

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 below

    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

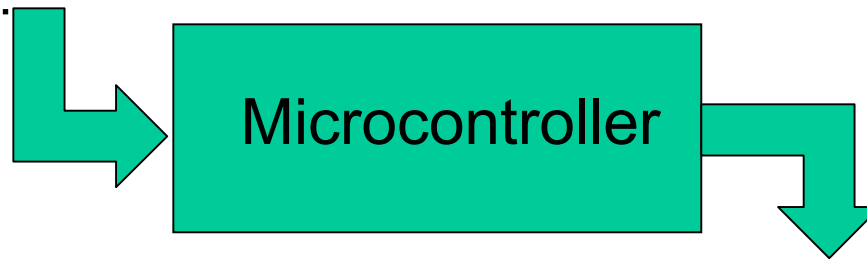
http://www.instructables.com/id/Conductive_Thread_Pressure_Sensor/

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



Sensors

- switches
- motion
- light
- position
- temperature
- etc....

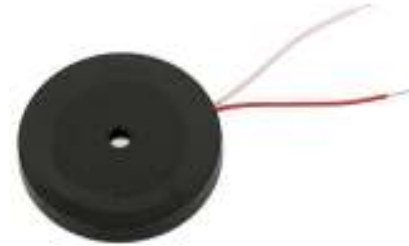


**Transducers:
Sound, Lights, & Motion**



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

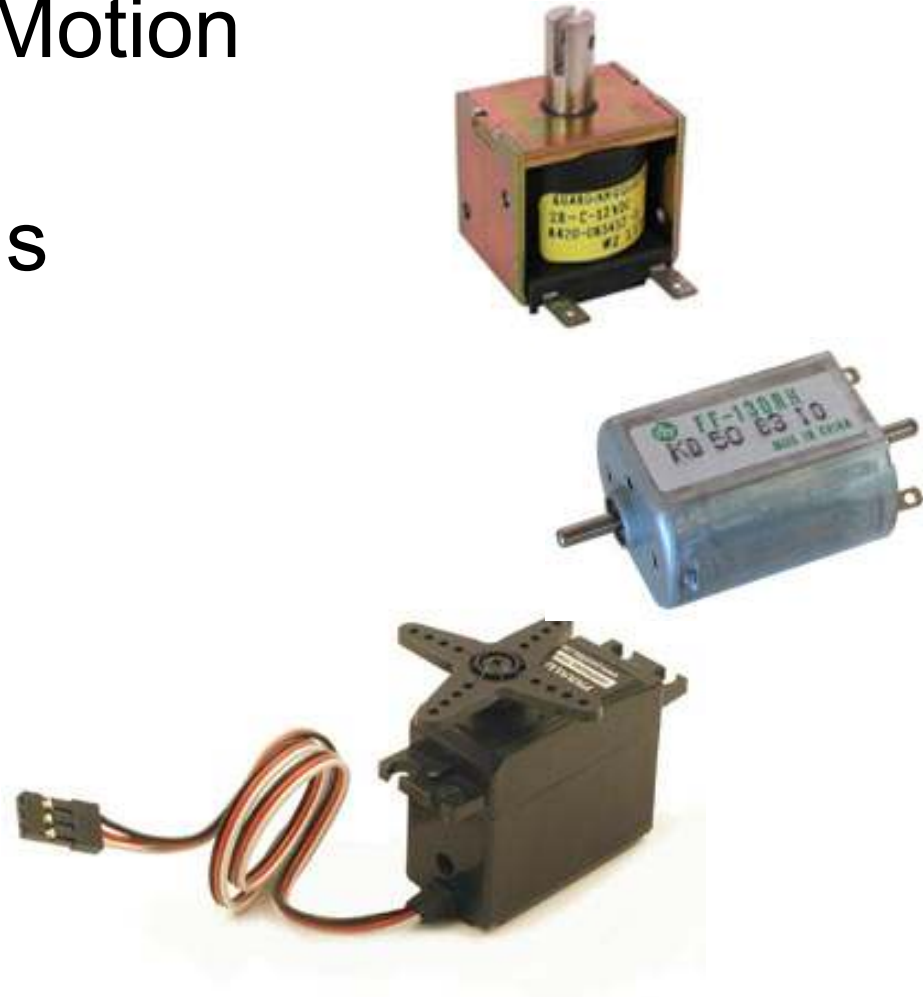


Note: LEDs are the only light producing device that can be driven directly by the microcontroller



