Assignments from last week

- Review LED flasher kits
- Review protoshields
- Need more soldering practice (see below)?

http://www.allelectronics.com/make-a-store/category/305/Kits/1.html
http://www.mpja.com/departments.asp?dept=61
http://www.hosfelt.com/contents/en-us/d447.html

Extra Credit Solution

Example 1

```
void setup()
{
  pinMode(7, OUTPUT);
}

void loop()
{
                // fade in from min to max in increments of 5 points:
                for(int fadeValue = 0 ; fadeValue <= 255; fadeValue +=5)
                {
                                analogWrite(9, fadeValue);
                                delay(30);
                }

                digitalWrite(7, HIGH);   // set the LED on

                // fade out from max to min in increments of 5 points:
                for(int fadeValue = 255 ; fadeValue >= 0; fadeValue -=5)
                {
                                analogWrite(9, fadeValue);
                                delay(30);
                }

                 digitalWrite(7, LOW);    // set the LED off
 }
```

Extra Credit Solution

Example 2

```
bool onoroff;

void setup()
{
  pinMode(7, OUTPUT);
}

void loop()
{
                for(int fadeValue = 0 ; fadeValue <= 255; fadeValue +=5)
                {
                                analogWrite(9, fadeValue);
                                delay(30);
                }

                for(int fadeValue = 255 ; fadeValue >= 0; fadeValue -=5)
                {
                                analogWrite(9, fadeValue);
                                delay(30);
                }

                if (onoroff==true)
                {
                                digitalWrite(7, LOW);    // set the LED off
                                onoroff = false;
                }
                else
                {
                                digitalWrite(7,HIGH);   // set the LED on
                                onoroff = true;
                }
 }
```

Functions & the While Loop

```
//FadingWithFunction.pde

int fadeValue = 0;
int increment;


void setup()
{
  pinMode(3, INPUT);
  digitalWrite(3, HIGH);       // turn on pullup resistors
}


void loop()
{

    while (digitalRead(3)==HIGH)      //monitor pin 3
    {
        LEDcontrol(fadeValue,255-fadeValue);      // use function defined belwo

        if (fadeValue >= 255) increment = -5;
        if (fadeValue <= 0) increment = 5;
        fadeValue = fadeValue+increment;

        delay(30);
    }
 }


void LEDcontrol(int pin9intensity, int pin10intensity)   // your own LED control function
{
   analogWrite(9, pin9intensity);
   analogWrite(10, pin10intensity);
}
```

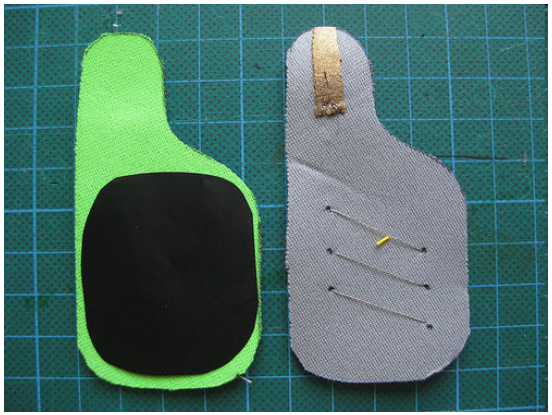
Photocell & Arduino Design Example

http://tomgerhardt.com/fireLight/

DIY Wearable Resistive Sensors

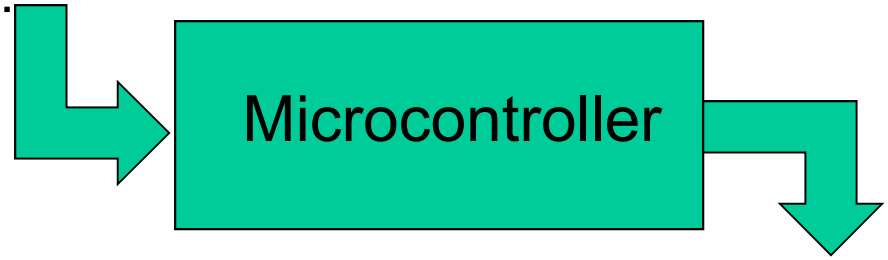
http://www.instructables.com/id/Conductive_Thread_Pressure_Sensor/

http://kobakant.at/index.php?menu=3&workshop=fs



Sensors

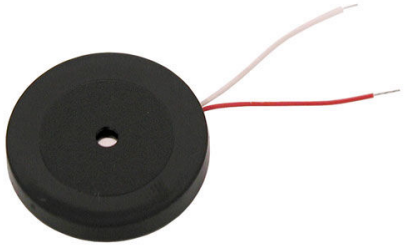
- switches
- motion
- light
- position
- temperature
- etc…



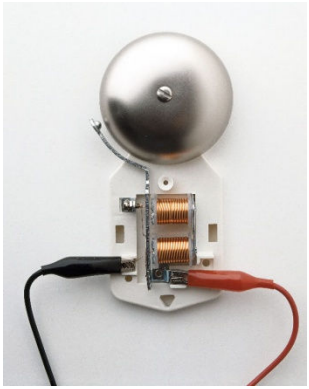
Transducers:
Sound, Lights, & Motion

Sound

- Speakers
- Piezoelectric Speakers



  - low power
  - can be driven directly from microcontroller
- Electromechanical devices



Note: Speakers and electromechanical devices should not be connected directly to the microcontroller.

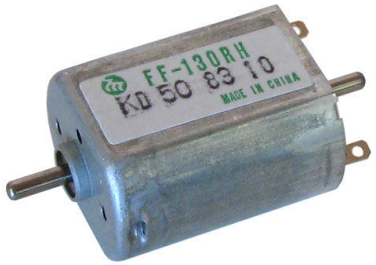
Light

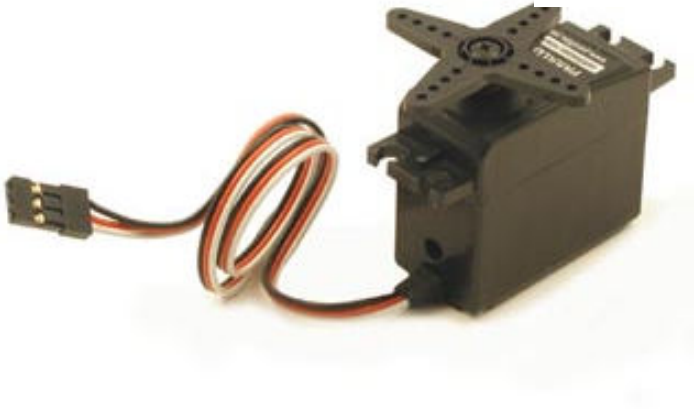
- LEDs
- incandescent bulbs
- Xenon Strobe
- EL wire

Note: LEDs are the only light producing device that can be driven directly by the microcontroller

Motion

- Solenoids
- Motors
- Servos





Solenoids

- electromagnetic lever or plunger
- simple “on-off” motion
- cannot be driven directly from microcontroller

Hacks:

