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

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/

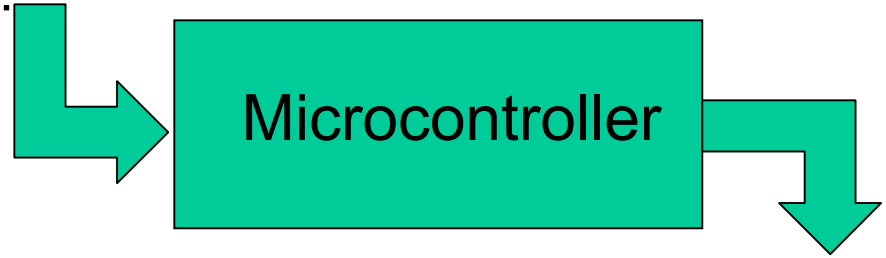
DIY Wearable Resistive Sensors

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)

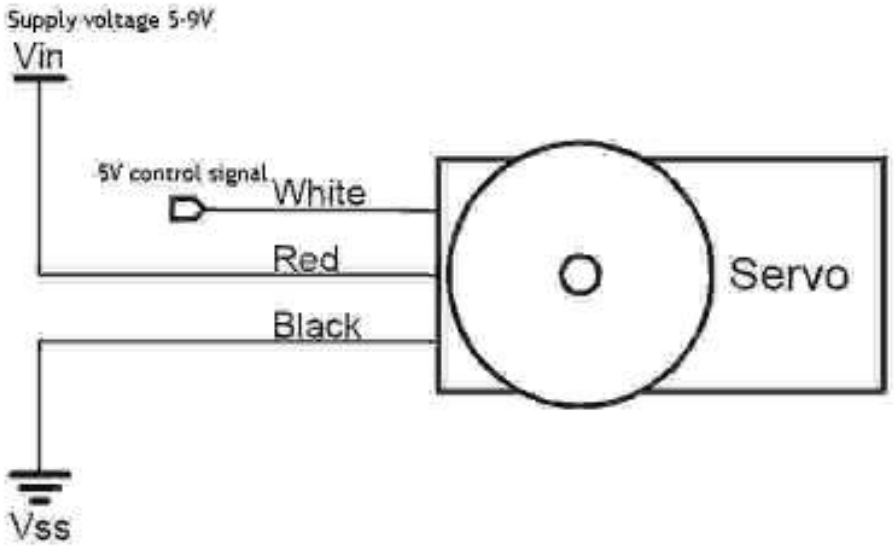
Gear head “timing” motor
(60 RPM or less)

Servomotors “Servos”

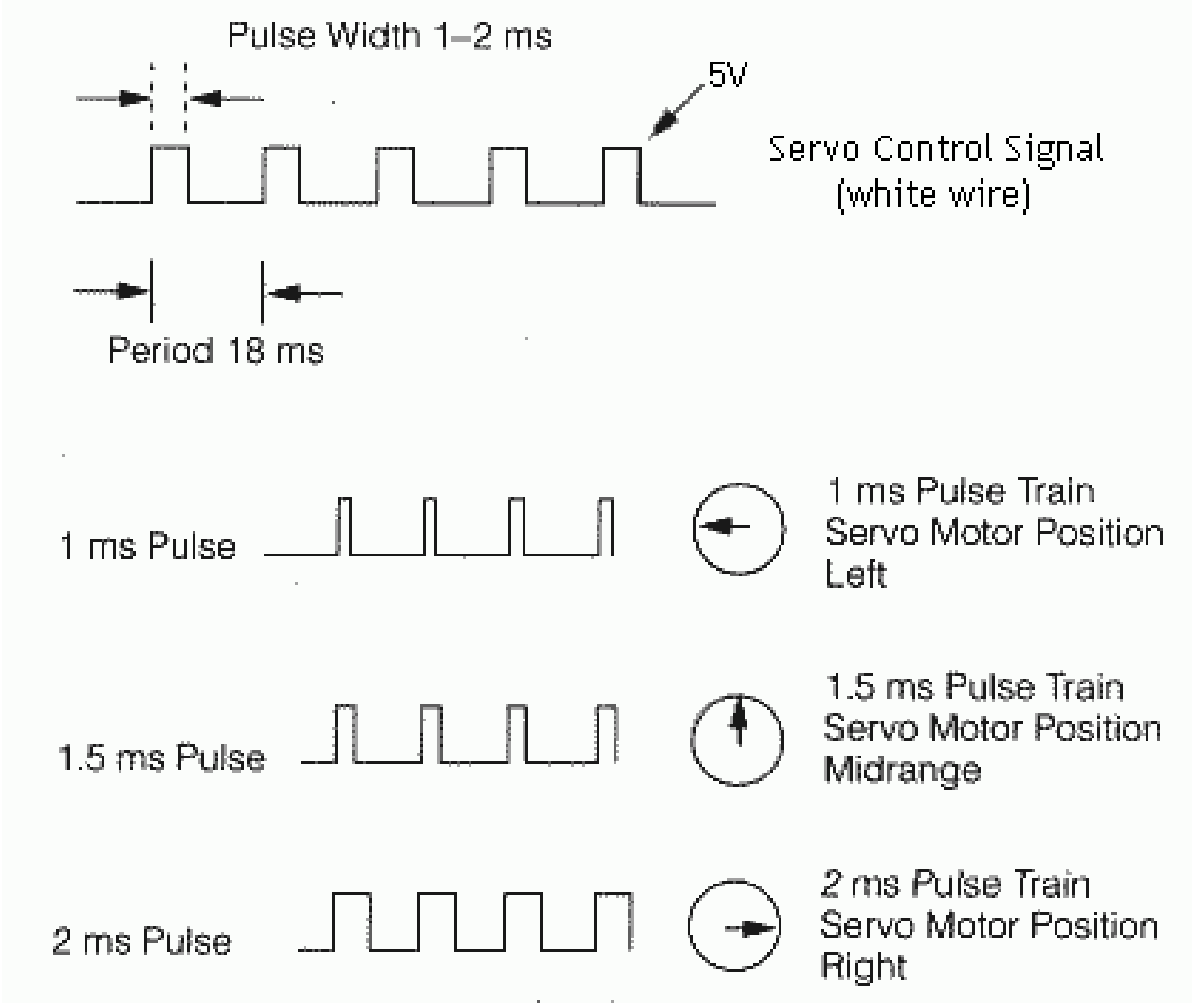
- rotational angular motion
- precise position control possible
- **can** be driven directly from microcontroller

