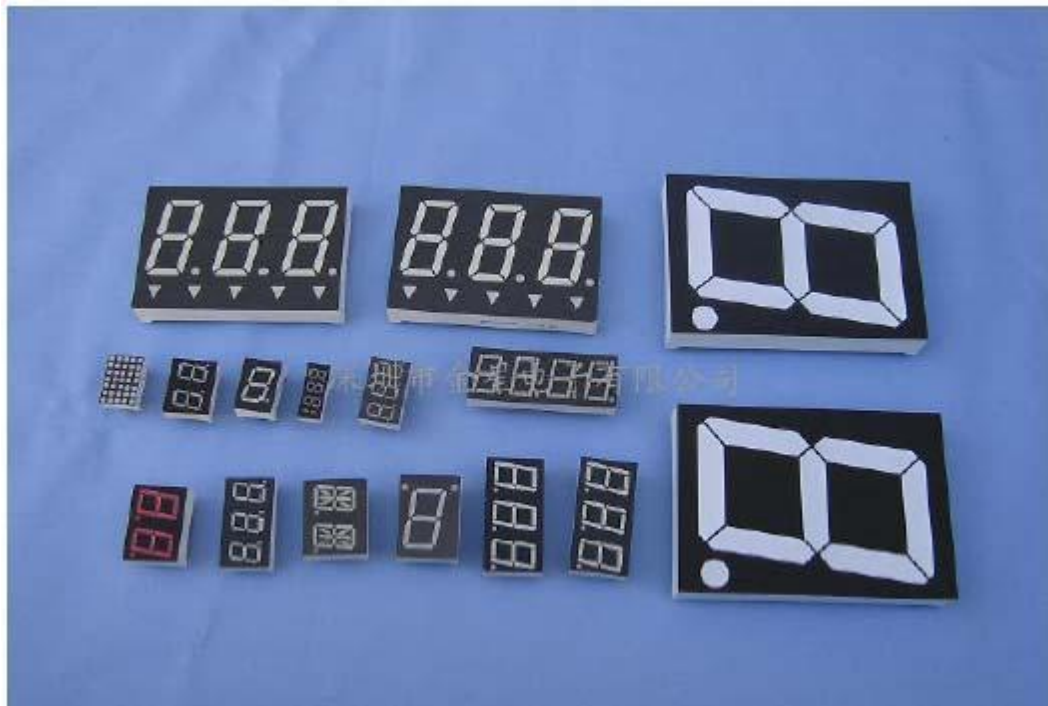
```
// display number8
void digital_8(void)
{
    unsigned char j;
    for(j=5;j<=11;j++)
        digitalWrite(j,LOW);
    digitalWrite(dp,HIGH);
}
void setup()
{
    int i;//define i
    for(i=4;i<=11;i++)
        pinMode(i,OUTPUT);//set pin4~pin11 output
}
void loop()
{
    while(1)
    {
        digital_1();//number 1
        delay(2000);//delay 2s
        digital_2();
        delay(2000);
        digital_3();
        delay(2000);
        digital_4();
        delay(2000);
        digital_5();
        delay(2000);
        digital_6();
        delay(2000);
        digital_7();
        delay(2000);
        digital_8();
        delay(2000);
    }
}
```


Chapter13 4-bit Nixie tube

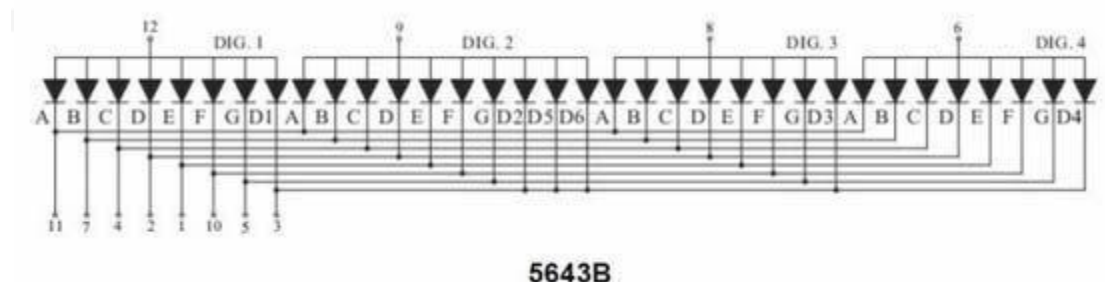
What's digital tube?

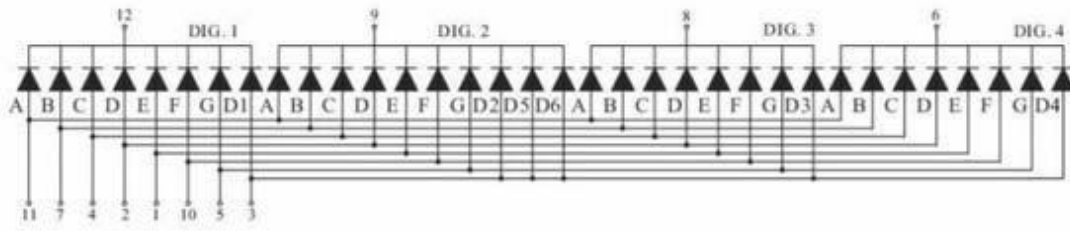
Digital tube is one kind semiconductor light emitting device. Their basic unit is light emitting diode. Digital tube is divided into 7 segment digital tube and 8 digital tube by the number of segments, 8 digital tube has one more light-emitting diode unit (a decimal point display) than 7 segment digital tube;

Digital tube has be divided into 1, 2, 4, and so on digital tube depend on how many "8" it can show.

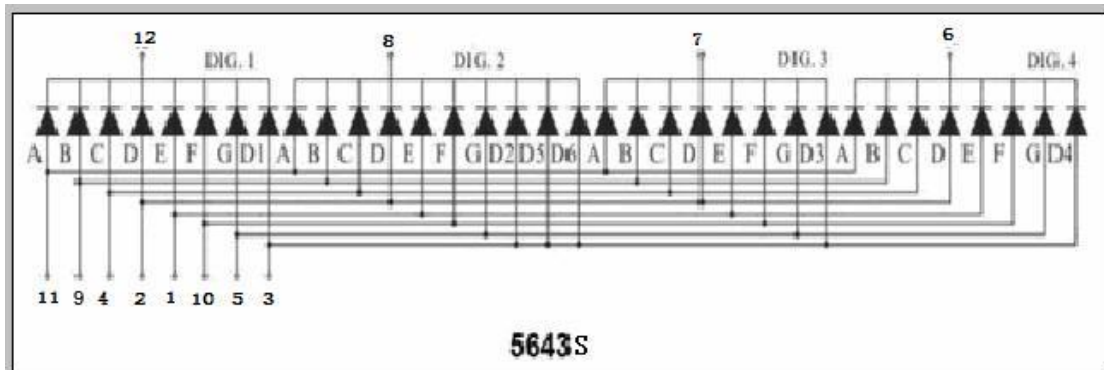


Digital tube is divided into common anode digital tube and common cathode digital tube by the connection of the light-emitting diode unit. The common anode digital tube is that connect light-emitting diode anode together to form a common anode (COM). Common anode digital tube public pole COM to +5 V, should be applied in light-emitting diode cathode when a field is low, the corresponding field lit. When a field of the cathode is high, the corresponding field is not bright.





5643A



5643S

Working principle

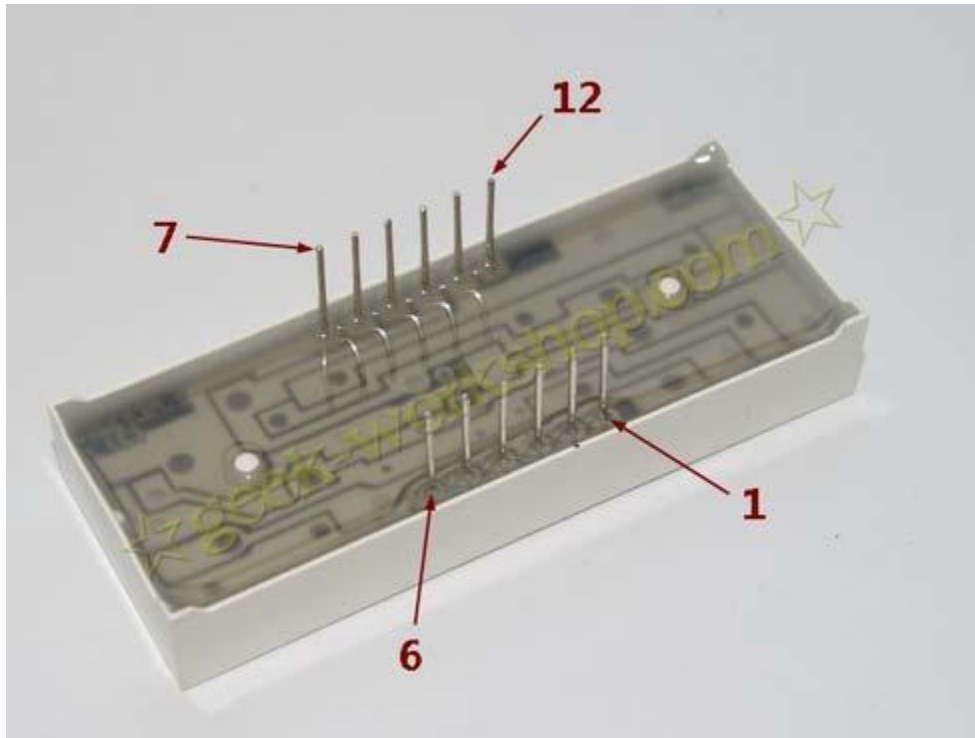
Each segment of the digital tube is made up of the light-emitting diode, and so when used with the light-emitting diode, it should connect with the current-limiting resistor as well, if not the excessive current may burn the light-emitting diode.

The digital tube used in this experiment is a common anode. The public pole COM received +5 V when the common anode digital tube is applied. The corresponding fields are alight when a field-emitting cathode of the diode is low, which are not bright when a field of the cathode is high.

Connection

One end of the current-limiting resistor plugged into the digital I/O pin is connected to the other end of the digital tube field, the six remaining fields and a decimal point followed by the return ways to access. If public COM is common anode received a +5 V, else received a GND.

There are a total of 12 pins in one 4-bit digital tube. The decimal point downward when being placed in front of, lower left corner has 1-bit. The other pins' sequences are rotated counterclockwise. Upper left corner is the largest 12th pin.



Digital tube display number

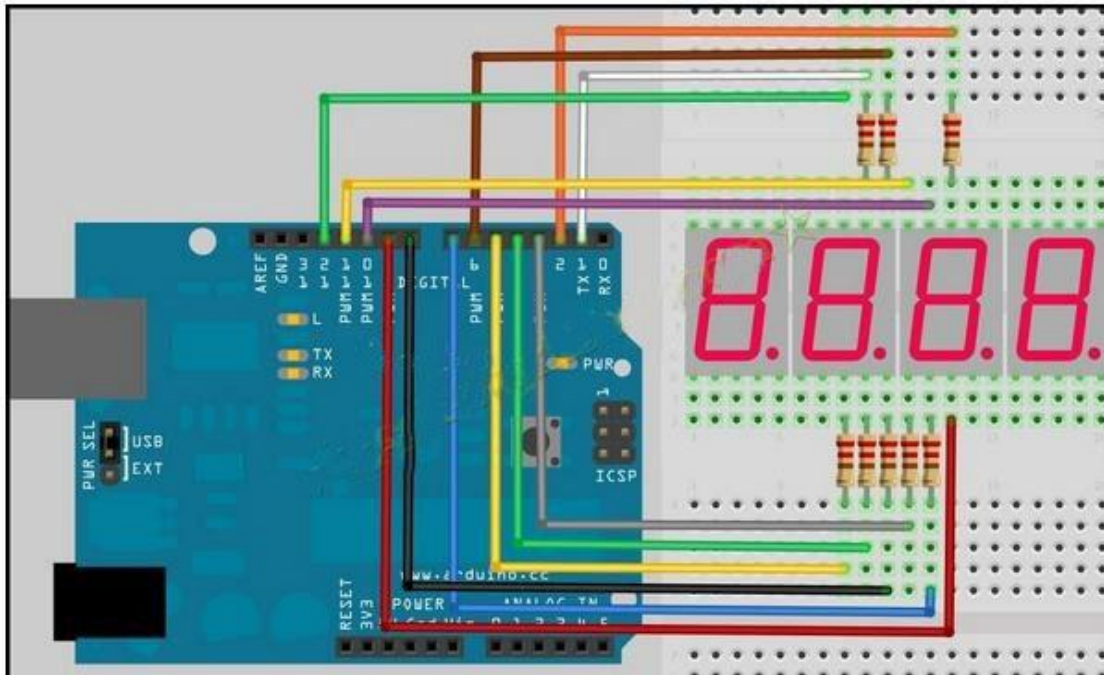
Experiment component

- 4-bit digital tube x1
- 220 Ω resistance x4
- Breadboard & jumper wire

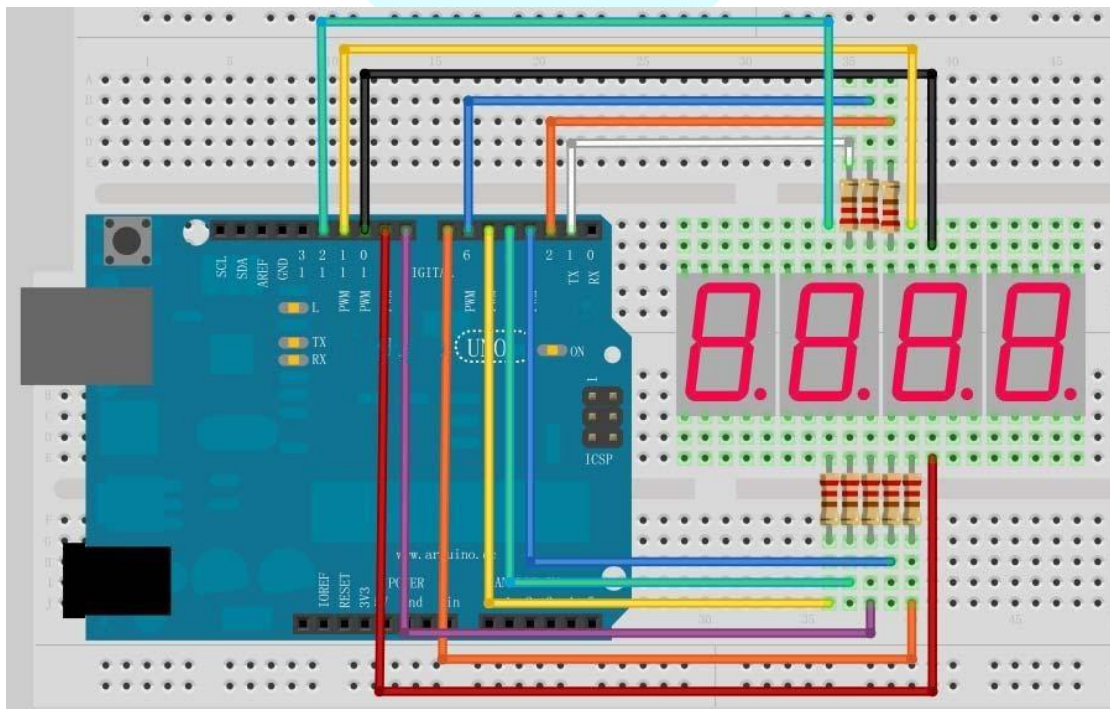
Connection

Driven digital tube current limiting resistor is certainly indispensable, there are 2 ways of limiting resistor connection. The first one is connected with D1-d4 anode, totally connect four. This connection method's benefit is needs of relatively less resistance, but generates different the digital brightness. The brightest is 1, 8 is the darkest. Another connection is use the other eight pins. The digital brightness of this method will be more like, but need more resistance. The experiments use eight 220 Ω resistances.