- Speaker
- Hard disk

Motors

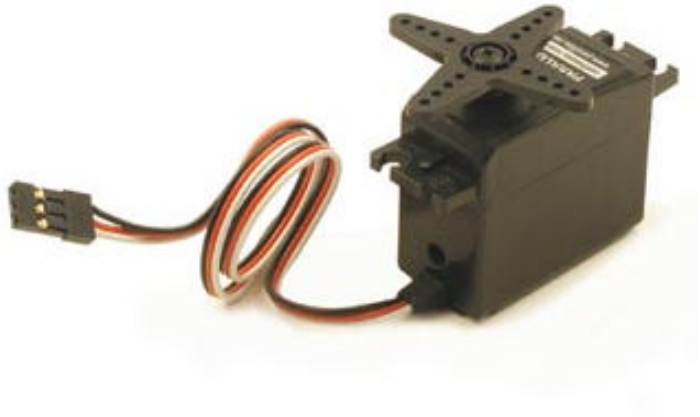
- spinning motion
- some speed control possible
- cannot be driven directly from microcontroller

Small DC motor
(3000-6000 RPM)

Gear head “timing” motor
(60 RPM or less)

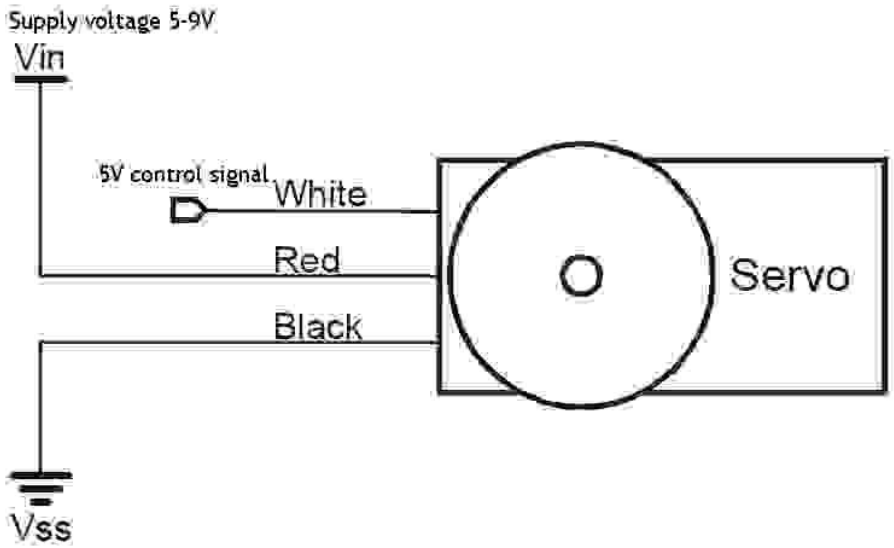
Servomotors “Servos”

- rotational angular motion
- precise position control possible
- **can** be driven directly from microcontroller

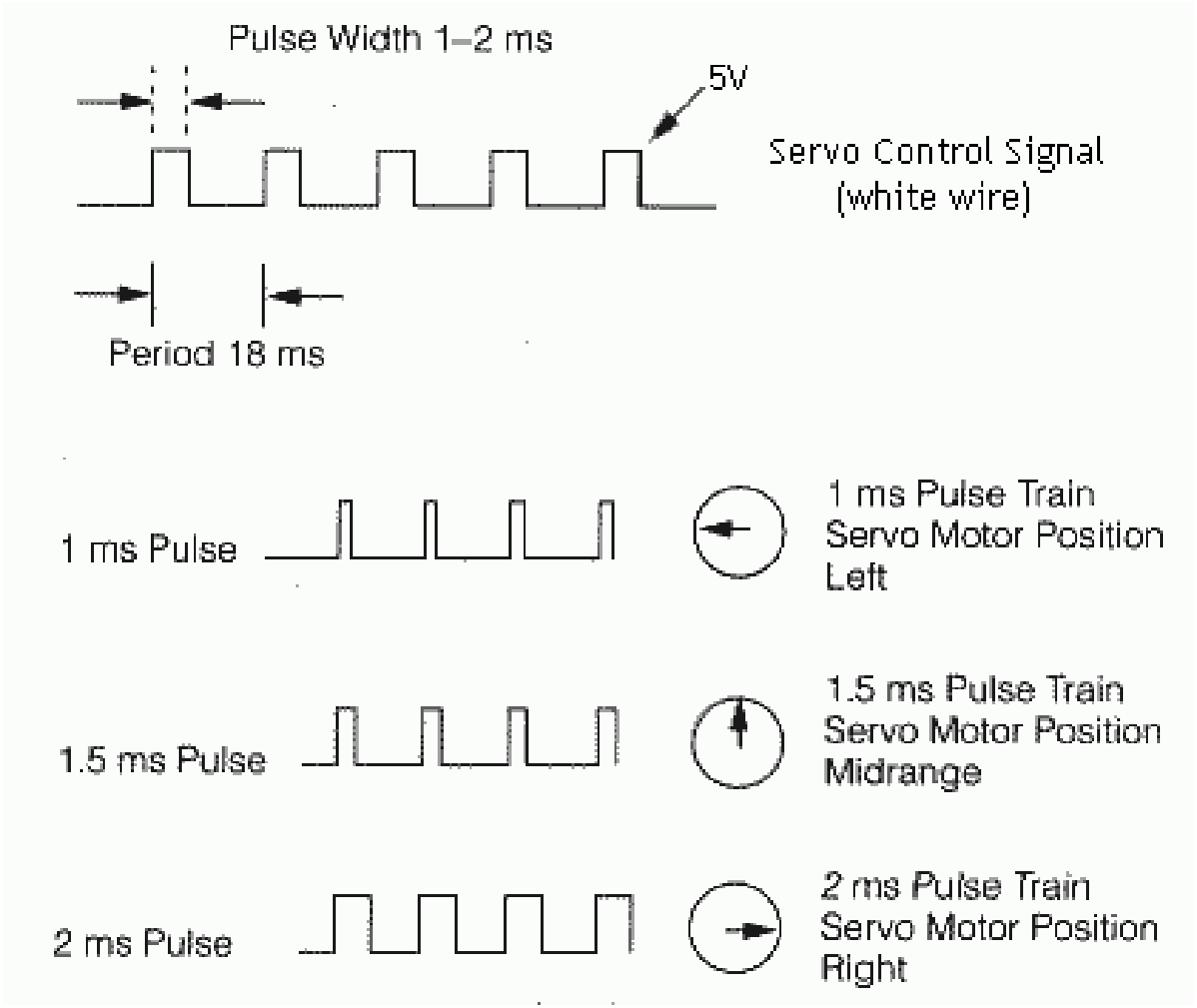


Controlling a Servo

- DC power goes to red & black wires
- Control signal goes to white wire
- Control signal is “PWM” (pulse width modulated)
- Control signal can come directly from microcontroller