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

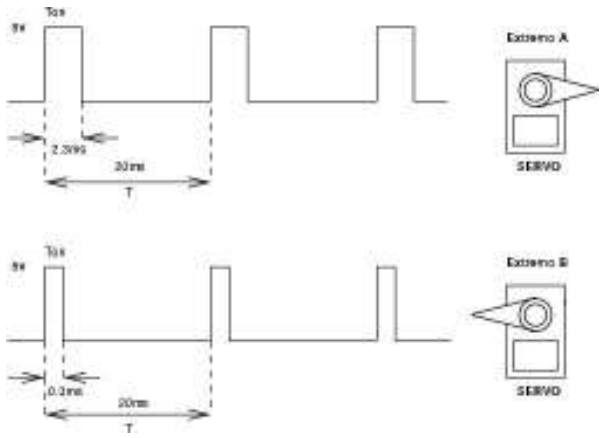


PWM Servo Control



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

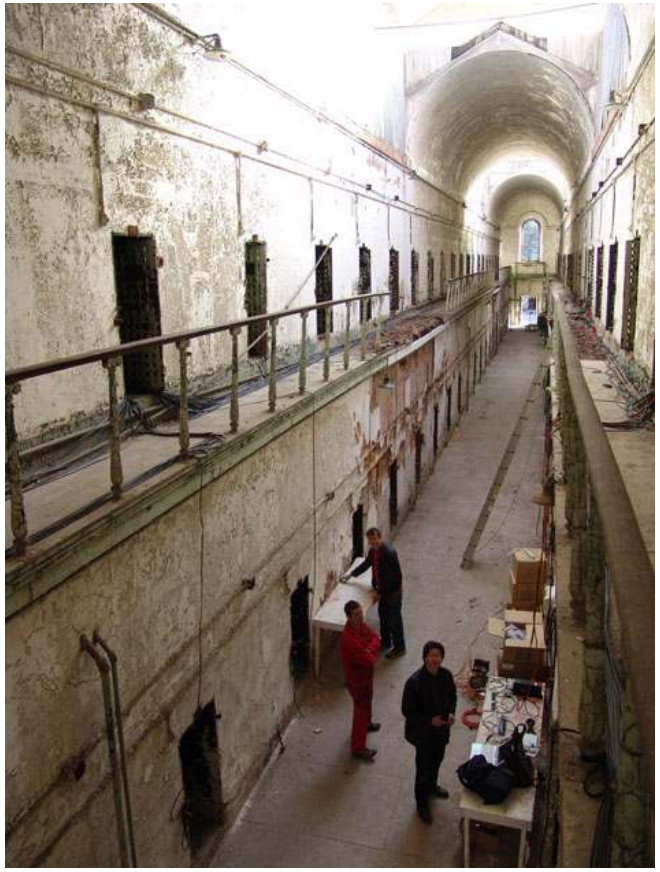
- begin()
- end()
- available()
- read()
- flush()
- print()
- println()
- write()

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

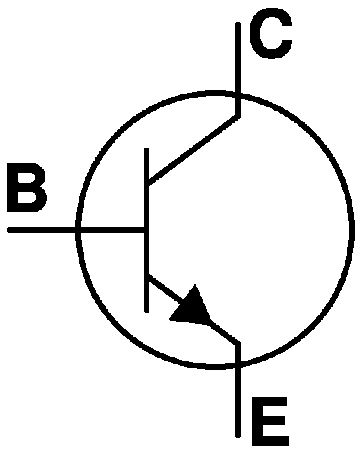
- Speakers
- Electromechanical devices
  - Motors
  - Relays
  - Solenoids
- Incandescent lights
- AC line voltage devices