Refer to figure below wiring for the 5643A



Refer to figure below wiring for the 5643S



Example code

This is a simple stopwatch. Its accuracy is not very high. You need to fine-tune the parameters.

```
//set anode interface  
int a = 1;  
int b = 2;  
int c = 3;  
int d = 4;
```

```
int e = 5;
int f = 6;
int g = 7;
int p = 8;
//set cathode interface
int d4 = 9;
int d3 = 10;
int d2 = 11;
int d1 = 12;
// Set variables
long n = 0;
int x = 100;
int del = 55; // This number is fine-tuning of the clock
void setup()
{
  pinMode(d1, OUTPUT);
  pinMode(d2, OUTPUT);
  pinMode(d3, OUTPUT);
  pinMode(d4, OUTPUT);
  pinMode(a, OUTPUT);
  pinMode(b, OUTPUT);
  pinMode(c, OUTPUT);
  pinMode(d, OUTPUT);
  pinMode(e, OUTPUT);
  pinMode(f, OUTPUT);
  pinMode(g, OUTPUT);
  pinMode(p, OUTPUT);
}

void loop()
{
  clearLEDs();
  pickDigit(1);
  pickNumber((n/x/1000)%10);
  delayMicroseconds(del);

  clearLEDs();
  pickDigit(2);
  pickNumber((n/x/100)%10);
  delayMicroseconds(del);

  clearLEDs();
  pickDigit(3);
  dispDec(3);
}
```

```
pickNumber((n/x/10)%10);
delayMicroseconds(del);

clearLEDs();
pickDigit(4);
pickNumber(n/x%10);
delayMicroseconds(del);

n++;

if (digitalRead(13) == LOW)
{
n = 0;
}
}

void pickDigit(int x) //defing pickDigit(x), its role is turn on the dx port
{
digitalWrite(d1, HIGH);
digitalWrite(d2, HIGH);
digitalWrite(d3, HIGH);
digitalWrite(d4, HIGH);

switch(x)
{
case 1:
digitalWrite(d1, LOW);
break;
case 2:
digitalWrite(d2, LOW);
break;
case 3:
digitalWrite(d3, LOW);
break;
default:
digitalWrite(d4, LOW);
break;
}
}

void pickNumber(int x) //define pickNumber(x), Its role is to show digital x
{
switch(x)
{
```

```
default:
  zero();
  break;
case 1:
  one();
  break;
case 2:
  two();
  break;
case 3:
  three();
  break;
case 4:
  four();
  break;
case 5:
  five();
  break;
case 6:
  six();
  break;
case 7:
  seven();
  break;
case 8:
  eight();
  break;
case 9:
  nine();
  break;
}

void dispDec(int x) // Set to open the decimal point
{
  digitalWrite(p, LOW);
}

void clearLEDs() //clear the screen
{
  digitalWrite(a, LOW);
  digitalWrite(b, LOW);
  digitalWrite(c, LOW);
  digitalWrite(d, LOW);
}
```



```
digitalWrite(e, LOW);
digitalWrite(f, LOW);
digitalWrite(g, LOW);
digitalWrite(p, LOW);
}

void zero() // Define the number 0 cathode pin switch
{
  digitalWrite(a, HIGH);
  digitalWrite(b, HIGH);
  digitalWrite(c, HIGH);
  digitalWrite(d, HIGH);
  digitalWrite(e, HIGH);
  digitalWrite(f, HIGH);
  digitalWrite(g, LOW);
}

void one()
{
  digitalWrite(a, LOW);
  digitalWrite(b, HIGH);
  digitalWrite(c, HIGH);
  digitalWrite(d, LOW);
  digitalWrite(e, LOW);
  digitalWrite(f, LOW);
  digitalWrite(g, LOW);
}

void two()
{
  digitalWrite(a, HIGH);
  digitalWrite(b, HIGH);
  digitalWrite(c, LOW);
  digitalWrite(d, HIGH);
  digitalWrite(e, HIGH);
  digitalWrite(f, LOW);
  digitalWrite(g, HIGH);
}

void three()
{
  digitalWrite(a, HIGH);
  digitalWrite(b, HIGH);
  digitalWrite(c, HIGH);
```



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```
digitalWrite(d, HIGH);  
digitalWrite(e, LOW);  
digitalWrite(f, LOW);  
digitalWrite(g, HIGH);  
}
```

```
void four()  
{  
  digitalWrite(a, LOW);  
  digitalWrite(b, HIGH);  
  digitalWrite(c, HIGH);  
  digitalWrite(d, LOW);  
  digitalWrite(e, LOW);  
  digitalWrite(f, HIGH);  
  digitalWrite(g, HIGH);  
}
```

```
void five()  
{  
  digitalWrite(a, HIGH);  
  digitalWrite(b, LOW);  
  digitalWrite(c, HIGH);  
  digitalWrite(d, HIGH);  
  digitalWrite(e, LOW);  
  digitalWrite(f, HIGH);  
  digitalWrite(g, HIGH);  
}
```

```
void six()  
{  
  digitalWrite(a, HIGH);  
  digitalWrite(b, LOW);  
  digitalWrite(c, HIGH);  
  digitalWrite(d, HIGH);  
  digitalWrite(e, HIGH);  
  digitalWrite(f, HIGH);  
  digitalWrite(g, HIGH);  
}
```

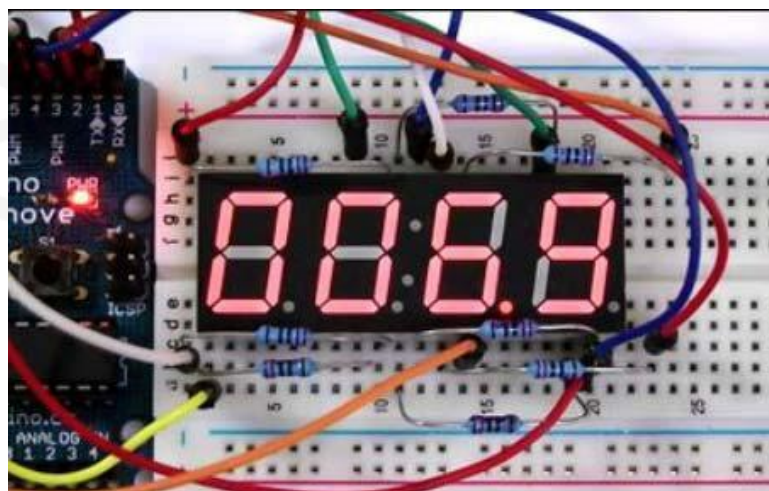
```
void seven()  
{  
  digitalWrite(a, HIGH);  
  digitalWrite(b, HIGH);  
  digitalWrite(c, HIGH);  
}
```



```
digitalWrite(d, LOW);  
digitalWrite(e, LOW);  
digitalWrite(f, LOW);  
digitalWrite(g, LOW);  
}  
  
void eight()  
{  
  digitalWrite(a, HIGH);  
  digitalWrite(b, HIGH);  
  digitalWrite(c, HIGH);  
  digitalWrite(d, HIGH);  
  digitalWrite(e, HIGH);  
  digitalWrite(f, HIGH);  
  digitalWrite(g, HIGH);  
}  
  
void nine()  
{  
  digitalWrite(a, HIGH);  
  digitalWrite(b, HIGH);  
  digitalWrite(c, HIGH);  
  digitalWrite(d, HIGH);  
  digitalWrite(e, LOW);  
  digitalWrite(f, HIGH);  
  digitalWrite(g, HIGH);  
}
```

In front of setup () defined range of digital display routines, the definition of these subroutines can be easy to use in the loop (), just write the name of the subroutine and it will.

Program function

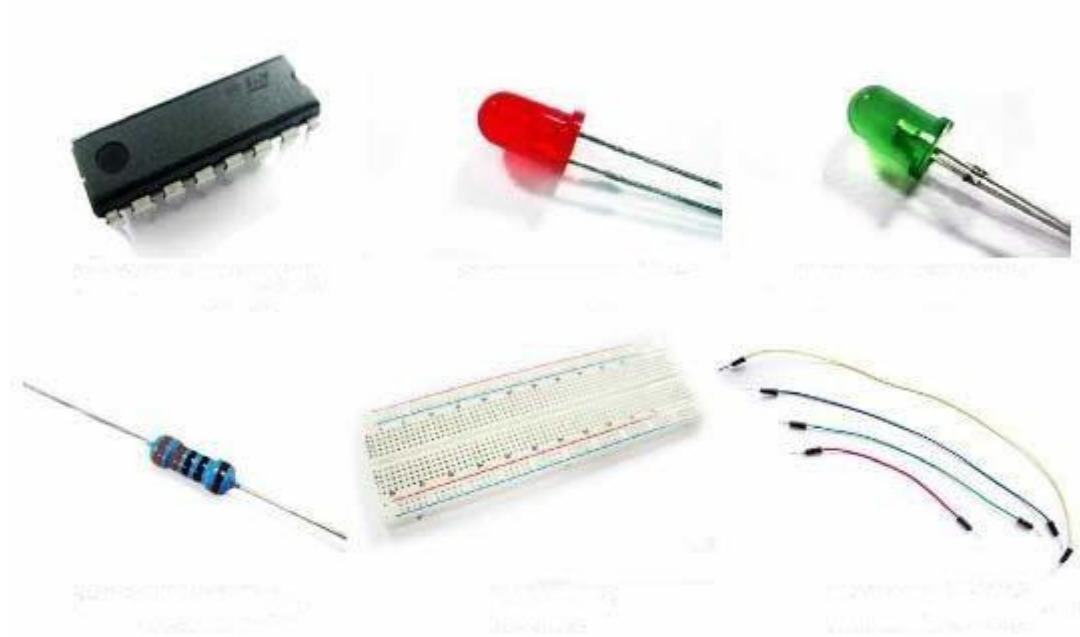


Chapter14 74HC595

What's 74HC595?

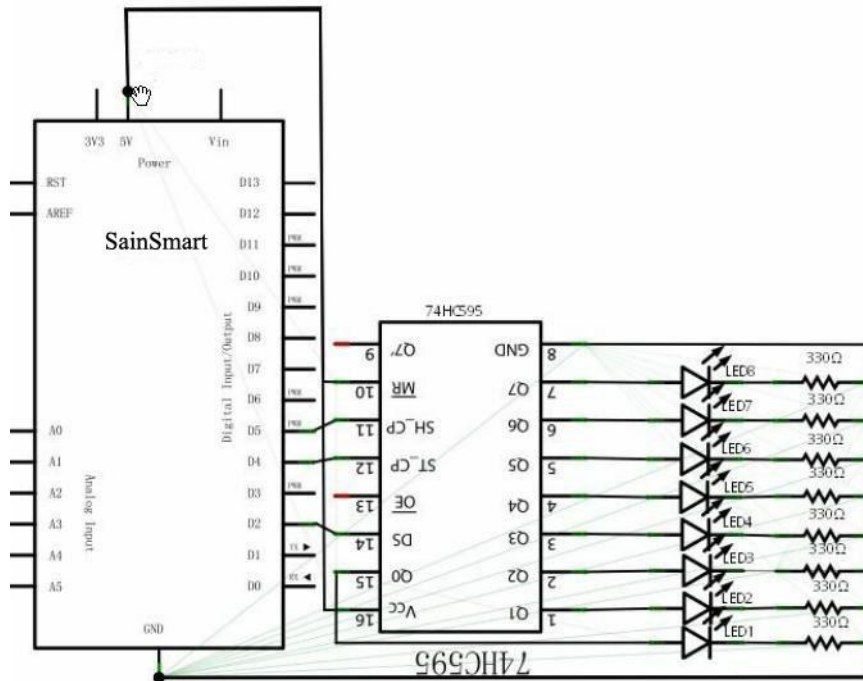
74HC595 with 8-bit register and a memory, and has three-state output function. we use it to control 8 LED lights. Why do we choose 74HC595? If we control eight small lights just with Arduino, how many its I / O will be occupied? The answer is eight. However one arduino uno only have 20 I/O port. 8 small lights have take up too many resources. The purpose we use 74HC595 is to reduce the occupation of the number of I / O port. With 74HC595 chip, we can use the 3 digital I / O port to control 8 LED lights. Why not?

Prepare experimental components below.

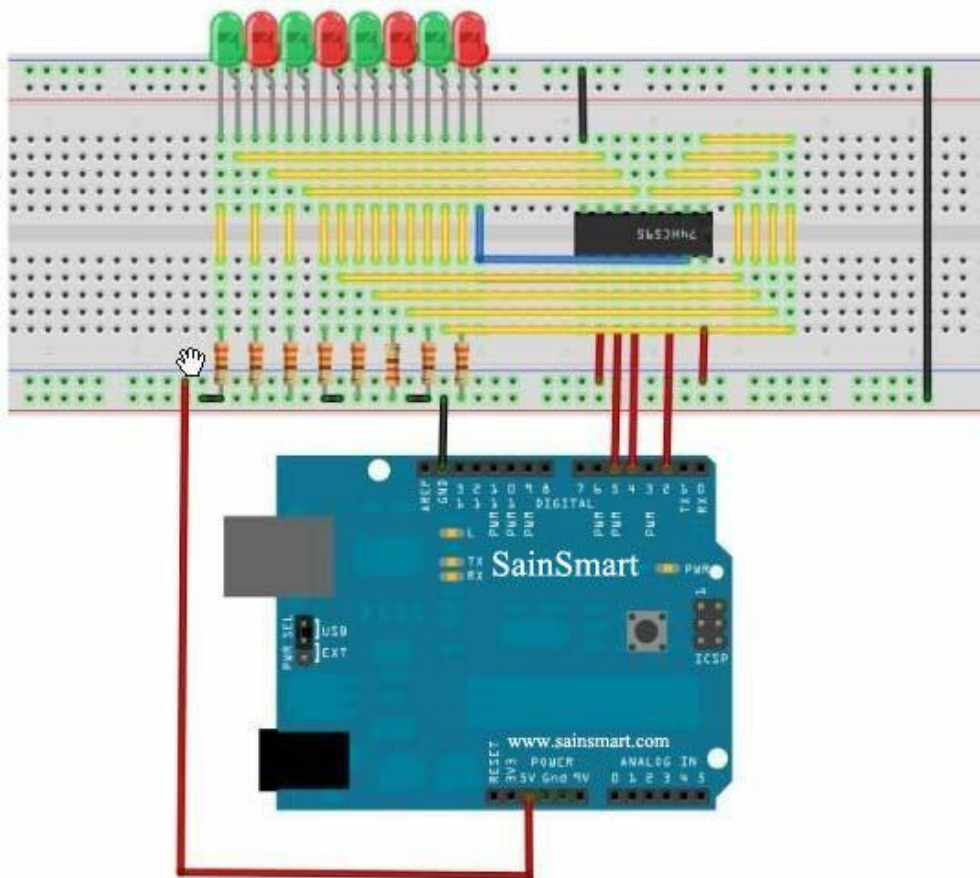


Connect the circuit diagram according the schematic diagram.

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This schematic seems are complex, after analysis and combined with reference we will find it very simple.



Example code