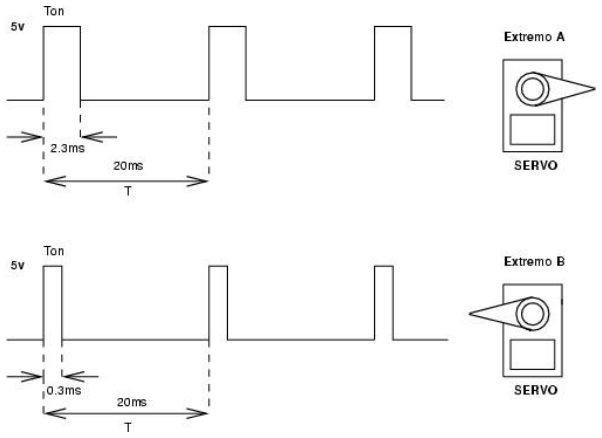


PWM Servo Control



Generating a PWM Signal

- The Arduino Servo **Object** does it for you
- Objects
  - Declared similar to variables
  - Multiple instances can exist
  - Contain a collection of related functions
- Arduino Libraries
  - A way of storing and reusing useful code
  - Extend the system's capabilities
  - Define objects used for special functions



Using the Servo Library

```
// Servo Sweep

#include <Servo.h>  // access functions in the servo library

Servo myservo;  // create servo object to control a servo
Servo anotherservo;  // create another servo object (there can be up to 8)

int pos = 0;    // variable to store the servo position

void setup()
{
   myservo.attach(9);  // attaches the servo on pin 9 to the servo object
}

void loop()
{
       for(pos = 0; pos < 180; pos += 1)  // goes from 0 degrees to 180 degrees
                  {
                  myservo.write(pos);           // tell servo to go to position in variable 'pos'
                  delay(15);                  // waits 15ms for the servo to reach the position
                  }

       for(pos = 180; pos>=1; pos-=1)     // goes from 180 degrees to 0 degrees
                  {
                  myservo.write(pos);           // tell servo to go to position in variable 'pos'
                  delay(15);                  // waits 15ms for the servo to reach the position
                  }
}
```

Servo Functions
http://arduino.cc/en/Reference/Servo

- attach()
- write()
- writeMicroseconds()
- read()
- attached()
- detach()

Using the Serial Object

```
/* Analog input, serial output */
/* Reads an analog input pin */
/* prints the results to the serial monitor */

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

void loop()
{
    // read the analog input into a variable:
    int analogValue = analogRead(0);

    // print the result:
    Serial.println(analogValue);

    delay(10);
}
```

Serial Functions
http://arduino.cc/en/Reference/Serial

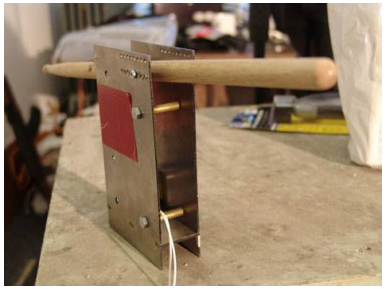
- begin()
- end()
- available()
- read()
- flush()
- print()
- println()
- write()

Using Servos

http://lemurbots.org/ultradrummer.mov

http://lemurbots.org/EmergencyBot.mov

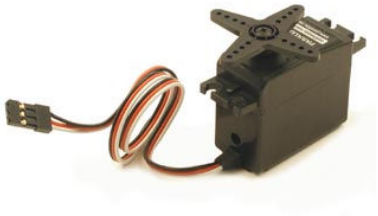
Pandemonium

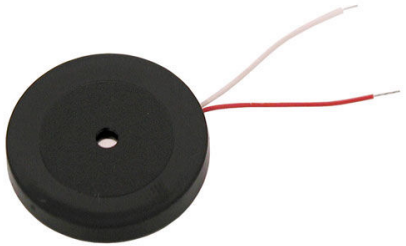


Janet Cardiff and George Bures Miller, at Eastern State Penitentiary

Devices which can be connected directly to the Microcontroller

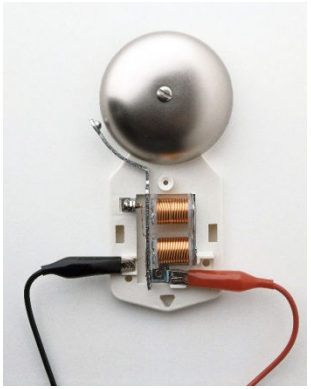
- LEDs (through a resistor)
- Piezoelectric Speakers
- Piezoelectric Buzzers
  - Do not require constant updating
  - free the microcontroller to do other things
- Servos (incorporate interface circuitry)





Higher Power Devices
- require intermediary interface circuitry

- Speakers
- Electromechanical devices
  - Motors
  - Relays
  - Solenoids
- Incandescent lights
- AC line voltage devices

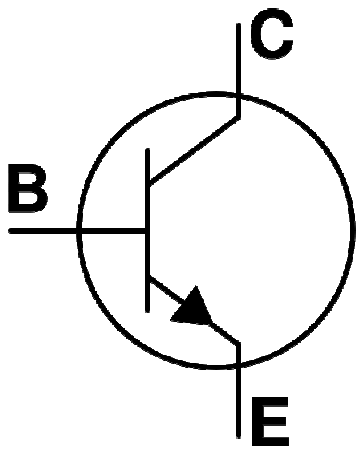


Transistors

- Act as electronic switches
- Let you control high power devices with low power signals
- Microcontroller pin maximum output is 5V and 25mA
- Transistors can handle 100s of Volts, 10A or more
- Many different flavors:NPN, PNP, FET, MOSFET…
- We will focus on the use of:
  - NPN transistors
  - N-channel MOSFETS