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

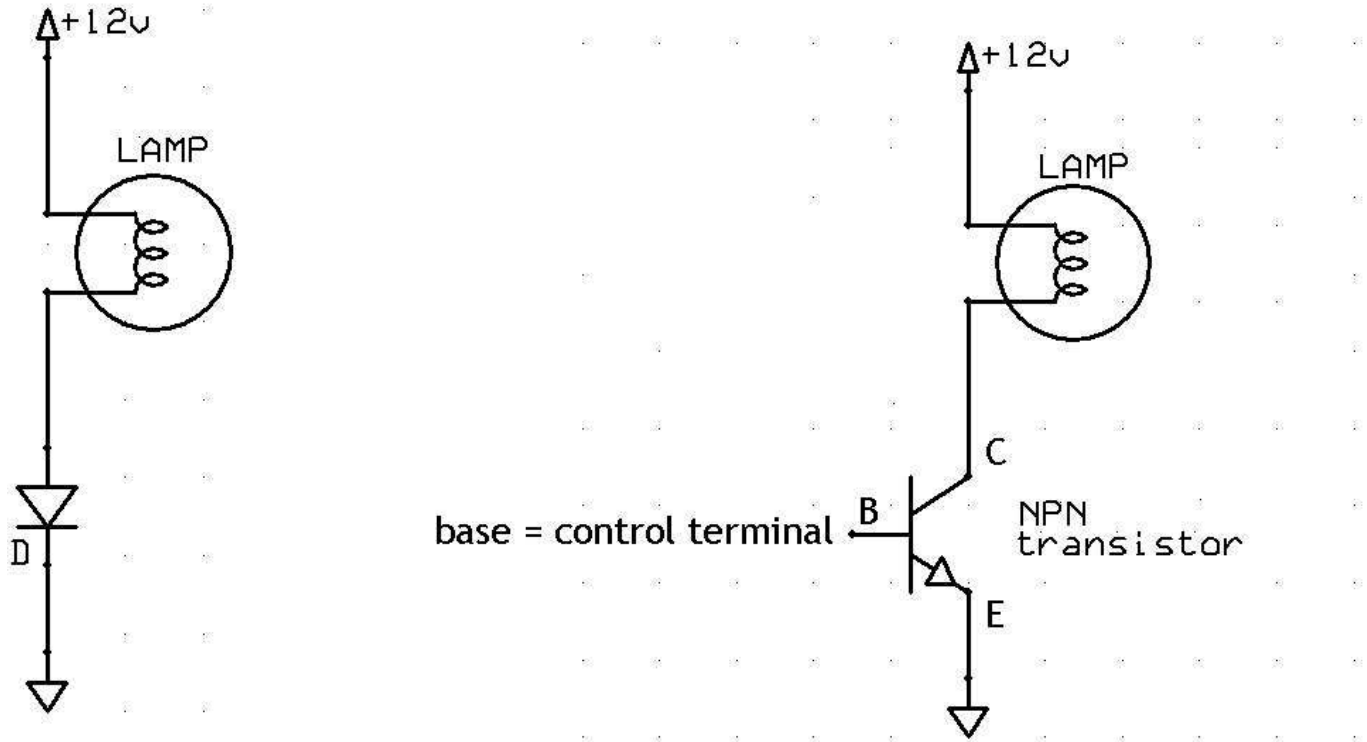
The NPN transistor

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