```
const int ON = HIGH ;
const int OFF = LOW ;
int latchPin = 5;           //connect 595 ' pin 12
int clockPin = 4;          //connect 595 's pin11
int dataPin = 2;           // connect 595 's pin 14
// connect 595's pin 16 with 5VDC
// connect 595's pin 8 with GND

int ledState = 0;

void setup() {
  pinMode(latchPin, OUTPUT);
  pinMode(clockPin, OUTPUT);
  pinMode(dataPin, OUTPUT);
}
void loop() {
  int delayTime = 100 ;
  for(int i=0;i<256;i++)
  {
    updateLEDs(i);
    delay(delayTime);
  }
}
void updateLEDs(int value)
{
  digitalWrite(latchPin,LOW);
  shiftOut(dataPin, clockPin, MSBFIRST, value);
  digitalWrite(latchPin,HIGH);
}

void updateLEDsLong(int value)
{
  digitalWrite(latchPin,LOW);
  for(int i=0;i<8;i++)
  {
    int bit = value&B10000000;
    value = value<<1;
    if(bit==128)
    {
      digitalWrite(dataPin,HIGH);
    }
    else
    {

```

```
        digitalWrite(dataPin,LOW);
    }
    digitalWrite(clockPin,HIGH);
delay(1);
    digitalWrite(clockPin,LOW);
    }
    digitalWrite(latchPin,HIGH);
}

int bits[] = {B00000001,B00000010,B00000100,B00001000,B00010000,B00100000,
B01000000,B10000000};
int masks[] = {B11111110,B11111101,B11111011,B11110111,B11101111,B11011111,
B10111111,B01111111};
void changeLED(int led,int state)
{
    ledState = ledState & masks[led];
    if(state == ON){ ledState = ledState | bits[led]; }
    updateLEDs(ledState);
}
```

Downloaded the program into the control panel, we can see the wonderful scene of small lights flashing.

In the connection circuit process, we should pay attention to the clear relay pin position. What's more, the IN4001 diodes are divided into positive and negative. Do not look at the relay circuit is slightly complex, but the kiev program is very simple. The relay is digital signal module. By opening and closing of the relay to the transistor digital signal to control high-power devices. We use LED lights as a high-power devices here.

In program, we use digital port 8 to output high and delay for one second, one second output low, like the switch off for one second and then turned on one second.

Code

```
int relayPin = 8 ;// define digital port 8, connected to the transistor base
void setup()
{
    pinMode(relayPin,OUTPUT);// define relayPin port to be output mode
}
void loop()
{
    digitalWrite(relayPin,HIGH);// drive relay closes conduction
    delay(1000);//delay one second
    digitalWrite(relayPin,LOW);//drive relay off
    delay(1000);//delay one second
}
```

Result

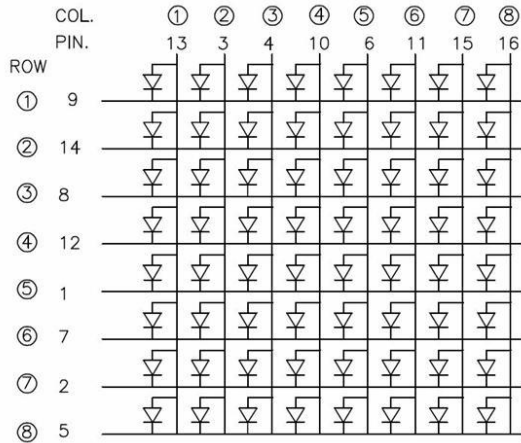
We will see small red lights and green lights flashing take turns. This is the end of this chapter's experiment, we hope that you could enjoy it and create more interactive works.



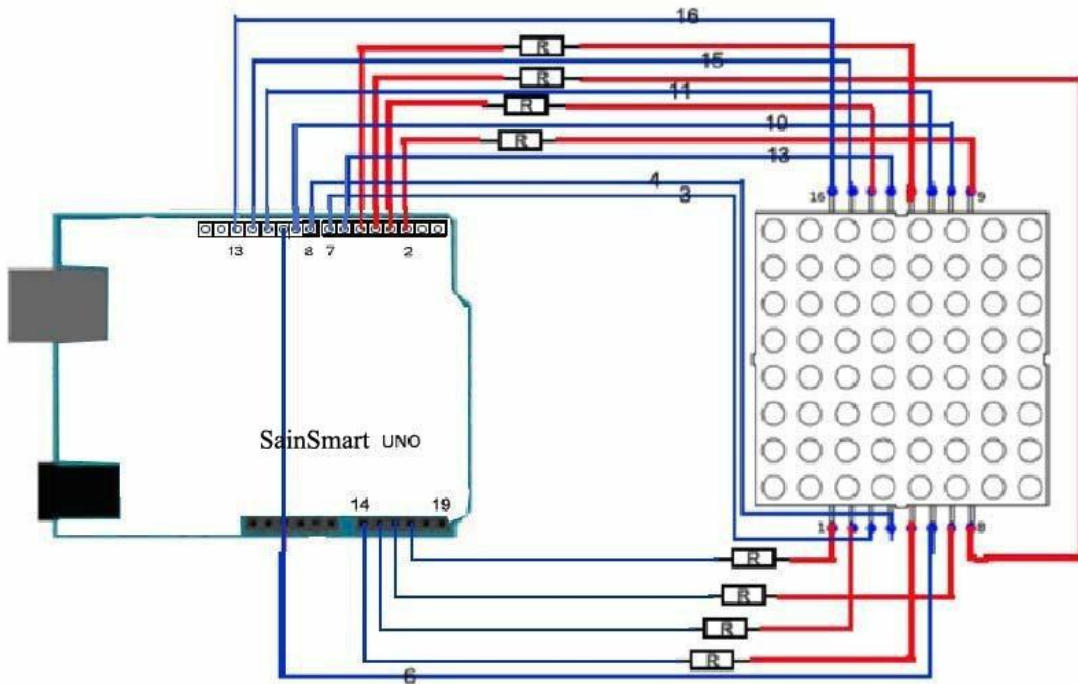
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Chapter15 8x8 matrix LEDs

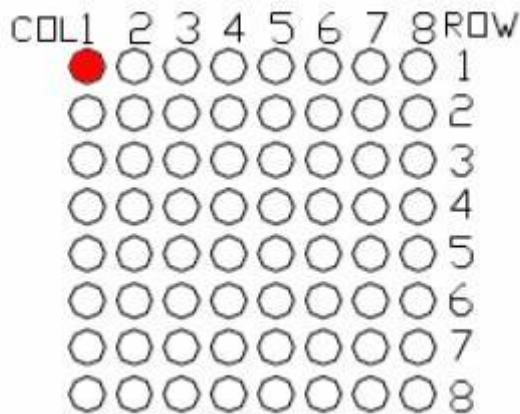
The following figure is a matrix LED internal schematic:



Wiring diagram:



One LED of LED 8X8 matrix is lit as follows:



Sample code:

```
//the pin to control ROW
const int row1 = 2; // the number of the row pin 9
const int row2 = 3; // the number of the row pin 14
const int row3 = 4; // the number of the row pin 8
const int row4 = 5; // the number of the row pin 12
const int row5 = 17; // the number of the row pin 1
const int row6 = 16; // the number of the row pin 7
const int row7 = 15; // the number of the row pin 2
const int row8 = 14; // the number of the row pin 5
//the pin to control COL
const int col1 = 6; // the number of the col pin 13
const int col2 = 7; // the number of the col pin 3
const int col3 = 8; // the number of the col pin 4
const int col4 = 9; // the number of the col pin 10
const int col5 = 10; // the number of the col pin 6
const int col6 = 11; // the number of the col pin 11
const int col7 = 12; // the number of the col pin 15
const int col8 = 13; // the number of the col pin 16

void setup(){
  int i = 0 ;
  for(i=2;i<18;i++)
  {
    pinMode(i, OUTPUT);
  }
  pinMode(row5, OUTPUT);
  pinMode(row6, OUTPUT);
  pinMode(row7, OUTPUT);
  pinMode(row8, OUTPUT);
}
```

```
for(i=2;i<18;i++) {
digitalWrite(i, LOW);
}
digitalWrite(row5, LOW);
digitalWrite(row6, LOW);
digitalWrite(row7, LOW);
digitalWrite(row8, LOW);
}
void loop(){
int i;
//the row # 1 and col # 1 of the LEDs turn on
digitalWrite(row1, HIGH);
digitalWrite(row2, LOW);
digitalWrite(row3, LOW);
digitalWrite(row4, LOW);
digitalWrite(row5, LOW);
digitalWrite(row6, LOW);
digitalWrite(row7, LOW);
digitalWrite(row8, LOW);

digitalWrite(col1, LOW);
digitalWrite(col2, HIGH);
digitalWrite(col3, HIGH);
digitalWrite(col4, HIGH);
digitalWrite(col5, HIGH);
digitalWrite(col6, HIGH);
digitalWrite(col7, HIGH);
digitalWrite(col8, HIGH);

delay(1000);

//turn off all
for(i=2;i<18;i++) {
digitalWrite(i, LOW);
}
delay(1000);
}
```

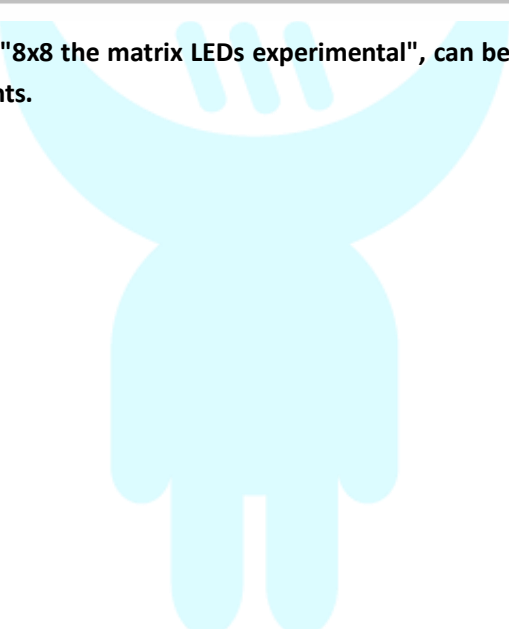
The experiment's code are as follows:

By dynamic scanning, it shows letter A in the position1 of the LED matrix.