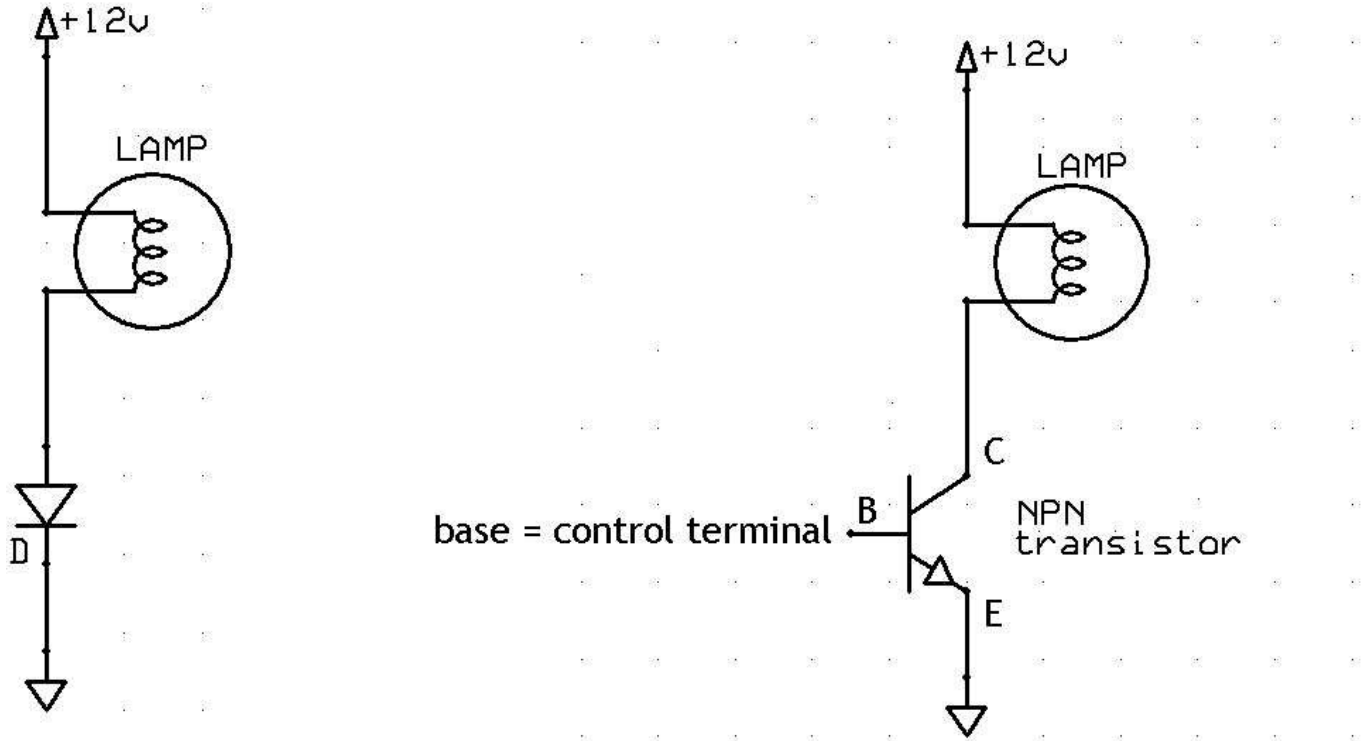
The NPN transistor

- Works like a “controllable diode”
- Three terminals
  - base ← the control terminal
  - collector
  - emitter
- C & E are connected in series with the controlled device