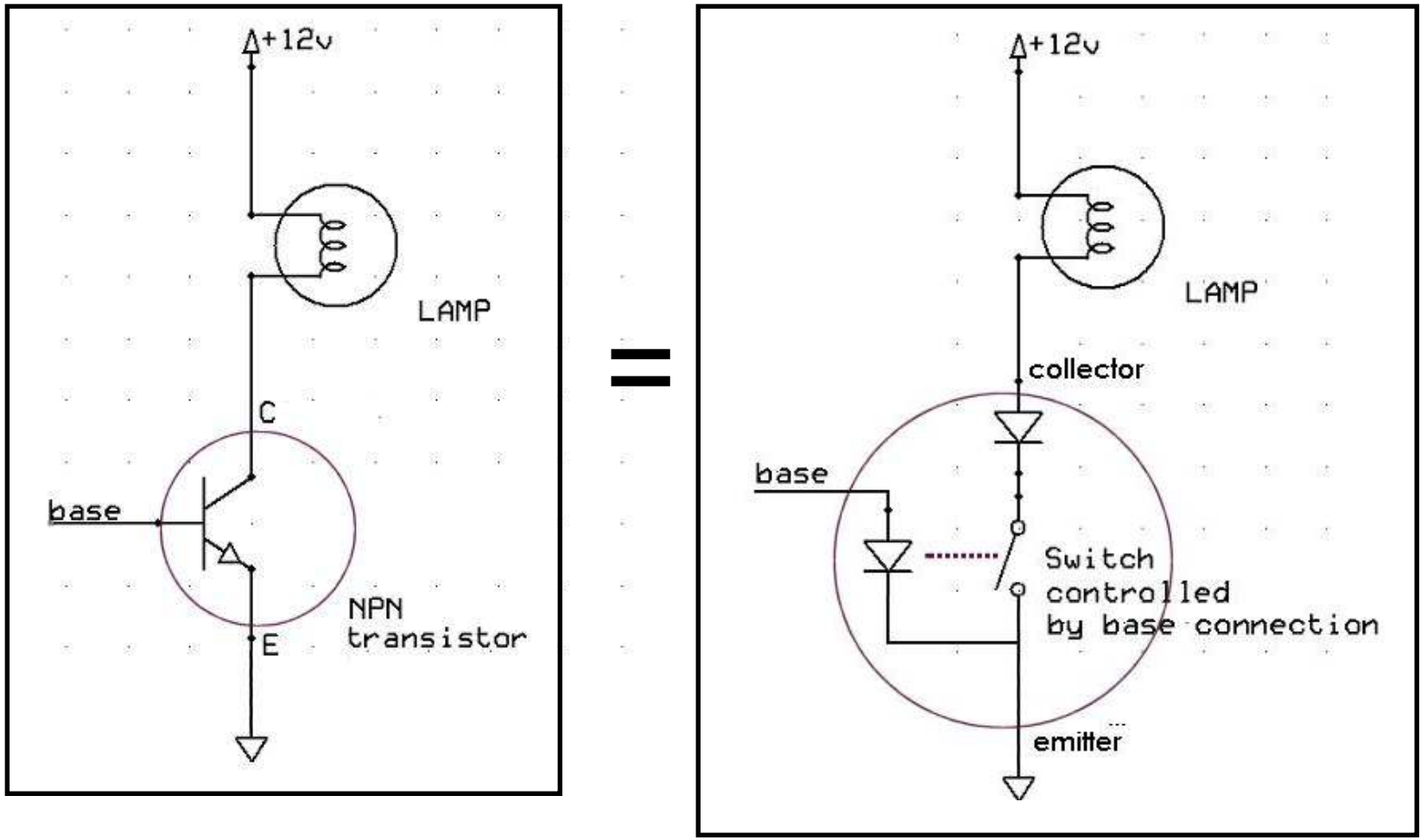


NPN transistor symbol

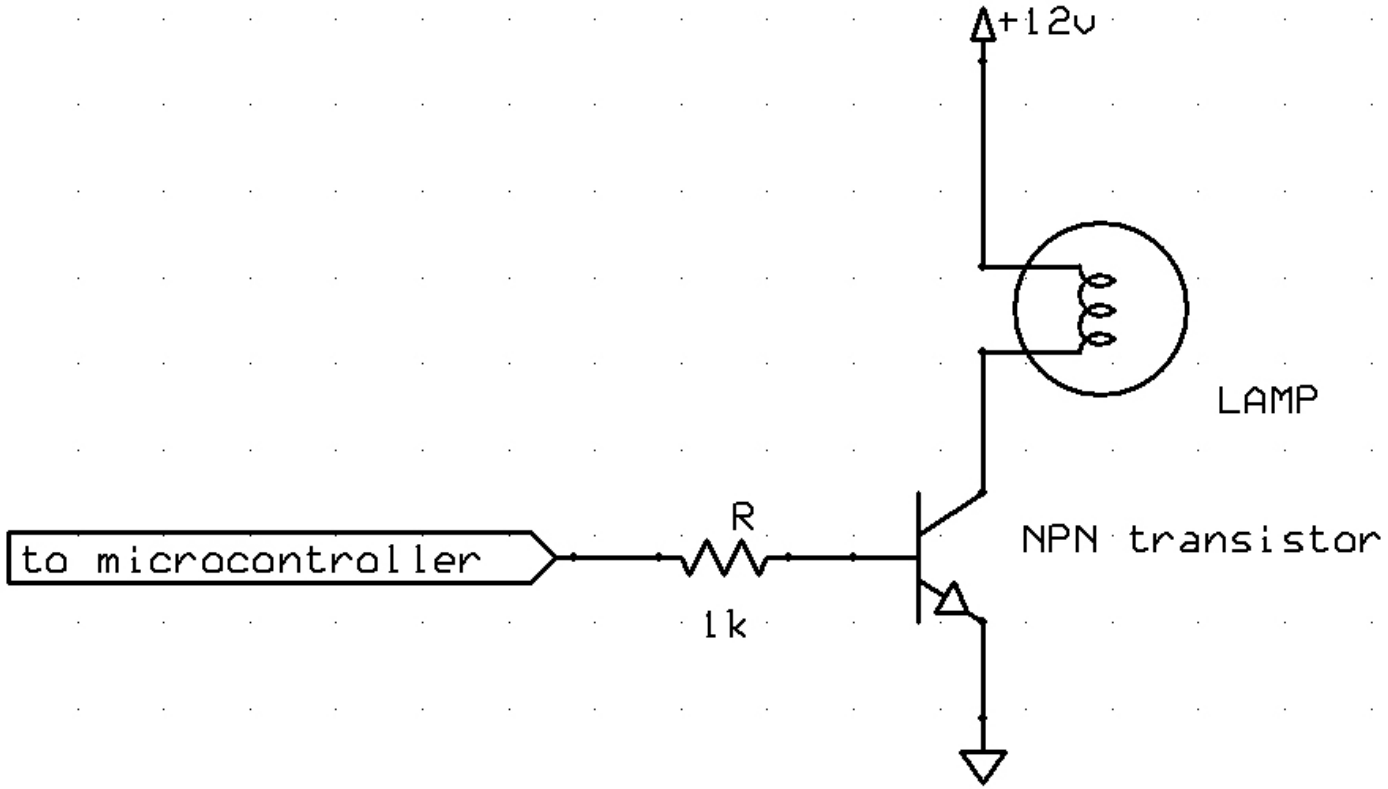
The transistor as a “controllable diode”



The transistor as a “diode controlled by a diode”