```
#define data_ascii_A 0x02,0x0C,0x18,0x68,0x68,0x18,0x0C,0x02 /*"A",0*/  
/**  
**"A"  
#define A { //  
    {0, 0, 0, 0, 0, 0, 1, 0}, //0x02  
    {0, 0, 0, 0, 1, 1, 0, 0}, //0x0C  
    {0, 0, 0, 1, 1, 0, 0, 0}, //0x18  
    {0, 1, 1, 0, 1, 0, 0, 0}, //0x68  
    {0, 1, 1, 0, 1, 0, 0, 0}, //0x68  
    {0, 0, 0, 1, 1, 0, 0, 0}, //0x18  
    {0, 0, 0, 0, 1, 1, 0, 0}, //0x0C  
    {0, 0, 0, 0, 0, 0, 1, 0} //0x02  
}
```

Set the value to 1 , then the Led will be turn on !

The code in the folder - "8x8 the matrix LEDs experimental", can be used as a reference, made more exciting experiments.



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Chapter16 Infrared remote control

Infrared receiving head

What's Infrared receiving head?

Infrared remote control signals sent a series of binary pulse code. In order to make it from other infrared signal interference during wireless transmission, typically modulated it on a particular carrier frequency, and then emitted it by the infrared-emitting diode. The infrared receiving apparatus will have to filter out other clutter, only the specific frequency of the signal and restoring it into a binary pulse code. That is demodulated.

How it work?

Built-in receiver tube infrared emission tube emitted light signal is converted to a weak signal. This signal via the IC internal amplifier amplifies. Then through automatic gain control, band pass filtering, demodulation, and waveform-shaped to restore the original encoding of the remote control transmitter, coded identification on the electrical input to circuit via a received signal output pin head.

How to connect?

Infrared receiving head has three pin:

VOUT connected to the analog port.

GND received experimental board's GND.

VCC received experimental board's +5 v.



Infrared remote control experiment

Experiment component

1. IR remote control x1
2. Infrared receiving head x1
3. Buzzer x1
4. 220 Ω resistance x1
5. Breadboard & jumper wires

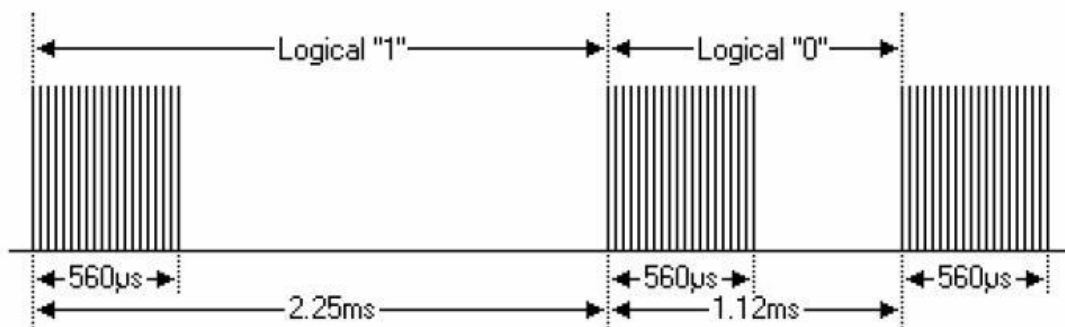
Experiment principle

If you want to decode remote control, you must understand the coding system of the remote controller first. The coding system of the remote control we used is NEC protocol. Now let's learn about NEC protocol:

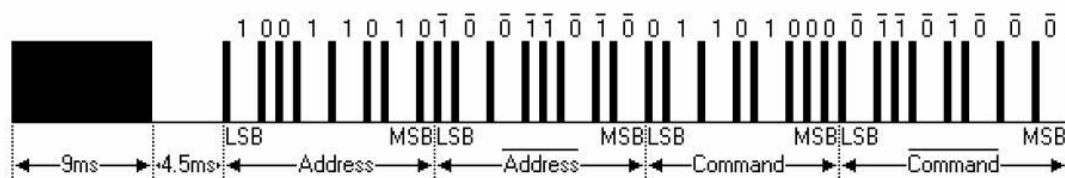
● NEC protocol introduction:

Feature:

- (1) 8-bit address spaces, 8-bit command spaces.
- (2) address bits and command bits are transmitted twice for reliability.
- (3) Pulse position modulation.
- (4) Carrier frequency 38khz.
- (5) Every bit's time is 1.125ms or 2.25ms.



Protocol:

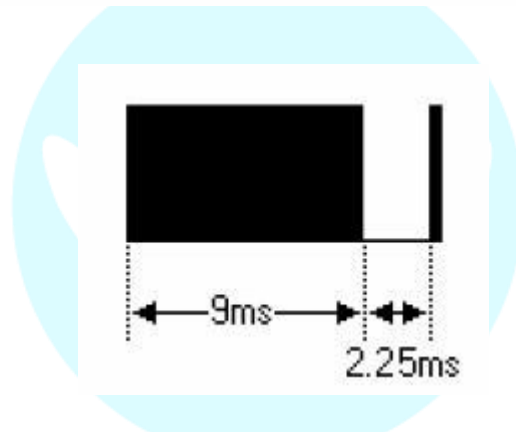
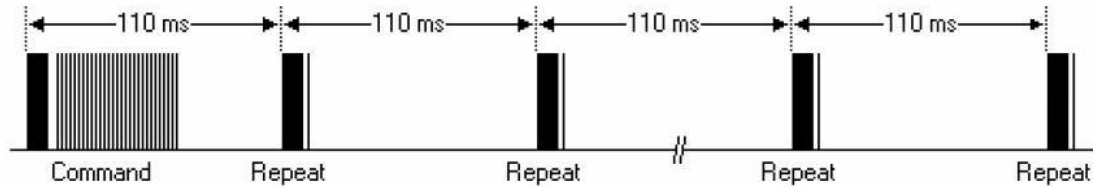


The above picture shows the typical NEC protocol pulse sequence. Note: This is the prior sending the LSB (least significant bit) agreement.

Pulse propagation's address is the 0x59 command 0x16 at the above. A message is start from a 9ms high level, followed by a 4.5ms low level (these two level made boot code) and then by the address code and command code.

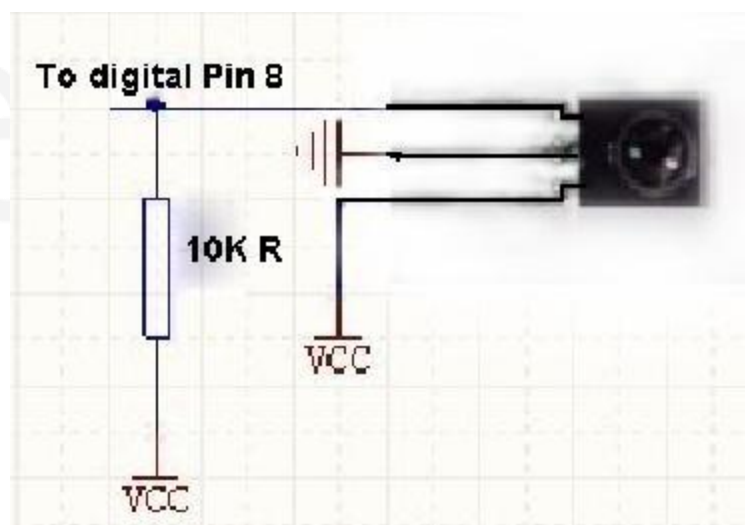
Address and command transfer twice. The second time all bits are inverted, can be used for use

in the received message recognized. The total transmission time is constant, because the duplication of every point of its length negated. If you're not interested, you can ignore this reliability negated address and command can also expand to 16!



According to the characteristics and the receiving end of the waveform of the NEC coding, this experiment will divided receiving end's wave form into four parts: Primer searching code (9ms And 4.5ms pulse), the address code 16 (including an 8-bit address and 8-bit address is negated), the command code 16 (package Including eight command-bit and 8-bit command negated), repeat code (9ms, 2.25ms, 560us pulse). HIGH segment of the received waveform and low section to be measured using the timer, based on the measured time to distinguish: a logical "0", a logical "1", cited seek pulse, repetitive pulses. Boot code and address code as long as the judge is correct pulse can be, without storage, but the command code must be stored, because each key command codes are different.

Connect your circuit as the below diagram.



Example code

```
#define IR_IN 8 // infrared receive

int Pulse_Width = 0; // storage pulse width
int ir_code = 0x00; // user code value
char adrL_code = 0x00; // Command code
char adrH_code = 0x00; // Command code base minus one's complement

void timer1_init(void) // timer initialization function
{
    TCCR1A = 0x00;
    TCCR1B = 0x05; // set timer clock source
    TCCR1C = 0x00;
    TCNT1 = 0x00;
    TIMSK1 = 0x00; // Ban timer interrupt overflow
}

void remote_deal(void) // Implement the decoding function
{
    // data presentation
    Serial.println(ir_code, HEX); // 16 Into system show
    Serial.println(adrL_code, HEX); // 16 Into system show
}

char logic_value() // Judgment logic value "0" and "1" son function
{
    TCNT1 = 0x00;
    while(!(digitalRead(IR_IN))); // if low wait
    Pulse_Width = TCNT1;
    TCNT1 = 0;
    if(Pulse_Width >= 7 && Pulse_Width <= 10) // low level 560us
    {
        while(digitalRead(IR_IN)); // if high wait
        Pulse_Width = TCNT1;
        TCNT1 = 0;
        if(Pulse_Width >= 7 && Pulse_Width <= 10) // high level 560us
            return 0;
        else if(Pulse_Width >= 25 && Pulse_Width <= 27) // high level 1.7ms
            return 1;
    }
    return -1;
}

void pulse_deal() // Receiving address code and command code pulse function
{
    int i;
    int j;
```

```
ir_code=0x00;// clear
adrL_code=0x00;// clear
adrH_code=0x00;// clear

// Analysis of the remote control code user code value
for(i = 0 ; i < 16; i++)
{
if(logic_value() == 1) // if 1
    ir_code |= (1<<i);//Save key value
}
// Analytical remote control code commands in the code
for(i = 0 ; i < 8; i++)
{
if(logic_value() == 1) // if 1
    adrL_code |= (1<<i);//save key value
}
// Analysis of the remote control code user code value
for(j = 0 ; j < 8; j++)
{
if(logic_value() == 1) //if 1
    adrH_code |= (1<<j);//save key value
}
}
void remote_decode(void)// Decoding function
{
    TCNT1=0X00;
    while(digitalRead(IR_IN))// if high wait
    {
        if(TCNT1>=1563) // When high level lasted for more than 100 ms, shows that at the
moment no key press
        {
            ir_code=0x00ff;// user code value
            adrL_code=0x00;// a byte value before Key code
            adrH_code=0x00;// a byte value after Key code
            return;
        }
    }

    // If high level can't last for more than 100 ms
    TCNT1=0X00;
    while(!(digitalRead(IR_IN))); //if low wait
    Pulse_Width=TCNT1;
    TCNT1=0;
    if(Pulse_Width>=140&&Pulse_Width<=141)// 9ms
```



```
{

while(digitalRead(IR_IN));//if high wait
Pulse_Width=TCNT1;
TCNT1=0;
if(Pulse_Width>=68&&Pulse_Width<=72)// 4.5ms
{
    pulse_deal();
    return;
}
else if(Pulse_Width>=34&&Pulse_Width<=36)//2.25ms
{
    while(!(digitalRead(IR_IN)));// if low wait
    Pulse_Width=TCNT1;
    TCNT1=0;
    if(Pulse_Width>=7&&Pulse_Width<=10)// 560us
    {
        return;
    }
}
}

void setup()
{
    Serial.begin(9600);
    pinMode(IR_IN,INPUT);// Set infrared receiving pin for input
    Serial.flush();
}