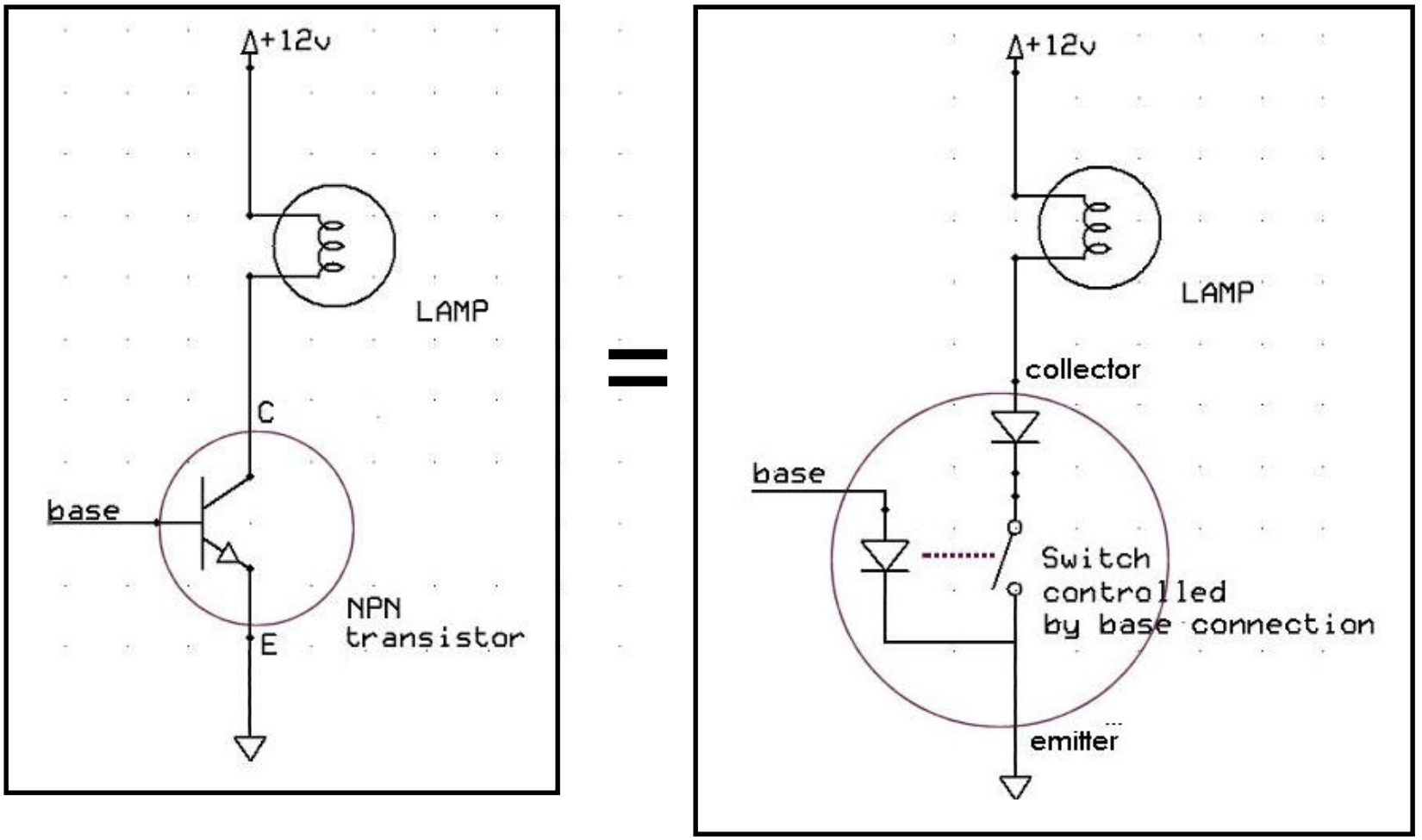


NPN transistor symbol

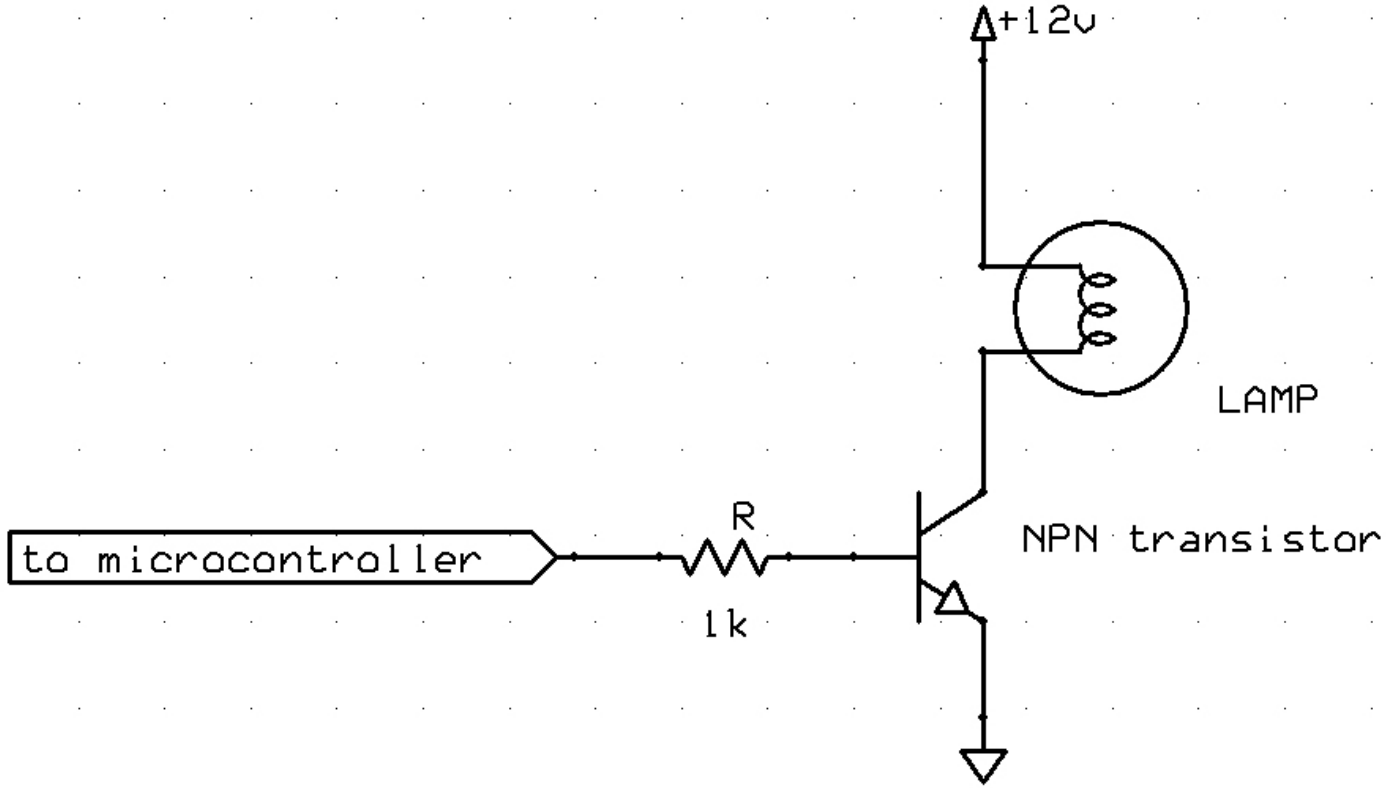
The transistor as a “controllable diode”



The transistor as a “diode controlled by a diode”

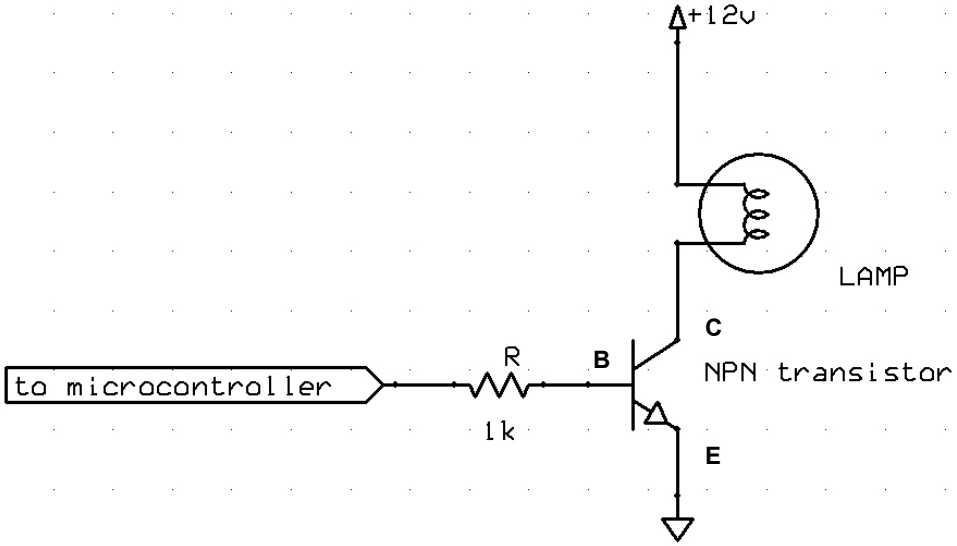


Using a transistor to control a light bulb



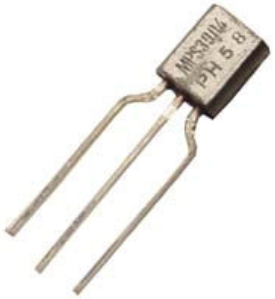
- Controller pin low (GND) → transistor is off
- Controller pin high (+5) → light!
- resistor limits current from microcontroller (only a little is required)

Transistor Advantages

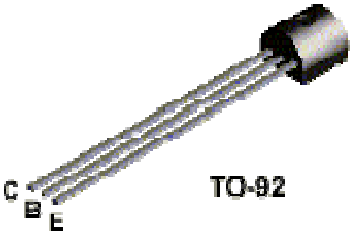


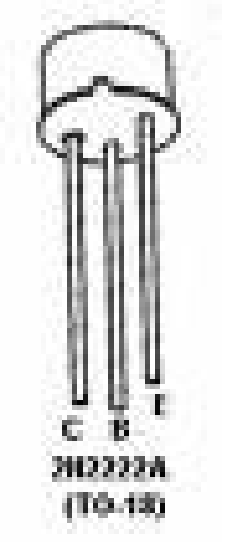
- Current into base is much smaller than current through lamp
  - base current ≅ 1-10 mA
  - C-E current 1-10A or larger, depending on size of transistor
- Voltage on lamp can be higher than 5V
- Signal from microcontroller is able to control higher voltages
- Signal from microcontroller is able to control higher currents

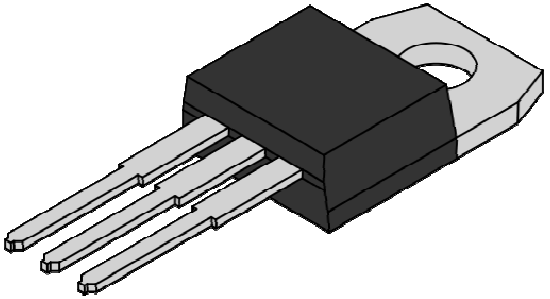
Transistor Packages & pinout

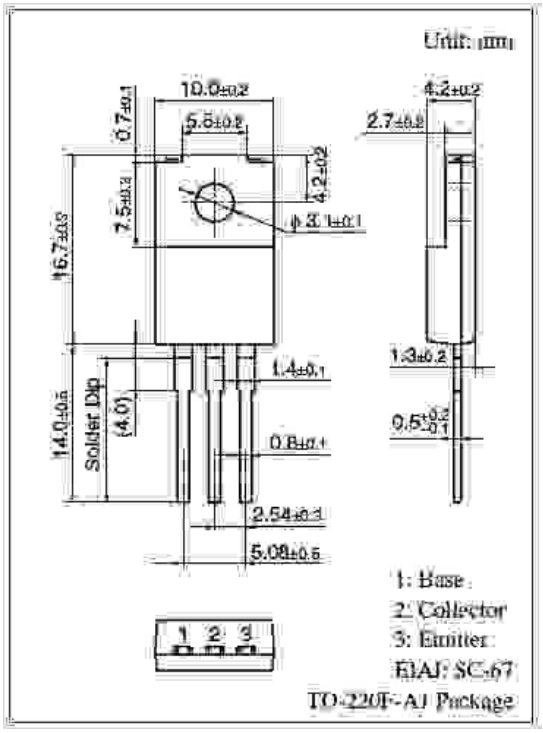


2N3904







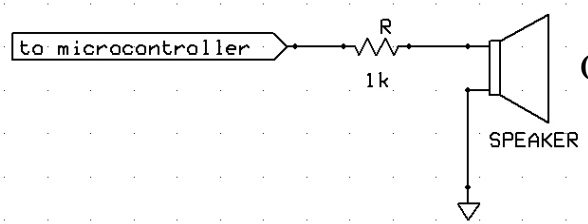


Check the datasheet!