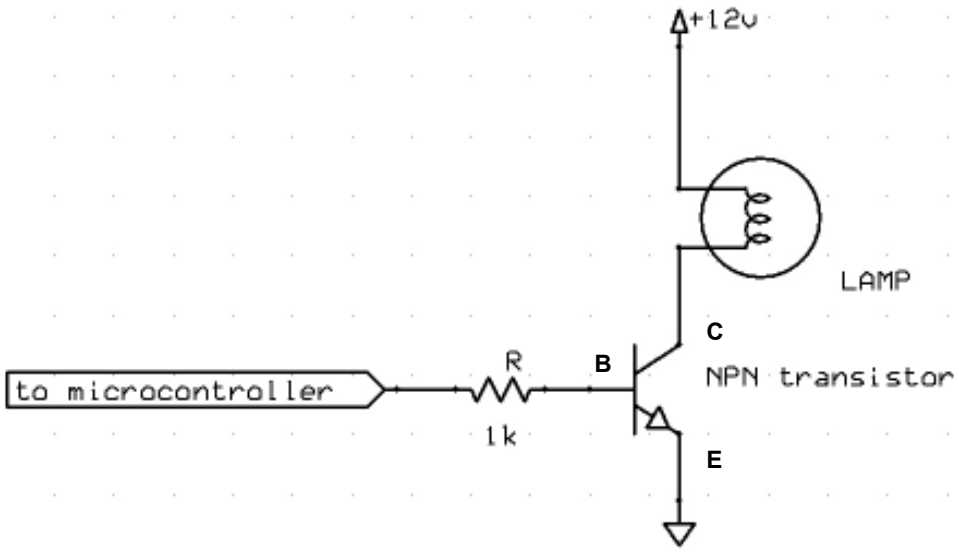


Using a transistor to control a light bulb



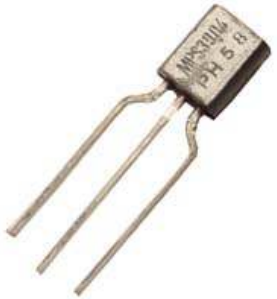
- Controller pin low (GND) → transistor is off
- Controller pin high (+5) → light!
- resistor limits current from microcontroller (only a little is required)

Transistor Advantages

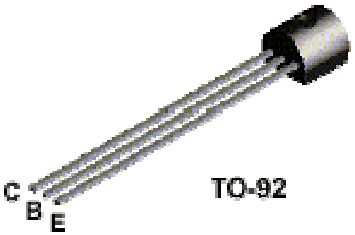


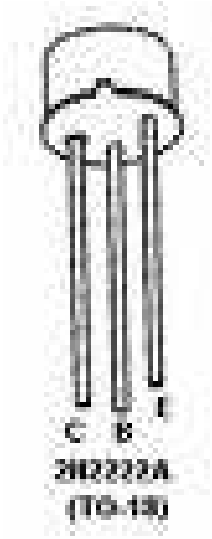
- Current into base is much smaller than current through lamp
  - base current ≅ 1-10 mA
  - C-E current 1-10A or larger, depending on size of transistor
- Voltage on lamp can be higher than 5V
- Signal from microcontroller is able to control higher voltages
- Signal from microcontroller is able to control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

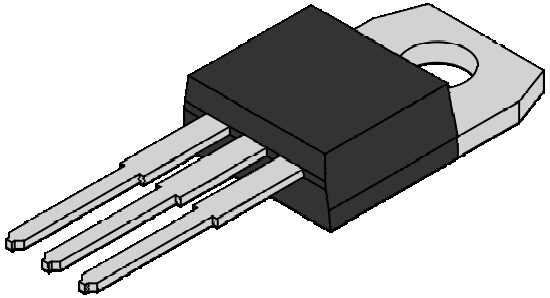
Transistor Packages & pinout

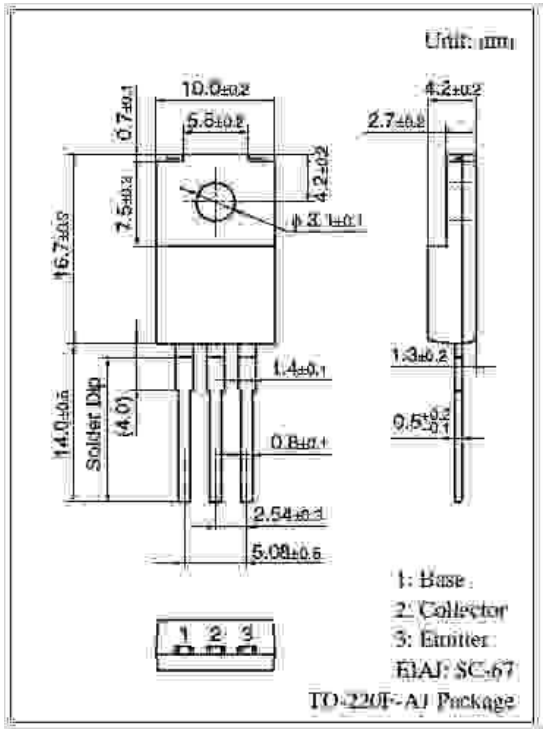


2N3904







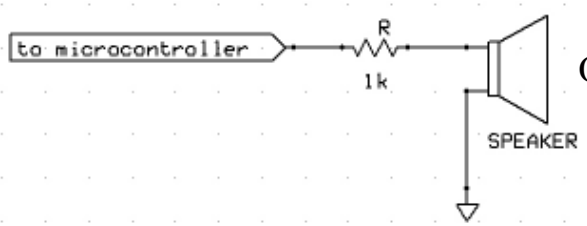


Check the datasheet!

Transistor Ratings

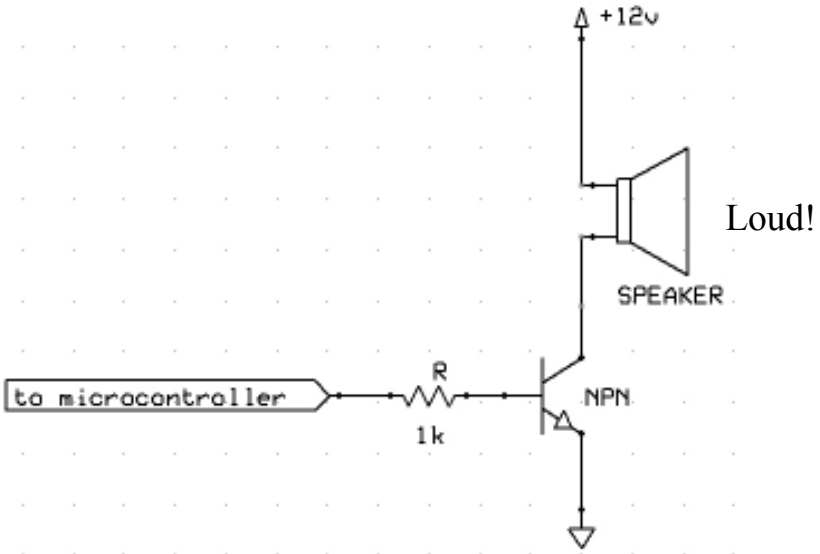
- V_{ce} maximum controllable voltage
- I_C maximum controllable current
- h_{fe} current gain