void loop()
{
    timer1_init();//Timer initialization
    while(1)
    {
        remote_decode(); // decode
        remote_deal(); // Executive decoding results
    }
}
```



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Chapter17 1602LCD

What's 1602LCD?

Nowadays 1602LCD is application of very wide range. The initial 1602 LCD used HD44780 controller. But now various manufacturers basically adopt compatible IC with their 1602 module. Their characteristics are basically the same.



1602LCD

Display capacity: 16x2 characters;
 Chip operating voltage: 4.5V~5.5V;
 Operating current: 2.0mA(5.0V);
 Best operating voltage: 5.0V;
 Character size: 2.95x4.35(WxH) mm.

Interface pin definition

number	symbol	states	number	symbol	states
1	VSS	GND	9	D2	Date I/O
2	VDD	VCC	10	D3	Date I/O
3	VL	VO	11	D4	Date I/O
4	RS	(V/L)	12	D5	Date I/O
5	R/W	Read/write(H/L)	13	D6	Date I/O
6	E	enable	14	D7	Date I/O
7	D0	Date I/O	15	BLA	Backlight anode
8	D1	Date I/O	16	BLK	Backlight cathode

- Two sets of power supply, a set of modules, the other one is the power of the backlight, generally using the 5V power supply.

2. VL is used to adjust the contrast. It connected in series the potentiometer is not greater than a 5KΩ. This experimental used one 1KΩ of resistor to set contrast. There are high potential connection and low potential connection. It connected in series 1KΩ resistance then connected to GND.

Basic Operation

Read status	Input	RS=L, R/W=H, E=H	Output	D0~D7=status word
Write command	Input	RS=L, R/W=L, D0~D7=command code, E= high pulse	Output	none
Read data	Input	RS=H, R/W=H, E=H	Output	D0~D7=data
Write data	Input	RS=H, R/W=L, D0~D7=data, E= high pulse	Output	none

output of the sketch on a 2x16 LCD

The LCDs have a parallel interface, meaning that the microcontroller has to manipulate several interface pins at once to control the display. The interface consists of the following pins:

A register select (RS) pin that controls where in the LCD's memory you're writing data to. You can select either the data register, which holds what goes on the screen, or an instruction register, which is where the LCD's controller looks for instructions on what to do next.

A Read/Write (R/W) pin that selects reading mode or writing mode

An Enable pin that enables writing to the registers

8 data pins (D0 -D7). The states of these pins (high or low) are the bits that you're writing to a register when you write, or the values you're reading when you read.

There's also a display contrast pin (Vo), power supply pins (+5V and Gnd) and LED Backlight (Bklt+ and Bklt-) pins that you can use to power the LCD, control the display contrast, and turn on and off the LED backlight, respectively.

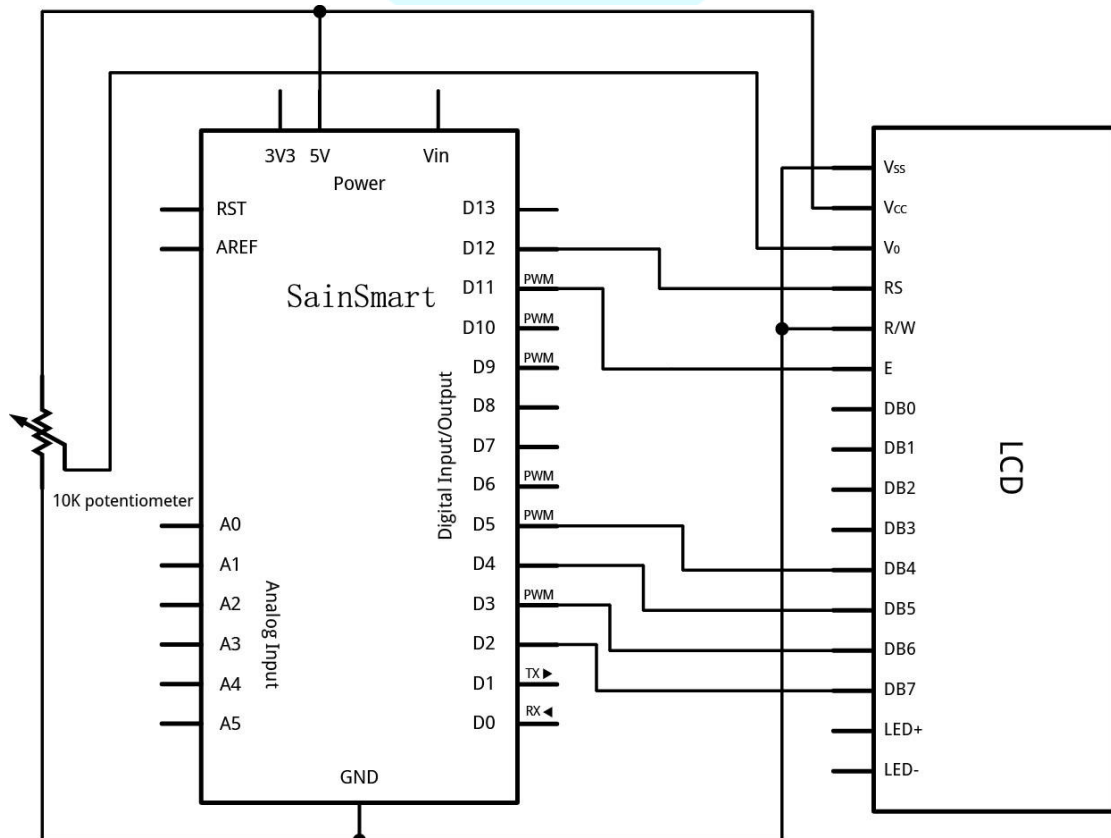
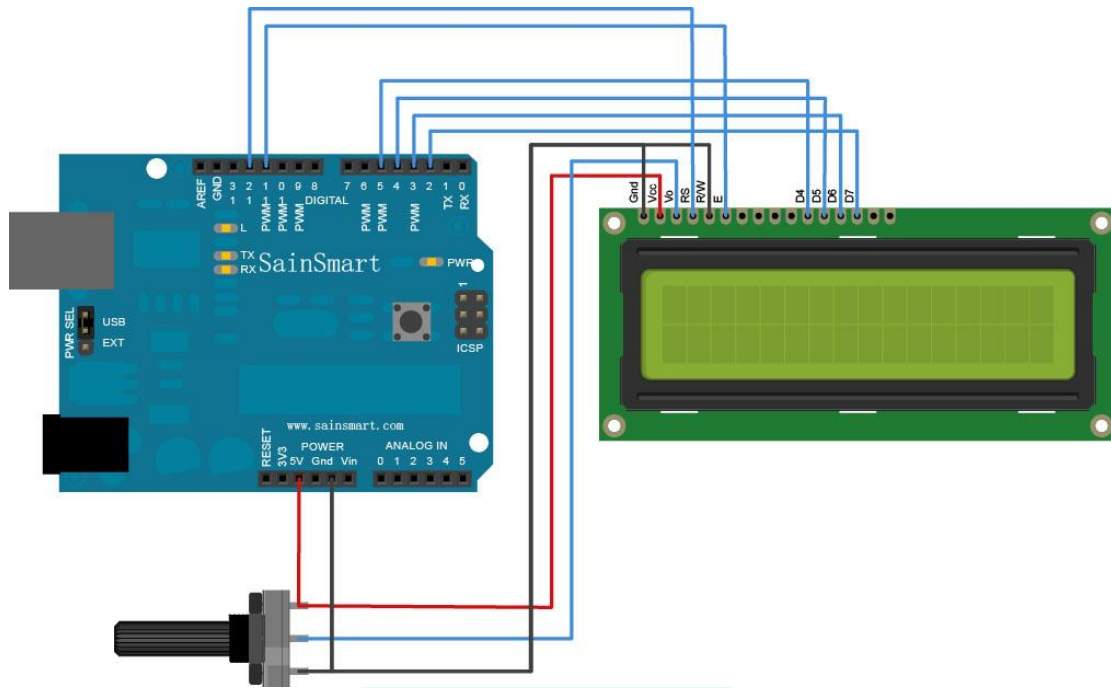
The process of controlling the display involves putting the data that form the image of what you want to display into the data registers, then putting instructions in the instruction register. The LiquidCrystal Library simplifies this for you so you don't need to know the low-level instructions. The Hitachi-compatible LCDs can be controlled in two modes: 4-bit or 8-bit. The 4-bit mode requires seven I/O pins from the Arduino, while the 8-bit mode requires 11 pins. For displaying text on the screen, you can do most everything in 4-bit mode, so example shows how to control a 2x16 LCD in 4-bit mode.

Circuit

To wire your LCD screen to your Arduino, connect the following pins:

- LCD RS pin to digital pin 12
- LCD Enable pin to digital pin 11
- LCD D4 pin to digital pin 5
- LCD D5 pin to digital pin 4
- LCD D6 pin to digital pin 3
- LCD D7 pin to digital pin 2

Additionally, wire a 10K pot to +5V and GND, with it's wiper (output) to LCD screens VO pin (pin3).



Example code

```
// include the library code:
#include <LiquidCrystal.h>
```

```
// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

void setup() {
  // set up the LCD's number of columns and rows:
  lcd.begin(16, 2);
  // Print a message to the LCD.
  lcd.print("hello, world!");
}

void loop() {
  // set the cursor to column 0, line 1
  // (note: line 1 is the second row, since counting begins with 0):
  lcd.setCursor(0, 1);
  // print the number of seconds since reset:
  lcd.print(millis()/1000);
}
```

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Chapter18 Relay module

What's relay?

It will be able to control various appliances, and other equipments with large current. It can be controlled directly by Micro-controller (Arduino , 8051, AVR, PIC, DSP, ARM, ARM, MSP430, TTL logic) .

This project will use 5V 2-Channel Relay interface board.



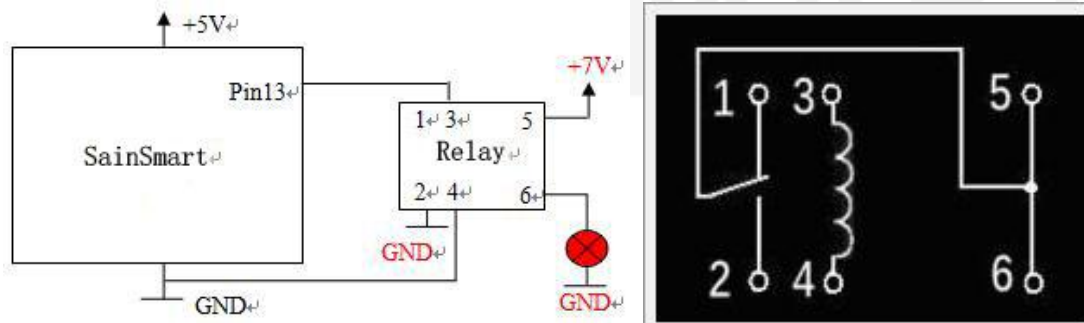
Product features:

- 5V 2-Channel Relay interface board, and each one needs 15-20mA Driver Current
- Equipped with high-current relay, AC250V 10A ; DC30V 10A
- Standard interface that can be controlled directly by microcontroller (Arduino , 8051, AVR, PIC, DSP, ARM, ARM, MSP430, TTL logic)
- Indication LED's for Relay output status

Experiment component

- Relay : 1
- LED : 1
- 10K resistor : 1
- 220Ω resistor : 1
- Breadboard & Jumper wires
- USB cable: 1

Connect your circuit as the below diagram.



Example

```
int jdqPin=13;
void setup()
{
  pinMode(jdqPin,OUTPUT);
  Serial.begin(9600);
}
void loop()
{
  digitalWrite(jdqPin,HIGH);
  delay(1000);
  digitalWrite(jdqPin,LOW);
  delay(1000);
}
```

Here I introduce how to use multimeter test relay pin.

General relay has housing mark. If not, is also very simple test with a multimeter:

- 5V power supply
- Multimeter

1. Find the coil pins

Use multimeter to measure the resistance between the pins. The value of which 2 feet is in hundreds to 1 k ohm resistance are coil pins. Note some of the relay coils are positive and negative, the reverse may not damage, but no action.

2. Find the NO (normally open) contact, NC (normally closed) contact.

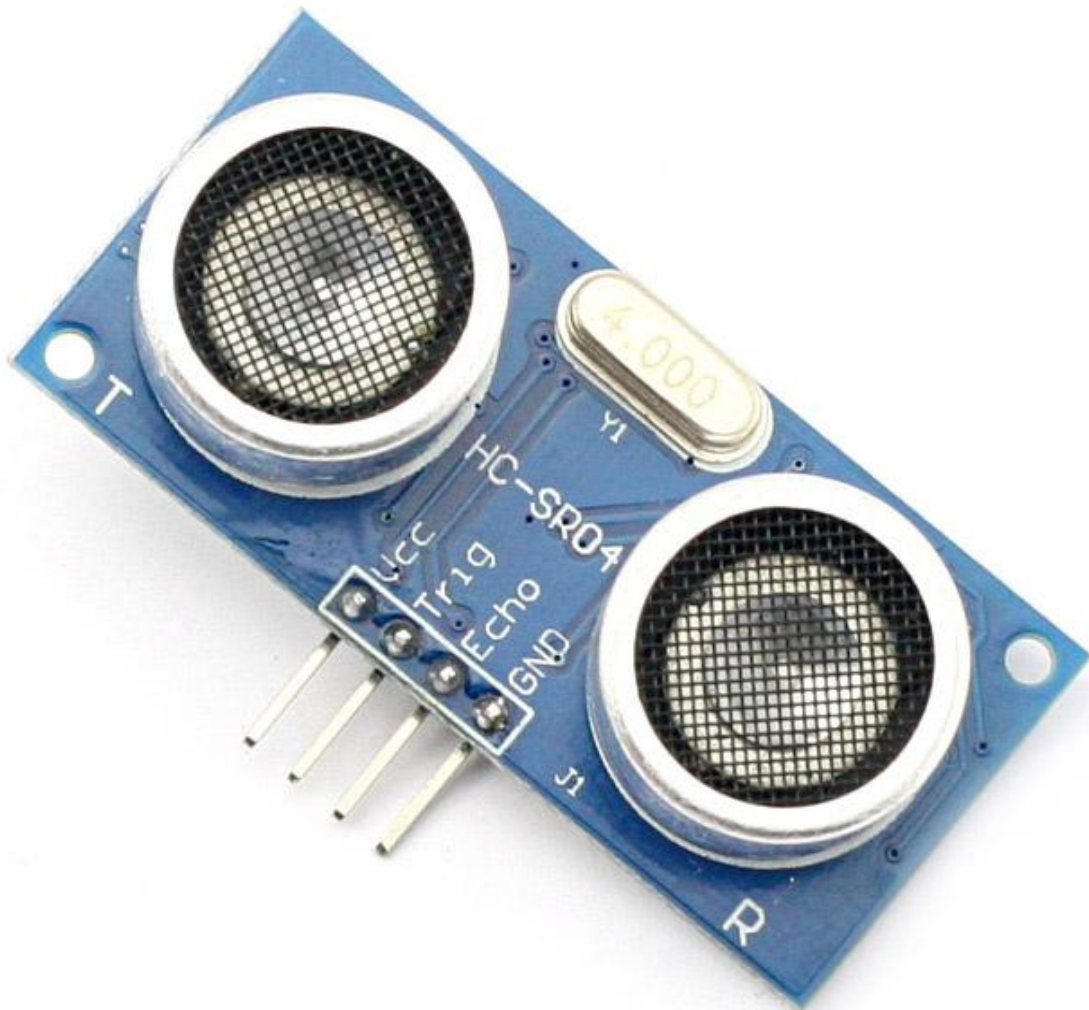
Use multimeter measuring four pins, which two pins breakover are NC contact, coil with 5v direct current, the relay action, they should be disconnected; If there is no disconnect, the internal relations is short sub.

Add 5v direct current to coils, make the relay action, this time test with a multimeter, if that two pins which disconnect before but connect this time, they are NO contact.

The pins which have something to do with NO contact, and have something to do with NC contact, is common port.

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Chapter19 Distance sensor



Product features:

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The basic principle of work:

- Using IO trigger for at least 10us high level signal,
- The Module automatically sends eight 40 kHz and detect whether there is a pulse signal back.
- IF the signal back, through high level , time of high output IO duration is the time from sending ultrasonic to returning. Test distance = (high level time×velocity of sound (340M/S) /2

Wire connecting direct as following:

- 5V Supply
- Trigger Pulse Input
- Echo Pulse Output

- 0V Ground

If you are sourcing a ultrasonic ranging module , the HC-SR04 is good choose . Its stable performance and high ranging accuracy make it a popular module in electronic market . Compared to the Sharp IR ranging module , HC-SR04 is more inexpensive than it . But it has the same ranging accuracy and longer ranging distance.

Specifications:

- power supply :5V DC
- quiescent current : <2mA
- effectual angle: <15°
- ranging distance : 2cm – 500 cm
- resolution : 0.3 cm

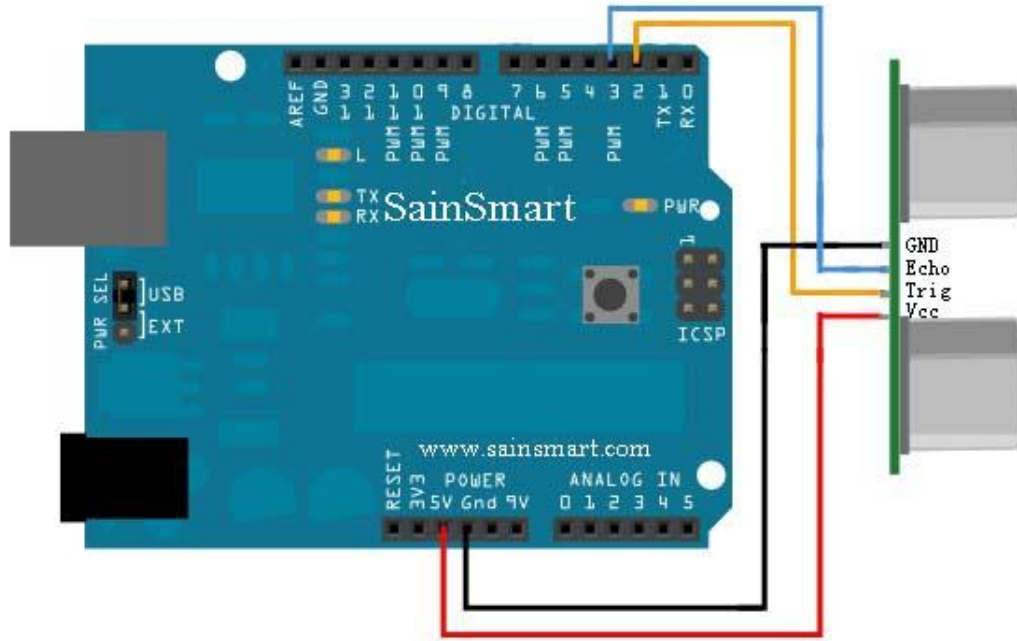
There are 4 pins out of the module : VCC , Trig, Echo, GND . So it's a very easy interface for controller to use it ranging. The all process is : pull the Trig pin to high level for more than 10us impulse , the module start ranging ; finish ranging , If you find an object in front , Echo pin will be high level , and based on the different distance, it will take the different duration of high level. So we can calculate the distance easily :

$$\text{Distance} = ((\text{Duration of high level}) * (\text{Sonic :340m/s})) / 2$$

finally , look at the back of the module .All of the chip in the module have been burnish , maybe the author want to prevent the design from plagiarism. But ultrasonic ranging module is nearly the same principle, so it's not hard to speculate that the role of the chip — I'm sure at least one 74series chip on it ;) . It is not a difficult task to crack it , but ... it's at so low a price , even cheaper than your copy.

Connect your circuit as the below diagram.

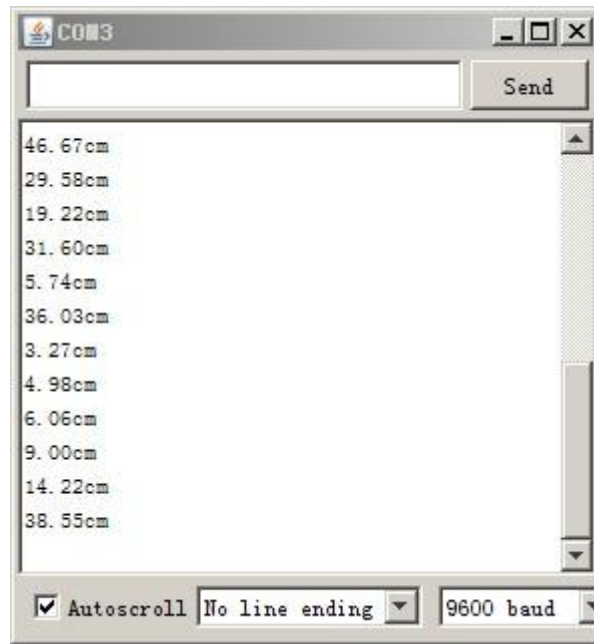
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Example code