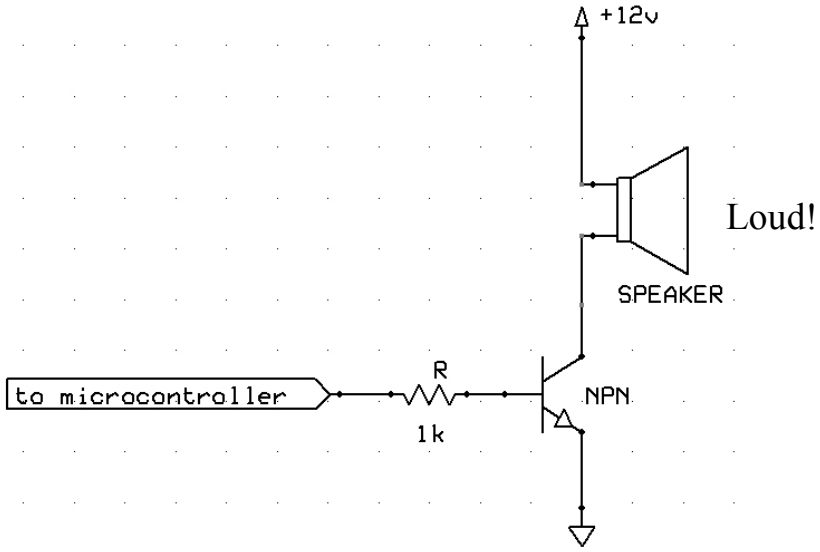
Transistor Ratings

- V_{ce} maximum controllable voltage
- I_C maximum controllable current
- h_{fe} current gain

A Simple Audio Amplifier

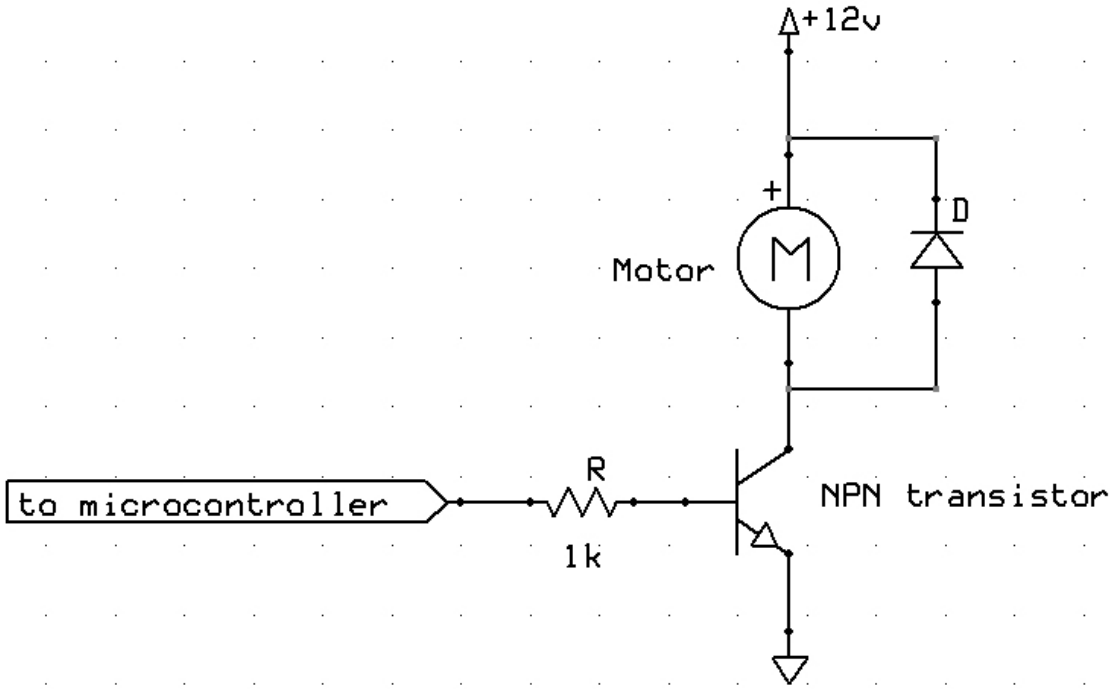


A typical speaker can be connected thru a resistor to limit the current



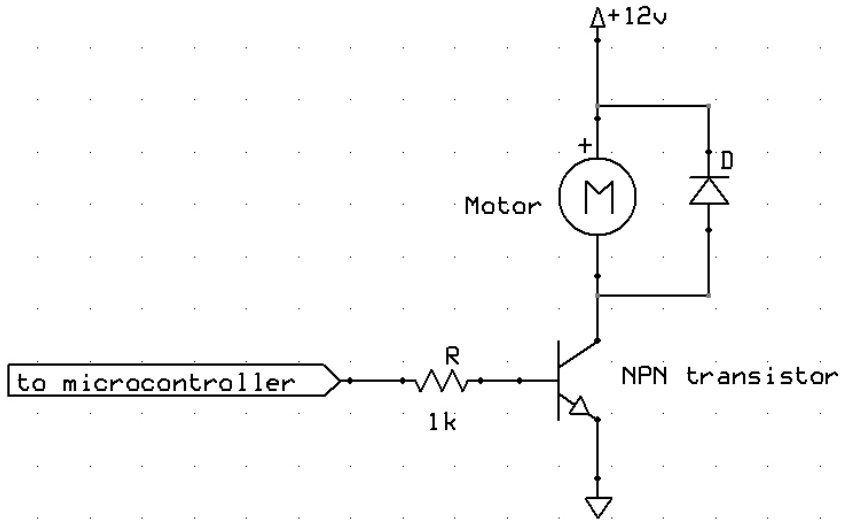
A transistor can be used to increase (amplify) the sound