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)

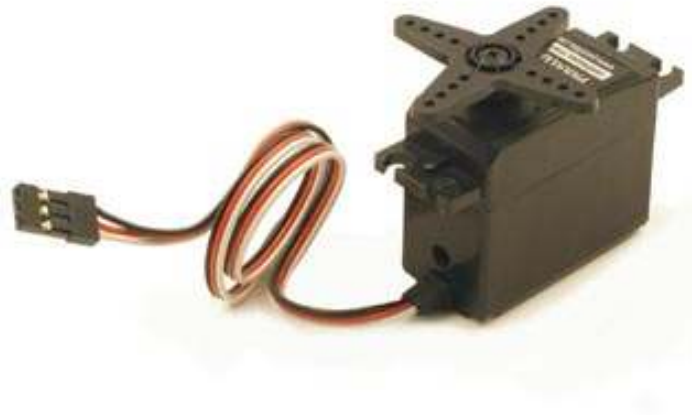


Gear head “timing” motor
(60 RPM or less)



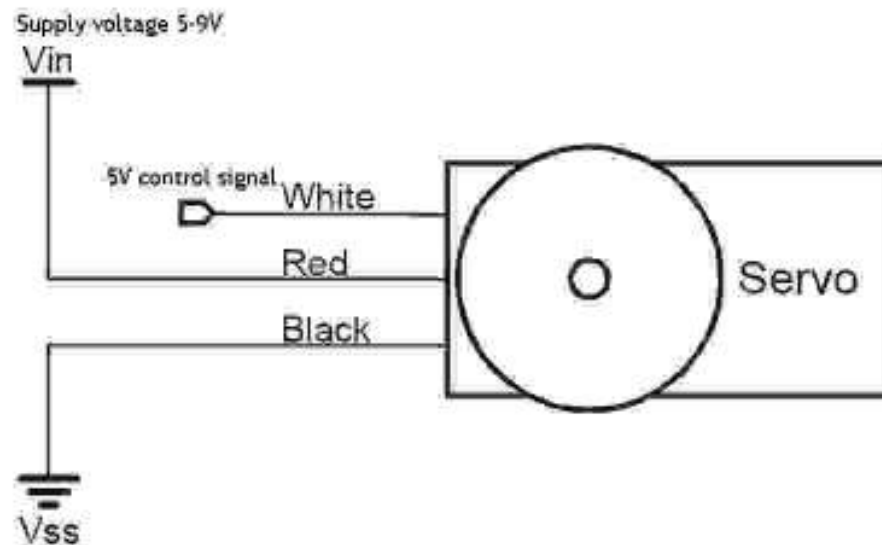
Servomotors “Servos”