```
const int TrigPin = 2;
const int EchoPin = 3;
float cm;
void setup()
{
  Serial.begin(9600);
  pinMode(TrigPin, OUTPUT);
  pinMode(EchoPin, INPUT);
}
void loop()
{
  digitalWrite(TrigPin, LOW); //Low-high-low level sent a short time pulse to TrigPin
  delayMicroseconds(2);
  digitalWrite(TrigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(TrigPin, LOW);

  cm = pulseIn(EchoPin, HIGH) / 58.0; //Echo time converted into cm
  cm = (int(cm * 100.0)) / 100.0; // retain two decimal places
  Serial.print(cm);
  Serial.print("cm");
  Serial.println();
  delay(1000);
}
```



Sain SMART

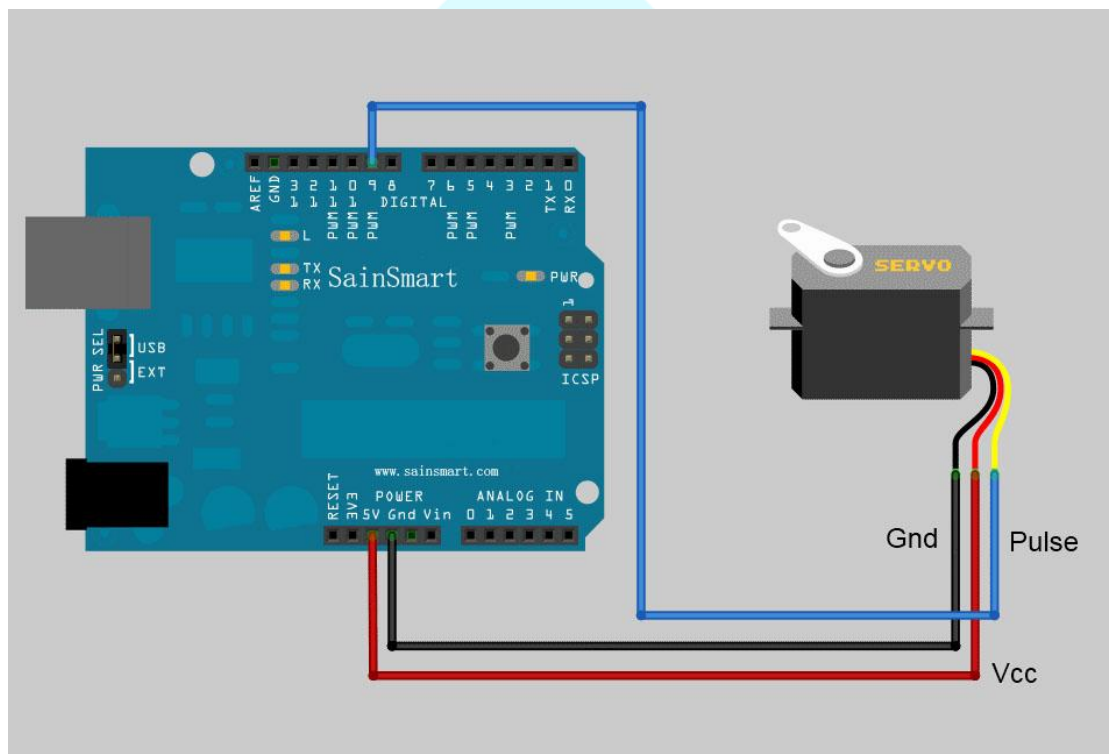
Chapter20 Servo Motor

Controlling a servo motor with an Arduino or other type of microcontroller is probably the easiest way to get started in robotics, motion art, or any other reason you may have to make your electronic project interact with the real world. Servos are very simple to interact with and in this post I'll show you how to connect one to an Arduino.

Servo motors are a specific type of motor, often used in hobby RC cars and planes, that rotate to a specific angle when a corresponding signal is applied to the pulse pin. Servo motors are very easy to program and very strong for their size. This makes them useful for a wide array of applications. The internal components of a servo motor consist of a regular DC motor, which does the actual work, a system of gears to increase the torque to the output shaft, and a circuit board and sensors to control the movement of the motor.

Wiring:

To get started controlling a servo with your Arduino, you only need to **connect three pins**. There are **two pins for power and ground**. For a small servo or just for testing, you can connect these directly to the Arduino. If you are controlling a large servo motor, you might want to use an external power source. Just remember to connect the ground from the external source to the ground of the Arduino.

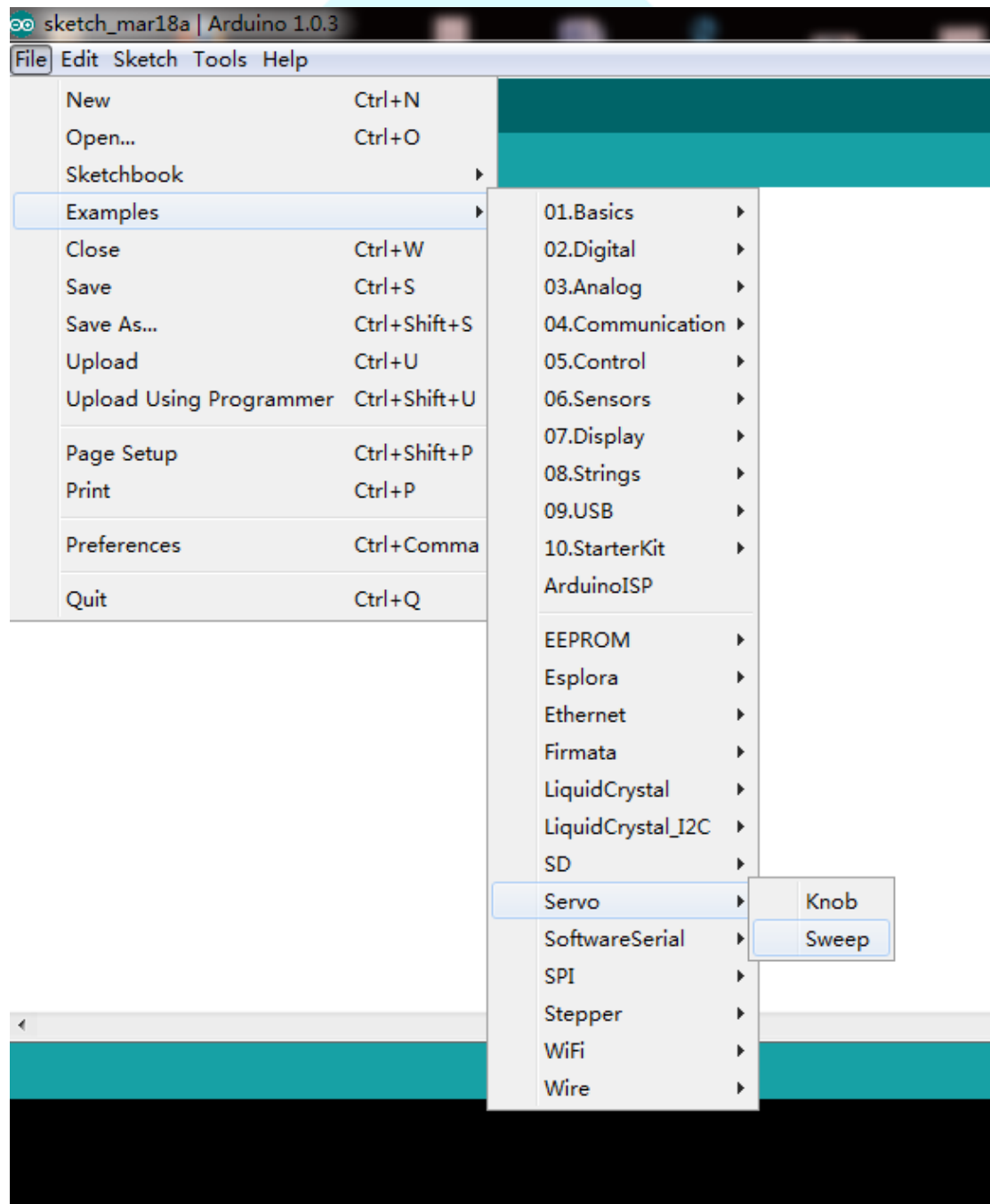


The third pin is the **pulse**, or **signal** pin. This accepts the signal from your controller that tells it what angle to turn to. The control signal is fairly simple compared to that of a stepper motor. It is just a pulse of varying lengths. The length of the pulse corresponds to the angle the motor turns to. Typically a pulse of **1.25 milliseconds causes the motor to rotate to 0 degrees** and a pulse of **1.75 milliseconds turns it 180 degrees**. Any length of pulse in between will rotate the servo shaft

to its corresponding angle. **Some servos will turn more or less than 180 degrees**, so you may need to experiment.

Programming:

The Arduino software comes with a sample servo sketch and servo library that will get you up and running quickly. Simply load it from the menu as shown below. Their example uses pin 9 for the pulse wire, so to keep it simple, that's what I used. You could use any of the data pins and, if you add more than one servo, you will need to. The Sweep sample simply rotates the servo back and forth from 0 degrees to 180. There is another sample sketch that uses a potentiometer as an input to control the angle of the motor, but I'll get in to that later.



The code is pretty basic and well documented. It first loads the library needed and sets up which

pin to use as the output.

This line tells it to move from 0 degrees to 180 degrees one degree at a time:

```
for(pos = 0; pos < 180; pos += 1)
```

And this line tells it to move back to 0 degrees one degree at a time.