Controlling a Motor, Relay, or Solenoid

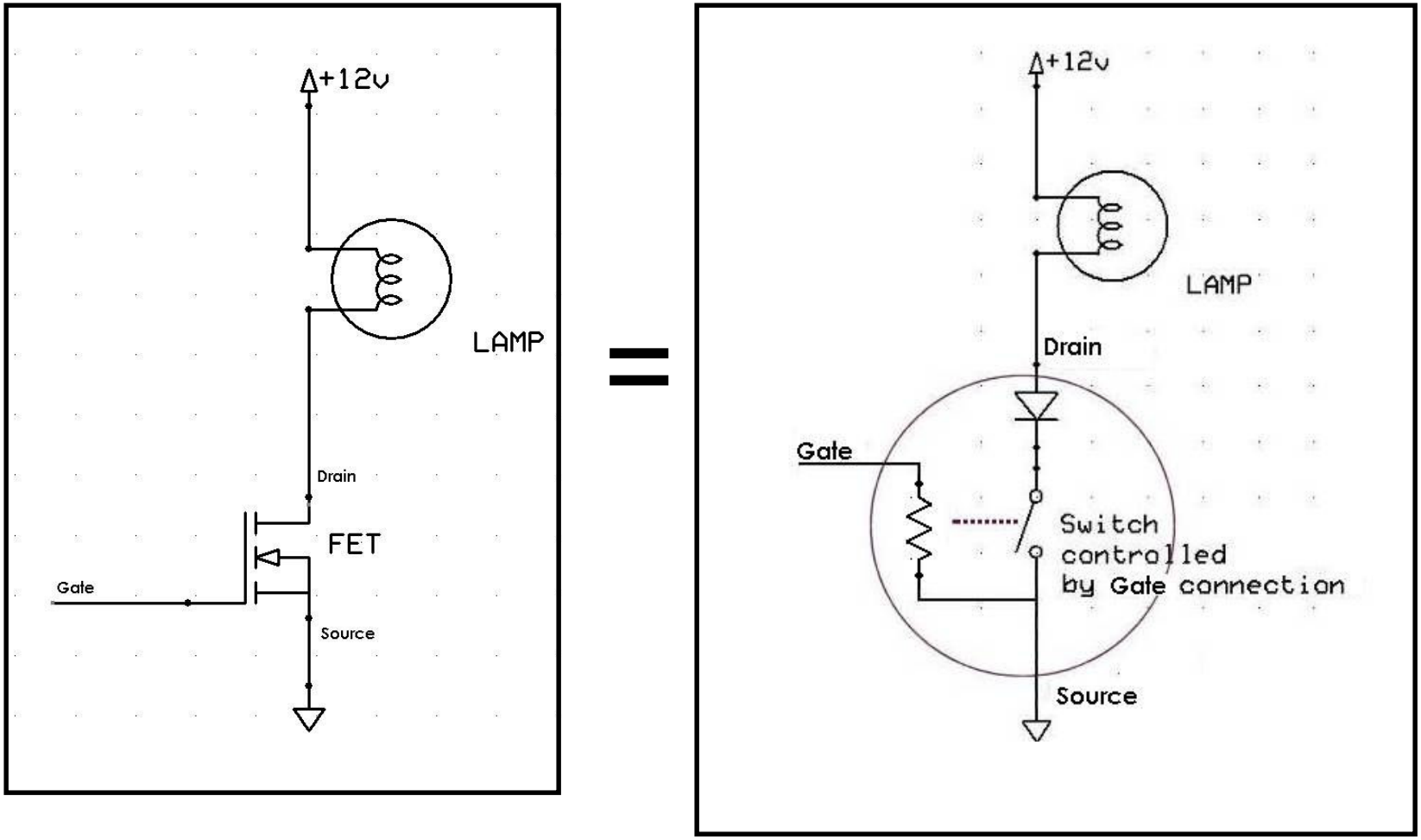


Always add a “snubber” diode across any inductive load!

- Magnetic energy is stored in an activated motor, relay, or solenoid
- There is a momentum in the current passing through the device
- This energy will “fight” the transistor’s attempt to turn off the device
- The diode provides a path for the current to flow after turn-off



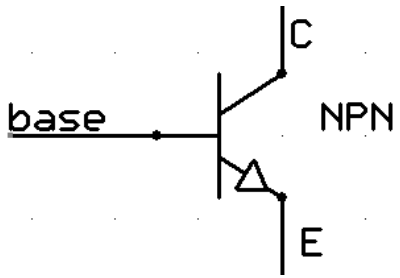
MOSFET Transistors



Two types of Transistors

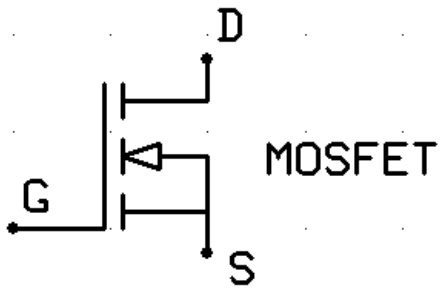
NPN Transistor
- – Collector
- – Base
- – Emitter

• Input (base - emitter)
• Input behaves like a diode



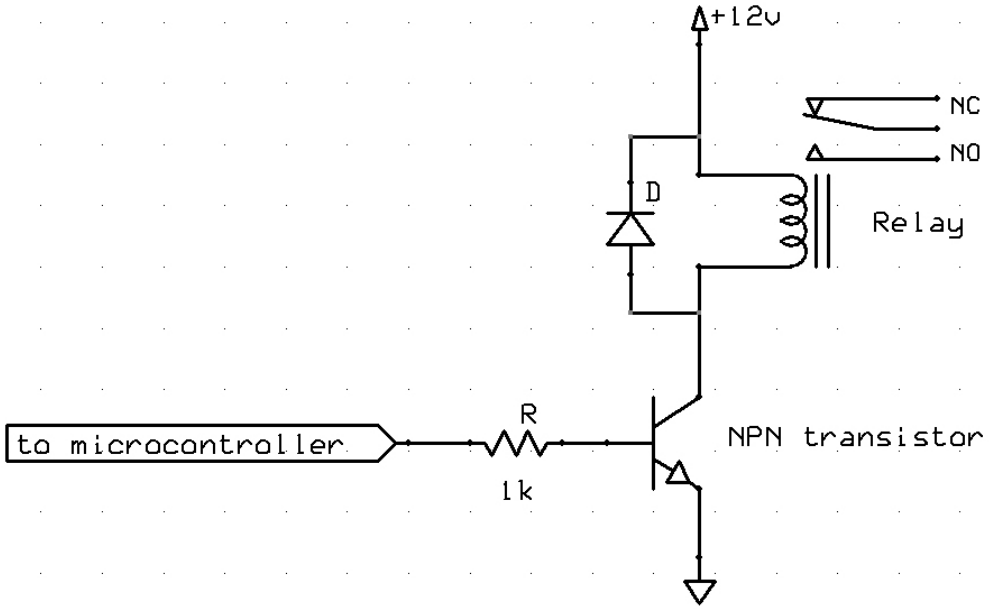
MOSFET transistor (N type)
- – Drain
- – Gate
- – Source

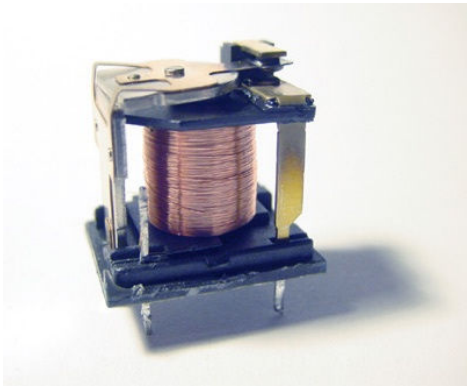
• Input (gate - source)
• Input behaves like a large resistor