A Simple Audio Amplifier



Quiet

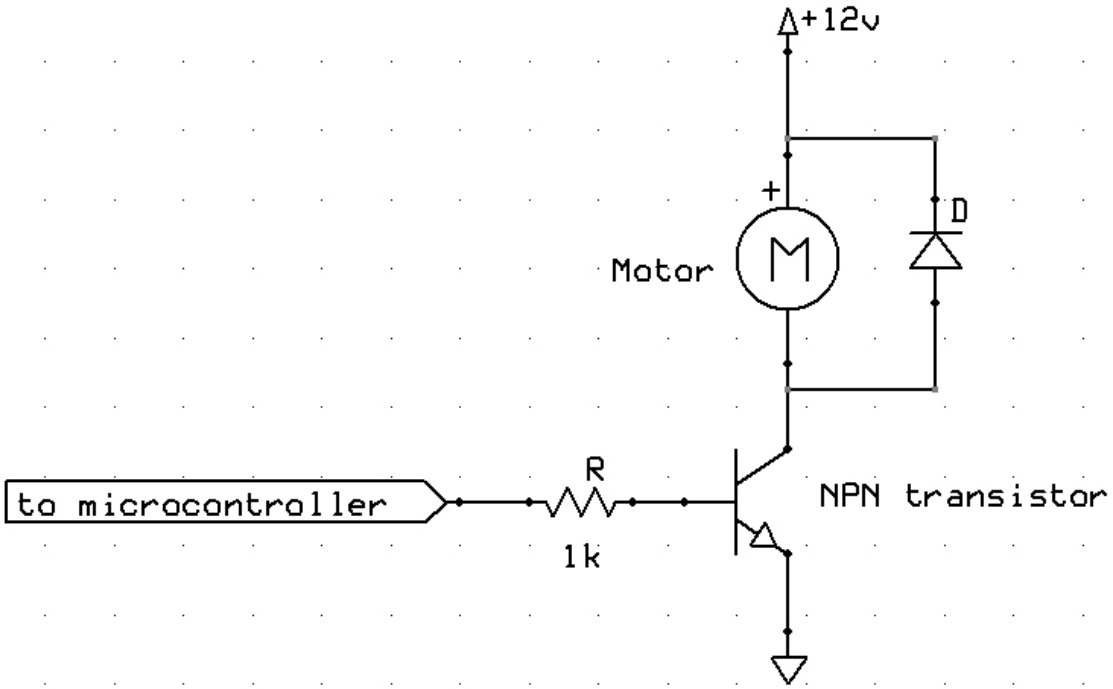
A typical speaker can be connected thru a resistor to limit the current



Loud!

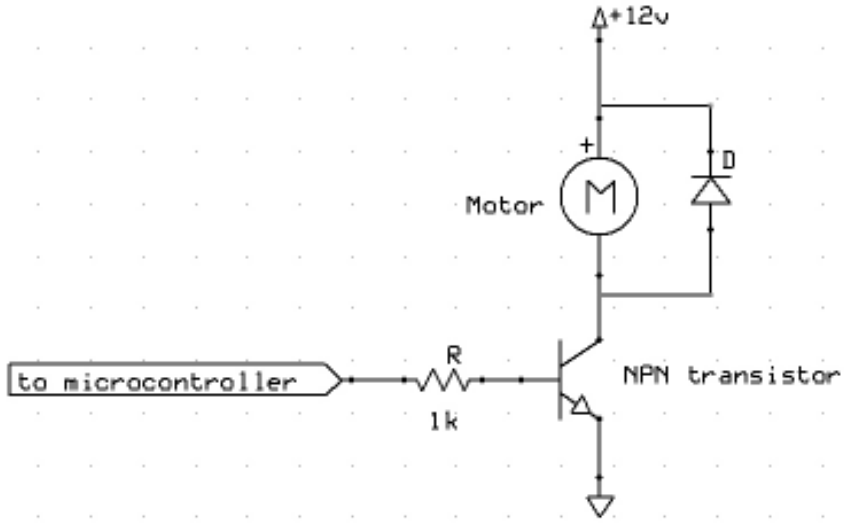
A transistor can be used to increase (amplify) the sound