```
for(pos = 180; pos >= 1; pos -= 1)
```

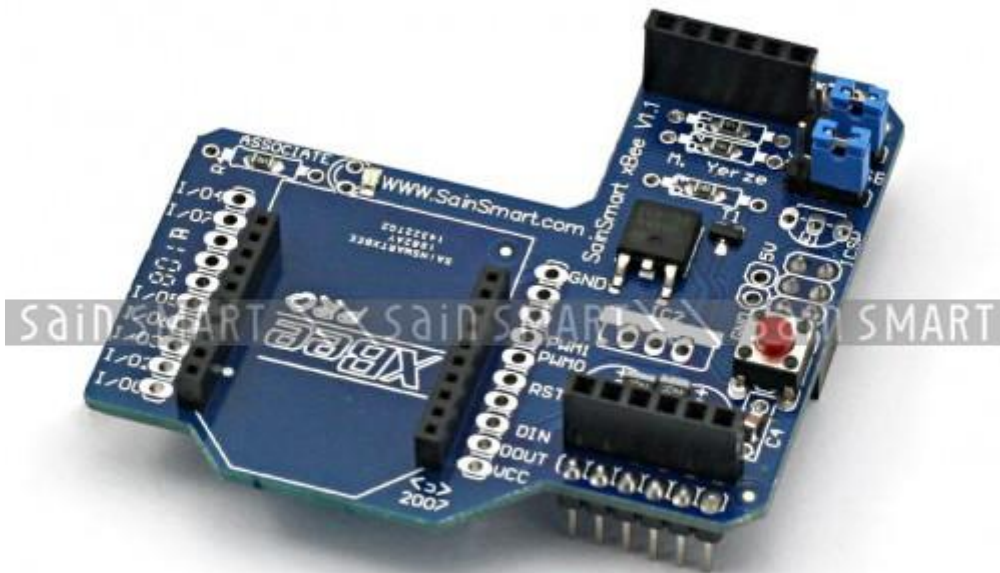


Sain SMART

Chapter21 XBee shield

What's XBee shield?

The Arduino XBee shield (an Expansion Board without XBee module) is a compliant solution designed to meet low-cost, low-power wireless sensor networks with special needs. The module is easy to use, low power consumption, and the provision of critical data between devices reliable transmission. As the innovative design, XBee-PRO can be in the range 2-3 times beyond the standard ZigBee modules. XBee-PRO modules work in the ISM 2.4 GHz frequency band. The MaxStream's XBee (1 mW) Zigbee module is pin-compatible.



The Xbee module is widely used in the United States, Canada, Australia, Israel and Europe. The establishment of RF communication does not require any configuration and the module's default configuration supports a wide range of data system applications. You can also use a simple AT command to advanced configuration. An OEM developer is now XBee code development package. It is self-developed in collaboration with the MaxStream ZigBee/802.15.4 RF module code.

Example

You should be able to get two SainSmart boards with XBee shields talking to each other without any configuration, using just the standard SainSmart serial commands.

To upload a sketch to an SainSmart board with a XBee shield, you'll need to put both jumpers on the shield to the "USB" setting (i.e. place them on the two pins closest to the edge of the board) or remove them completely (but be sure not to lose them!). Then, you can upload a sketch normally from the SainSmart environment. In this case, upload the Communication | Physical Pixel sketch to one of the boards. This sketch instructs the board to turn on the LED attached to pin 13 whenever it receives an 'H' over its serial connection, and turn the LED off when it gets an 'L'. You can test it by connecting to the board with the SainSmart serial monitor (be sure it's set at 9600 baud), typing an H, and pressing enter (or clicking send). The LED should turn on. Send an L and the LED should turn off. If nothing happens, you may have an SainSmart board that doesn't have a built-in LED on pin 13.

Once you've uploaded the Physical Pixel sketch and made sure that it's working, unplug the first SainSmart board from the computer. Switch the jumpers to the XBee setting (i.e. place each on the center pin and the pin farthest from the edge of the board). Now, you need to upload a sketch to the other board. Make sure its jumpers are in the USB setting. Then upload the following sketch to the board:

```
void setup()
{
  Serial.begin(9600);
}

void loop()
{
  Serial.print('H');
  delay(1000);
  Serial.print('L');
  delay(1000);
}
```

When it's finished uploading, you can check that it's working with the SainSmart serial monitor. You should see H's and L's arriving one a second. Turn off the serial monitor and unplug the board. Switch the jumpers to the XBee setting. Now connect both boards to the computer. After a few seconds, you should see the LED on the first board turn on and off, once a second. (This is the LED on the SainSmart board itself, not the one on the XBee shield, which conveys information about the state of the XBee module.) If so, congratulations, your SainSmart boards are communicating wirelessly. This may not seem that exciting when both boards are connected to the same computer, but if you connect them to different computers (or power them with an external power supply - being sure to switch the power jumper on the SainSmart board), they should still be able to communicate.

Addressing

There are multiple parameters that need to be configured correctly for two modules to talk to each other (although with the default settings, all modules should be able to talk to each other). They need to be on the same network, as set by the ID parameter (see "Configuration" below for more details on the parameters). The modules need to be on the same channel, as set by the CH parameter. Finally, a module's destination address (DH and DL parameters) determine which

modules on its network and channel will receive the data it transmits. This can happen in a few ways:

- If a module's DH is 0 and its DL is less than 0xFFFF (i.e. 16 bits), data transmitted by that module will be received by any module whose 16-bit address MY parameter equals DL.
- If DH is 0 and DL equals 0xFFFF, the module's transmissions will be received by all modules.
- If DH is non-zero or DL is greater than 0xFFFF, the transmission will only be received by the module whose serial number equals the transmitting module's destination address (i.e. whose SH equals the transmitting module's DH and whose SL equals its DL).

Again, this address matching will only happen between modules on the same network and channel. If two modules are on different networks or channels, they can't communicate regardless of their addresses.

Configuring the XBee module

You can configure the XBee module from code running on the SainSmart board or from software on the computer. To configure it from the SainSmart board, you'll need to have the jumpers in the Xbee position. To configure it from the computer, you'll need to have the jumpers in the USB configuration and have removed the microcontroller from your SainSmart board.

To get the module into configuration mode, you need to send it three plus signs: +++ and there needs to be at least one second before and after during which you send no other character to the module. Note that this includes newlines or carriage return characters. Thus, if you're trying to configure the module from the computer, you need to make sure your terminal software is configured to send characters as you type them, without waiting for you to press enter. Otherwise, it will send the plus signs immediately followed by a newline (i.e. you won't get the needed one second delay after the +++). If you successfully enter configuration mode, the module will send back the two characters 'OK', followed by a carriage return.

Send Command	Expected Response
+++	OK<CR>

Once in configuration mode, you can send AT commands to the module. Command strings have the form ATxx (where xx is the name of a setting). To read the current value of the setting, send the command string followed by a carriage return. To write a new value to the setting, send the command string, immediately followed by the new setting (with no spaces or newlines in-between), followed by a carriage return. For example, to read the network ID of the module (which determines which other XBee modules it will communicate with), use the 'ATID command:

Send Command	Expected Response
ATID<enter>	3332<CR>

To change the network ID of the module:

Send Command	Expected Response
ATID3331<enter>	OK<CR>

Now, check that the setting has taken effect:

Send Command	Expected Response
ATID<enter>	3331<CR>

Unless you tell the module to write the changes to non-volatile (long-term) memory, they will only be in effect until the module loses power. To save the changes permanently (until you explicitly modify them again), use the **ATWR** command:

Send Command	Expected Response
ATWR<enter>	OK<CR>

To reset the module to the factory settings, use the **ATRE** command:

Send Command	Expected Response
ATRE<enter>	OK<CR>

Note that like the other commands, the reset will not be permanent unless you follow it with the **ATWR** command.

Here are some of the more useful parameters for configuring your XBee module.

Command	Description	Valid Values	Default Value
ID	The network ID of the XBee module.	0 - 0xFFFF	3332
CH	The channel of the XBee module.	0x0B - 0x1A	0X0C
SH and SL	The serial number of the XBee module (SH gives the high 32 bits, SL the low 32 bits). Read-only.	0 – 0xFFFFFFFF (for both SH and SL)	different for each module
MY	The 16-bit address of the module.	0 - 0xFFFF	0
DH and DL	The destination address for wireless communication (DH is the high 32 bits, DL the low 32).	0 – 0xFFFFFFFF (for both DH and DL)	0 (for both DH and DL)
BD	The baud rate used for serial communication with the Arduino board or computer.	0 (1200 bps) 1 (2400 bps) 2 (4800 bps) 3 (9600 bps) 4 (19200 bps) 5 (38400 bps) 6 (57600 bps) 7 (115200 bps)	3 (9600 baud)

Note: although the valid and default values in the table above are written with a prefix of "0x" (to indicate that they are hexadecimal numbers), the module will not include the "0x" when reporting the value of a parameter, and you should omit it when setting values.

Here are a couple more useful commands for configuring the Xbee module (you'll need to prepend AT to these too).

Command	Description
RE	Restore factory default settings (note that like parameter changes, this is not permanent unless followed by the WR command).

WR	Write newly configured parameter values to non-volatile (long-term) storage. Otherwise, they will only last until the module loses power.
CN	Exit command mode now. (If you don't send any commands to the module for a few seconds, command mode will timeout and exit even without a CN command.)

API mode

As an alternative to Transparent Operation, API (Application Programming Interface) Operations are available. API operation requires that communication with the module be done through a structured interface (data is communicated in frames in a defined order). The API specifies how commands, command responses and module status messages are sent and received from the module using a UART Data Frame.

Read the manual if you are going to use the API mode.

Jumper setting

The XBee shield has two jumpers (the small removable plastic sleeves that each fit onto two of the three pins labelled Xbee/USB). These determine how the XBee's serial communication connects to the serial communication between the microcontroller (ATmega8 or ATmega168) and FTDI USB-to-serial chip on the SainSmart board.

With the jumpers in the XBee position (i.e. on the two pins towards the interior of the board), the DOUT pin of the XBee module is connected to the RX pin of the microcontroller; and DIN is connected to TX. Note that the RX and TX pins of the microcontroller are still connected to the TX and RX pins (respectively) of the FTDI chip - data sent from the microcontroller will be transmitted to the computer via USB as well as being sent wirelessly by the XBee module. The microcontroller, however, will only be able to receive data from the XBee module, not over USB from the computer.

With the jumpers in the USB position (i.e. on the two pins nearest the edge of the board), the DOUT pin the XBee module is connected to the RX pin of the FTDI chip, and DIN on the XBee module is connected to the TX pin of the FTDI chip. This means that the XBee module can communicate directly with the computer - however, this only works if the microcontroller has been removed from the SainSmart board. If the microcontroller is left in the SainSmart board, it will be able to talk to the computer normally via USB, but neither the computer nor the microcontroller will be able to talk to the XBee module.

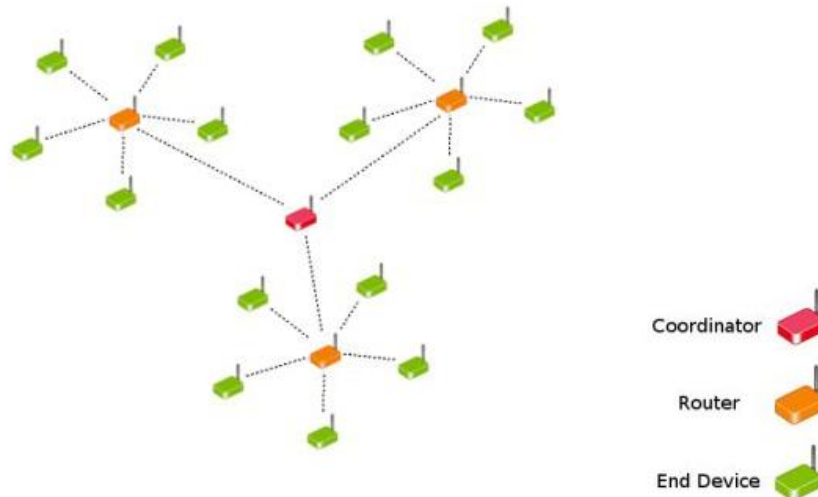
Using Series 2 ZB XBee's

Series 2 XBee's (ZigBee protocol) are quite different to 802.15.4 ones.

ZigBee networks are called personal area networks or PANs. Each network is defined with a unique PAN identifier (PAN ID). XBee ZB supports both a 64-bit (extended) PAN ID and a 16-bit PAN ID.

The 16-bit PAN ID is used in all data transmissions. The 64-bit PAN ID is used during joining, and to resolve 16-bit PAN ID conflicts that may occur.

ZigBee defines three different device types: coordinator, router, and end devices.



Coordinator

- Selects a channel and PAN ID (both 64-bit and 16-bit) to start the network
- Can allow routers and end devices to join the network
- Can assist in routing data
- Cannot sleep--should be mains powered.

Router

- Must join a ZigBee PAN before it can transmit, receive, or route data
- After joining, can allow routers and end devices to join the network
- After joining, can assist in routing data
- Cannot sleep--should be mains powered.

End device

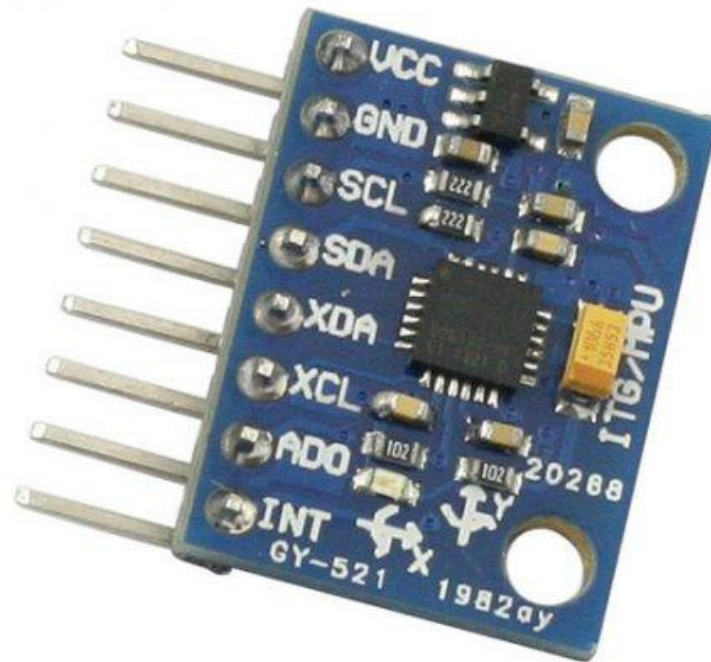
- Must join a ZigBee PAN before it can transmit or receive data
- Cannot allow devices to join the network
- Must always transmit and receive RF data through its parent. Cannot route data.
- Can enter low power modes to conserve power and can be battery-powered.

In ZigBee networks, the coordinator must select a PAN ID (64-bit and 16-bit) and channel to start a network. After that, it behaves essentially like a router. The coordinator and routers can allow other devices to join the network and can route data.

After an end device joins a router or coordinator, it must be able to transmit or receive RF data through that router or coordinator. The router or coordinator that allowed an end device to join becomes the "parent" of the end device. Since the end device can sleep, the parent must be able to buffer or retain incoming data packets destined for the end device until the end device is able to wake and receive the data.

Chapter22 MPU6050 Sensor

What's MPU6050 Sensor?



Description

Key Features

Model: GY-521

Color: Blue

Material: PCB + Plastic + copper

Chip: MPU-6050

Power supply: 3~5V

Communication mode: standard IIC communication protocol

Chip built-in 16bit AD converter, 16bit data output

Gyroscopes range: +/- 250 500 1000 2000 degree/sec

Acceleration range: +/- 2g, +/- 4g, +/- 8g, +/- 16g

Immersion Gold plating PCB, machine welding process to ensure quality

Pin pitch: 2.54mm

Great for DIY projects

Packing list: 1 x Module 2 x Pins
Specification
sDimensions (cm): 2.1 x 1.6 x 0.3
Weight (kg): 0.005

If you need more information about MPU6050, visit:

<http://www.sainsmart.com/sainsmart-mpu-6050-3-axis-gyroscope-module.html>

Example code

- **This code is without the algorithm, so the result is just raw data!**