Mechanical Relays

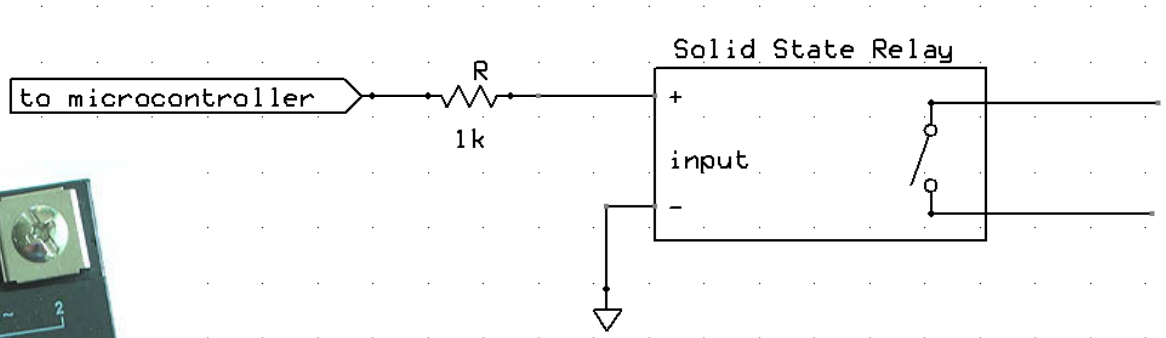
- A switch controlled by an electromagnet
- Switch contacts are electrically isolated from control circuitry
- Contacts can handle more power
- Can control AC and DC powered devices
- Use a snubber diode!





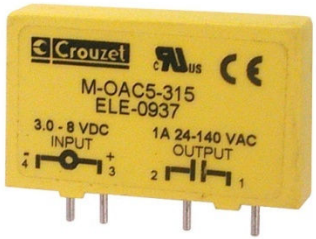
Solid State Relays

- Often the best solution
- Can control AC and DC circuits
- Output is electrically isolated from control circuitry
- No snubber diode needed



Relay Ratings

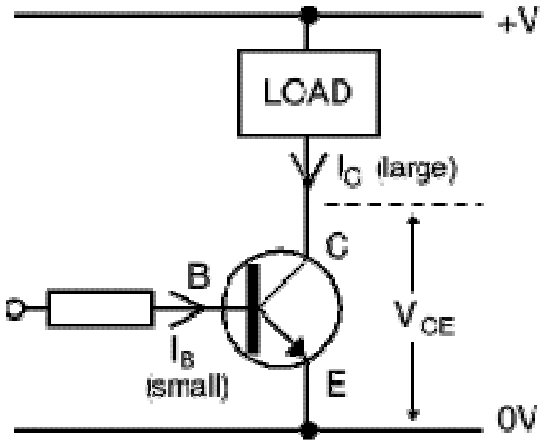
- Input
  - Control voltage
  - Control current (negligible for SSR)
- Output
  - Maximum voltage
  - maximum current



Summary

- Transistors are a way to control higher power DC devices with the microcontroller
- Transistors amplify the power you can control
- Relays isolate & control higher power devices
- Solid state relays are an easy way to control higher power AC & DC devices with the microcontroller

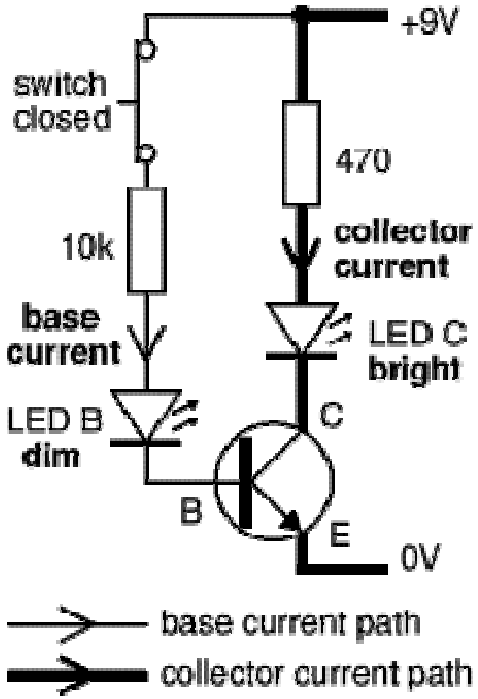
Transistor is a Current Amplifier



- Ratio of I_c to I_b is the transistor's "gain"
- Gain is sometimes abbreviated as h_{fe} or β
- β is typically around 100
- **Actual I_c may be limited by resistance of load**

$$\beta = \frac{I_C}{I_B} \approx 100$$

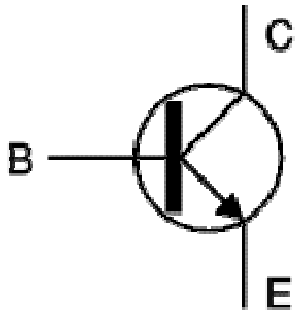
Transistors as Amplifiers

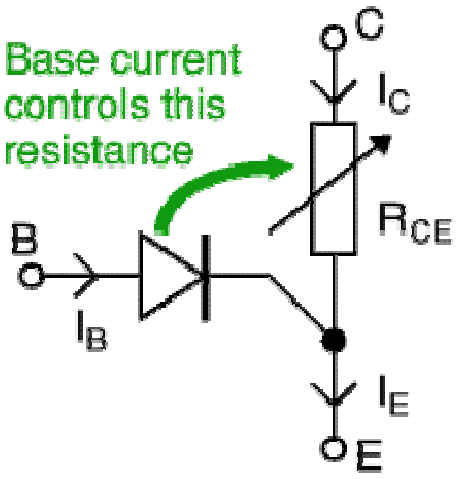


- Small base current controls large collector current
- Base current (in this circuit) < 1mA
- Collector current could be >100mA

http://www.kpsec.freeuk.com/trancirc.htm

Transistors as Amplifiers





- Transistor is equivalent to a variable resistor controlled by the current through a diode
- A transistor contains an internal diode between Base & Emitter
- The voltage across this diode will always be about 0.6V when there is current flowing into the base (transistor on)
- The current through the diode controls the current through the CE resistor (R_{CE})

Assignments due 25 Feb 2010

- Read: Chapters 9 & 10 in Physical Computing
- Proposal for project #1 (see following page)
- Bring in an electronic toy or other device for the circuit bending lab.

Proposal for Project #1

Write a one page proposal for Project #1 “The ACTIVE OBJECT”
The proposal is due next week Thursday February 25th
The project will be presented in class three weeks later on March 18th

For this first project, you will use at least 3 separate sensors (such as switches, potentiometers, flex sensors, light sensors, thermistors, ping distance sensors, IR distance sensors, accelerometers, etc…) and at least one type of transducer creating light, sound, or motion (incandescent bulbs, LEDs, speakers, servos, DC motors…) along with the Arduino and other materials (such as plastic, wood, cloth, cardboard, stone, etc.) to create an object that reacts to changes in its environment.

Try to make the object as engaging/interesting as possible. It may help to first choose a category for the device you want to make such as “toy”, “game”, “sculpture”, “fashion accessory”, or “musical instrument”.

In your proposal please include a description of what you want the device to do and how it will react and interact with its environment. Also provide a breakdown of its intended behavior describing how the hardware and software will function, for example:

–If the reading from the light sensor is below a certain level, turn on first red LED.
–If the reading from the light sensor is at a medium level, turn off red LED and turn on six yellow LEDs.
–If the reading from the light sensor is at or above a certain higher level, turn off red and yellow LEDs and move the servo to the center position…