Controlling a Motor, Relay, or Solenoid

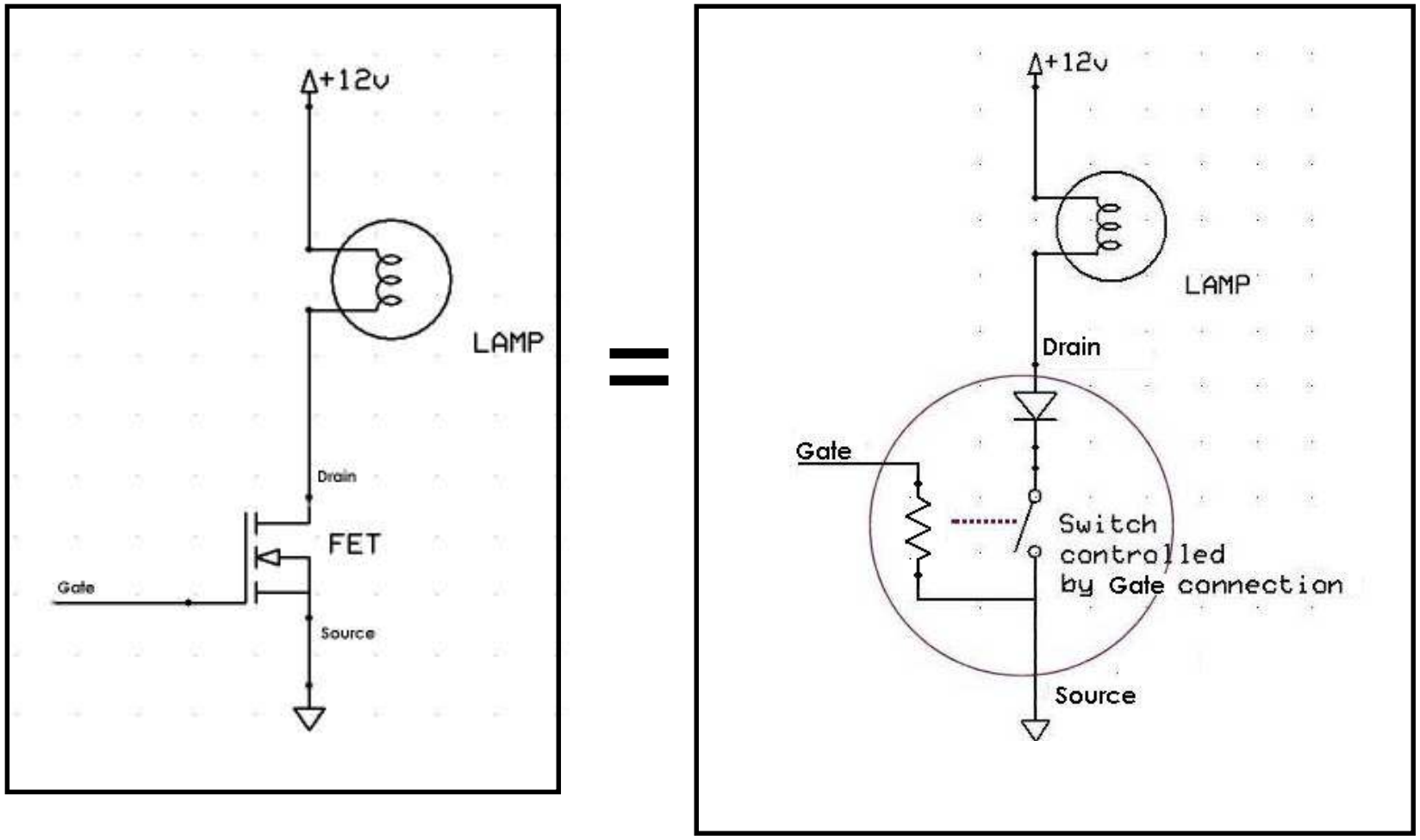


Always add a “snubber” diode across any inductive load!

- 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



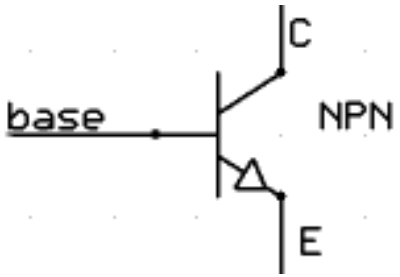
MOSFET Transistors



Two types of Transistors

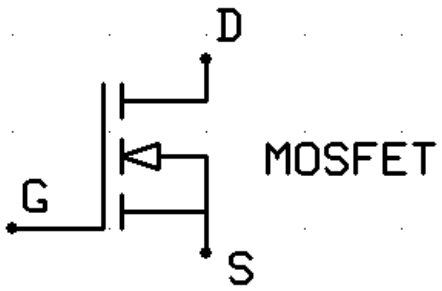
NPN Transistor
- – Collector
- – Base
- – Emitter

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



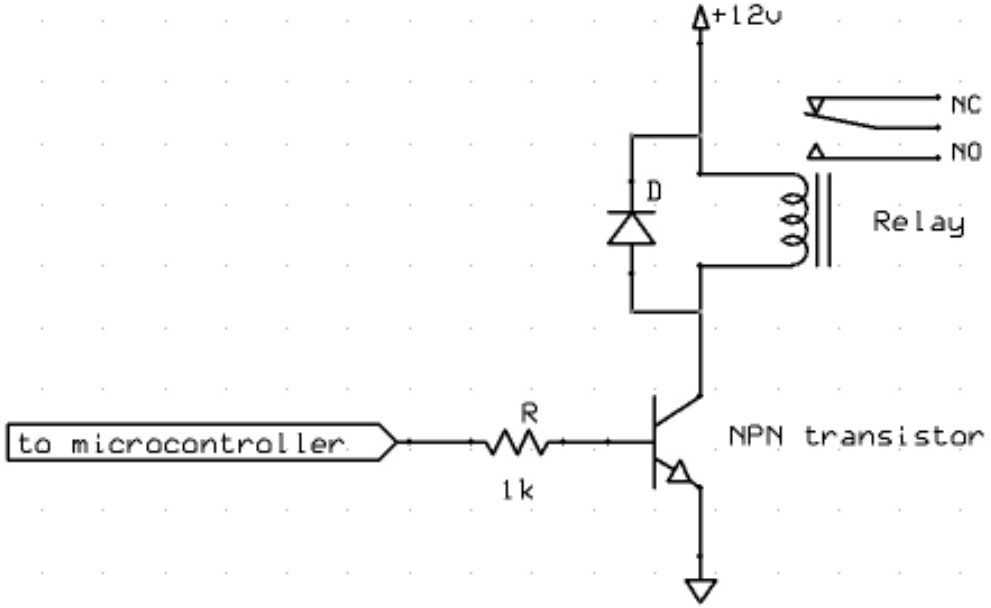
MOSFET transistor (N type)
- – Drain
- – Gate
- – Source