```
// Arduino Wire library is required if I2Cdev I2CDEV_ARDUINO_WIRE implementation
// is used in I2Cdev.h
#include "Wire.h"

// I2Cdev and MPU6050 must be installed as libraries, or else the .cpp/.h files
// for both classes must be in the include path of your project
#include "I2Cdev.h"
#include "MPU6050.h"

// class default I2C address is 0x68
// specific I2C addresses may be passed as a parameter here
// AD0 low = 0x68 (default for InvenSense evaluation board)
// AD0 high = 0x69
MPU6050 accelgyro;

int16_t ax, ay, az;
int16_t gx, gy, gz;

#define LED_PIN 13
bool blinkState = false;

void setup() {
    // join I2C bus (I2Cdev library doesn't do this automatically)
    Wire.begin();

    // initialize serial communication
    // (38400 chosen because it works as well at 8MHz as it does at 16MHz, but
    // it's really up to you depending on your project)
    Serial.begin(38400);

    // initialize device
    Serial.println("Initializing I2C devices...");
```

```
accelgyro.initialize();
// verify connection
Serial.println("Testing device connections...");
Serial.println(accelgyro.testConnection() ? "MPU6050 connection successful" : "MPU6050
connection failed");
// configure Arduino LED for
pinMode(LED_PIN, OUTPUT);
}
void loop() {
// read raw accel/gyro measurements from device
accelgyro.getMotion6(&ax, &ay, &az, &gx, &gy, &gz);

// these methods (and a few others) are also available
//accelgyro.getAcceleration(&ax, &ay, &az);
//accelgyro.getRotation(&gx, &gy, &gz);

// display tab-separated accel/gyro x/y/z values
Serial.print("a/g:\t");
Serial.print(ax);
Serial.print("\t");
Serial.print(ay);
Serial.print("\t");
Serial.print(az);
Serial.print("\t");
Serial.print(gx);
Serial.print("\t");
Serial.print(gy);
Serial.print("\t");
Serial.println(gz);

// blink LED to indicate activity
blinkState = !blinkState;
digitalWrite(LED_PIN, blinkState);
}
```

- **This is the code with algorithm.**

```
#include "Wire.h"
#include "I2Cdev.h"
#include "MPU6050.h"MPU6050 accelgyro;

int16_t ax, ay, az;
int16_t gx, gy, gz;
```



```
bool blinkState = false;

void setup() {

    Wire.begin();
    Serial.begin(38400);

    accelgyro.initialize();
}
void loop() {

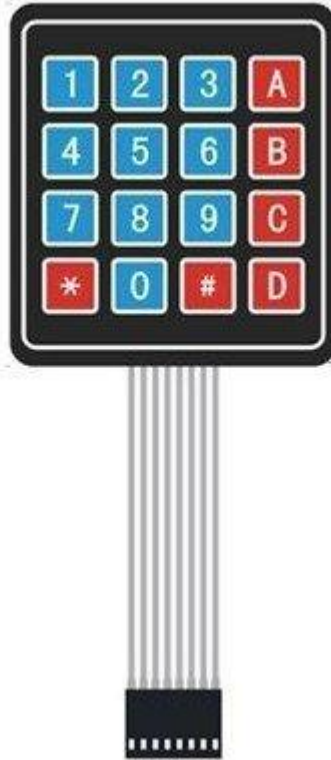
    accelgyro.getMotion6(&ax, &ay, &az, &gx, &gy, &gz);
    Serial.print("a/g:\t");
    Serial.print(ax/16384);
    Serial.print("\t");
    Serial.print(ay/16384);
    Serial.print("\t");
    Serial.print(az/16384);
    Serial.print("\t");
    Serial.print(gx/131);
    Serial.print("\t");
    Serial.print(gy/131);
    Serial.print("\t");
    Serial.println(gz/131);
    blinkState = !blinkState;

}
```

Sain SMART

Chapter23 Keypad

What's keypad?



Feature.

8P DuPont head, pitch 2.54mm, can be inserted in the Pin connection circuit;

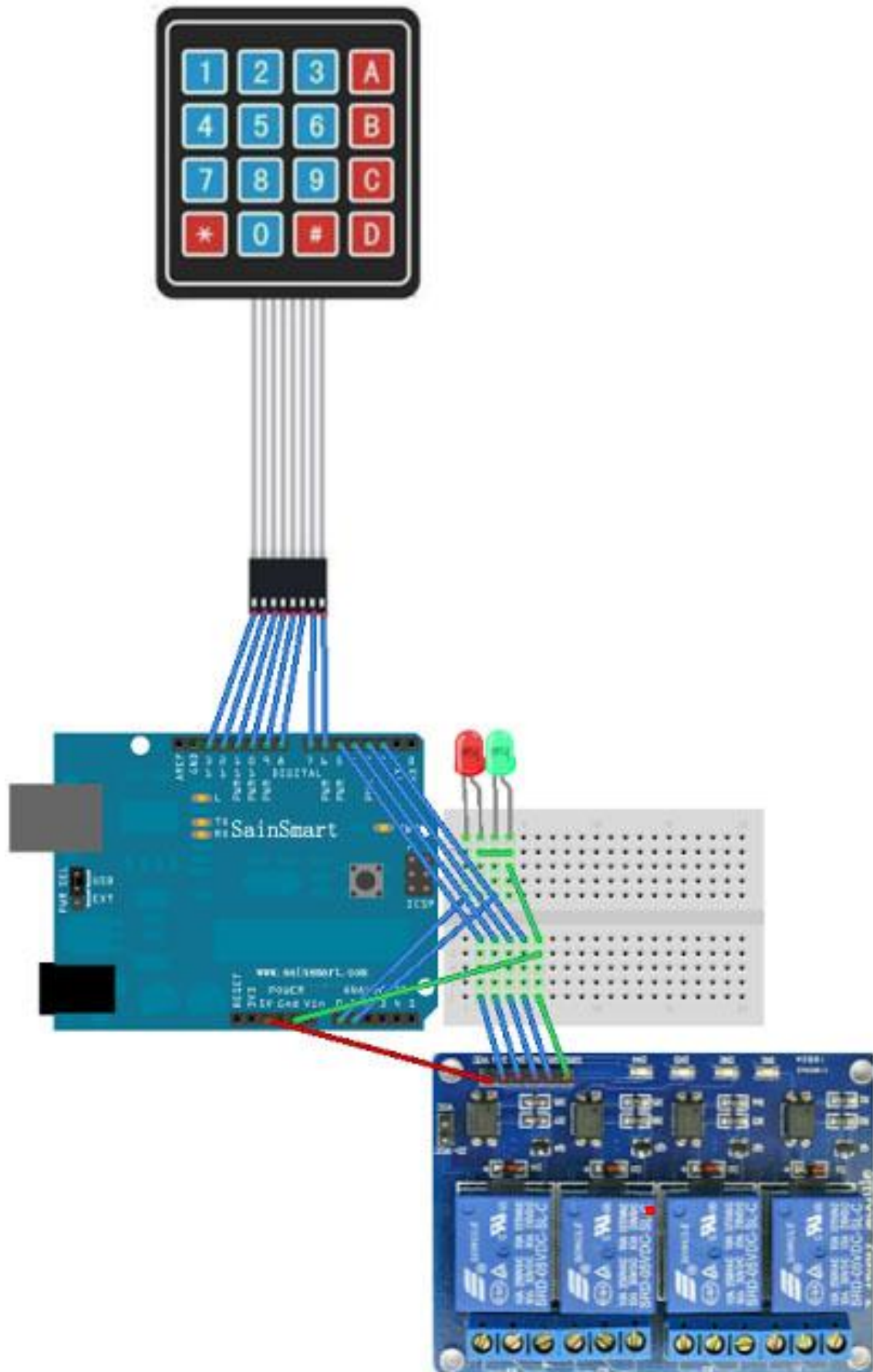
Peel off the white sticker on the back of the keyboard can be securely affixed to the surface of the chassis

Experiment component

- Relay : 1
- LED: 2
- UNO R3: 1
- Keypad : 1
- Breadboard & Jumper wires
- USB cable: 1

Wiring

Wiring up the parts is easier than it might seem. Note that D0 and D1 are used for serial programming. D13 has a resistor wired into it so not good for the relay signaling. Analog pins with LEDs is a bit of a hack for some more I/O.



LEDs

Red LED positive connected to Arduino Uno Analog A0
Green LED positive connected to Arduino Uno Analog A1
Ground legs connected to Arduino Ground

Relays

VCC connected to Arduino 5v
IN1 connected to Arduino D2
IN2 connected to Arduino D3
IN3 connected to Arduino D4
IN4 connected to Arduino D5
Ground connected to Arduino Ground

Keypad

Connected to Arduino D6-D13

Power

9V battery connected to Arduino Ground and VIN when not connected to computer USB

Example code

```
/* Locked Relays
 *
 * An SainSmart Uno, Keypad, Relays and some LEDs for fun
 *
 * Using a password to enable the relays, then selective
 * toggle the relays by key.
 *
 * Needed libraries
 * http://arduino.cc/playground/uploads/Code/Keypad.zip
 * http://arduino.cc/playground/uploads/Code/Password.zip
 */

#include <Keypad.h>/*
#include <Password.h>/*

int relay1 = 2;
int relay2 = 3;
int relay3 = 4;
int relay4 = 5;

int locked = 1;
int passinput = 0;
int lockedled = 14;
int unlockedled = 15;

long ledflashvar = 0;
long ledflashtime = 300;
```

```
const byte ROWS = 4;
const byte COLS = 4;
char keys[ROWS][COLS] = {{'1','2','3','A'},{'4','5','6','B'},{'7','8','9','C'},{'*','0','#','D'}};
byte rowPins[ROWS] = {13, 12, 11, 10};
byte colPins[COLS] = {9, 8, 7, 6};

Keypad keypad = Keypad( makeKeymap(keys), rowPins, colPins, ROWS, COLS );
Password password = Password("0000");

void setup(){
  Serial.begin(9600);
  pinMode(relay1, OUTPUT);
  digitalWrite(relay1, 255);
  pinMode(relay2, OUTPUT);
  digitalWrite(relay2, 255);
  pinMode(relay3, OUTPUT);
  digitalWrite(relay3, 255);
  pinMode(relay4, OUTPUT);
  digitalWrite(relay4, 255);
  pinMode(lockedled, OUTPUT);
  digitalWrite(lockedled, 255);
  pinMode(unlockedled, OUTPUT);
  digitalWrite(unlockedled, 0);
}

void loop(){
  char key = keypad.getKey();
  if(locked){
    if(passinput){
      unsigned long ledcurrentvar = millis();
      if(ledcurrentvar - ledflashvar > ledflashtime) {
        ledflashvar = ledcurrentvar;
        digitalWrite(lockedled, !digitalRead(lockedled));
      }
    }
  }
  else{
    digitalWrite(lockedled, 255);
  }
  digitalWrite(unlockedled, 0);
}
if (key != NO_KEY){
  Serial.println(key);
  password.append(key);
}
```

```
passinput = 1;
if(key == '*'){
    password.reset();
    passinput = 0;
    locked = 1;
    digitalWrite(relay1, HIGH);
    digitalWrite(relay2, HIGH);
    digitalWrite(relay3, HIGH);
    digitalWrite(relay4, HIGH);
}
if(password.evaluate()) {
    locked = !locked;
    password.reset();
    passinput = 0;
}
if(!locked) {
    passinput = 0;
    digitalWrite(lockedled, 0);
    digitalWrite(unlockedled, 255);
    switch (key) {
        case 'A':
            digitalWrite(relay1, !digitalRead(relay1));
            break;
        case 'B':
            digitalWrite(relay2, !digitalRead(relay2));
            break;
        case 'C':
            digitalWrite(relay3, !digitalRead(relay3));
            break;
        case 'D':
            digitalWrite(relay4, !digitalRead(relay4));
            break;
    }
    password.reset();
}
}
```