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



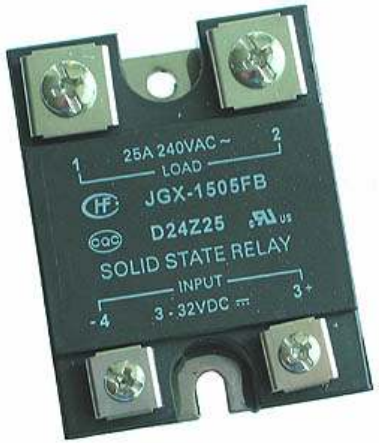
Mechanical Relays

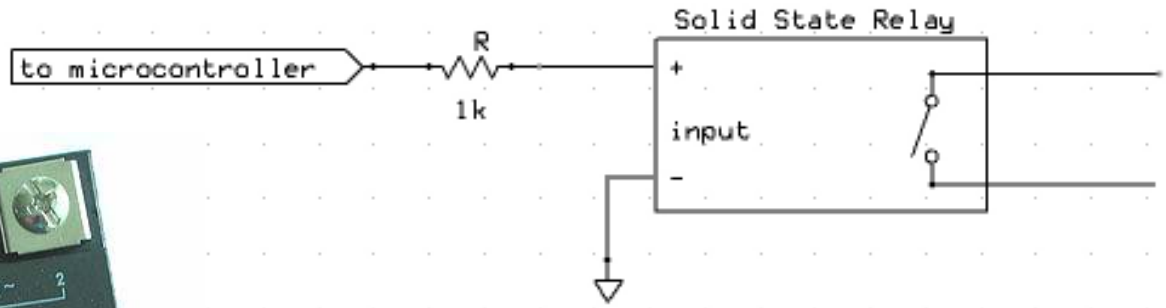
- A switch controlled by an electromagnet
- Switch contacts are electrically isolated from control circuitry
- Contacts can handle more power
- Can control AC and DC powered devices
- Use a snubber diode!



Solid State Relays

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





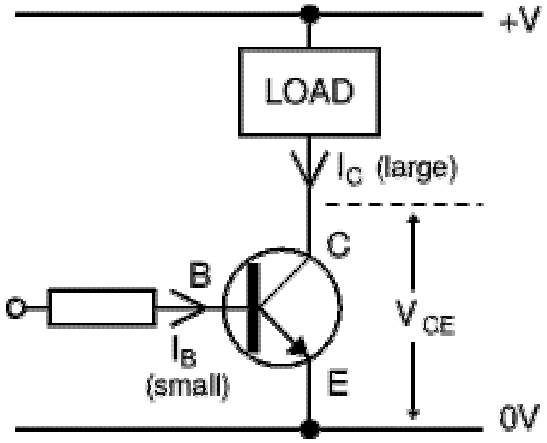
Relay Ratings

- 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

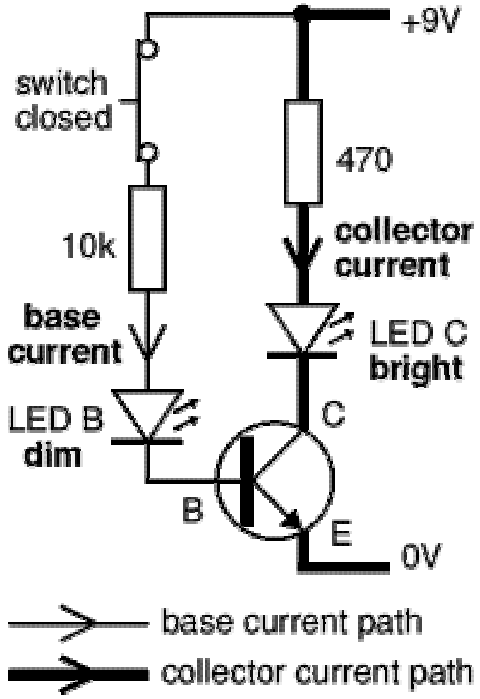
Transistor is a Current Amplifier



- 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**

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

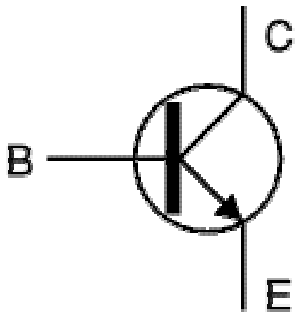
Transistors as Amplifiers

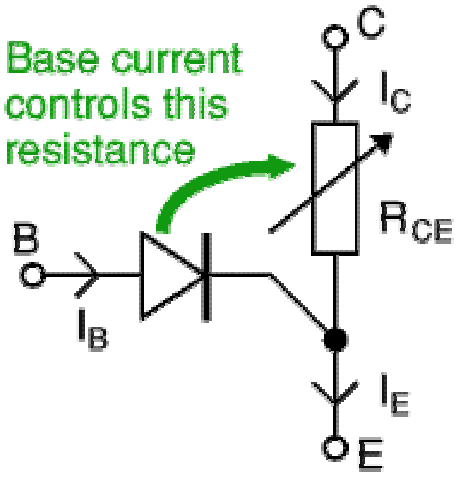


- Small base current controls large collector current
- Base current (in this circuit) < 1mA
- Collector current could be >100mA

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})