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

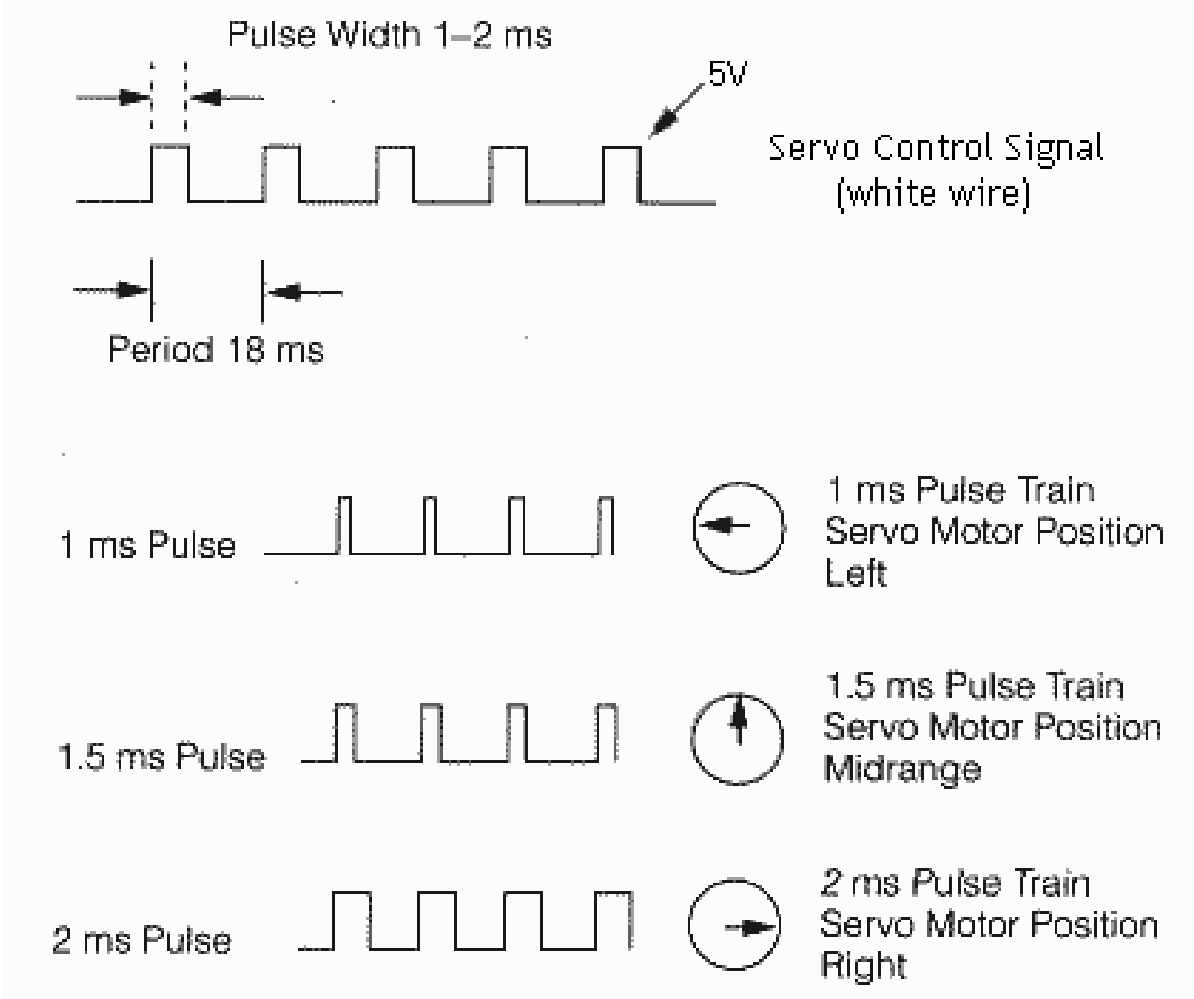


Controlling a Servo

- 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

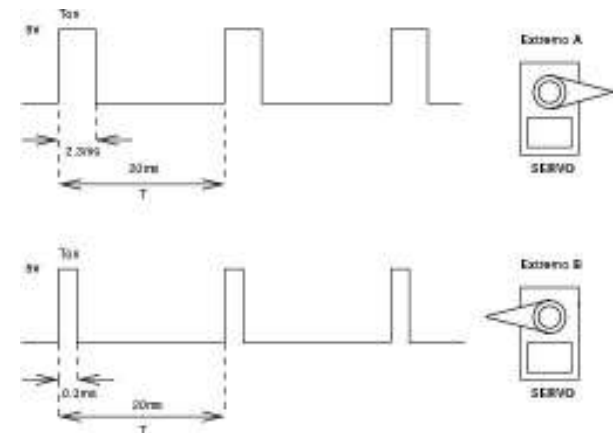


PWM Servo Control



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

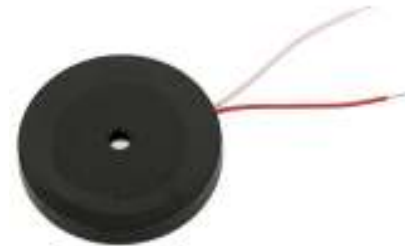


Janet Cardiff and George Bures Miller, at Eastern State Penitentiary



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



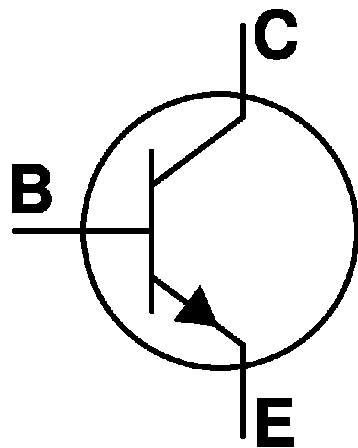
Transistors

- 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

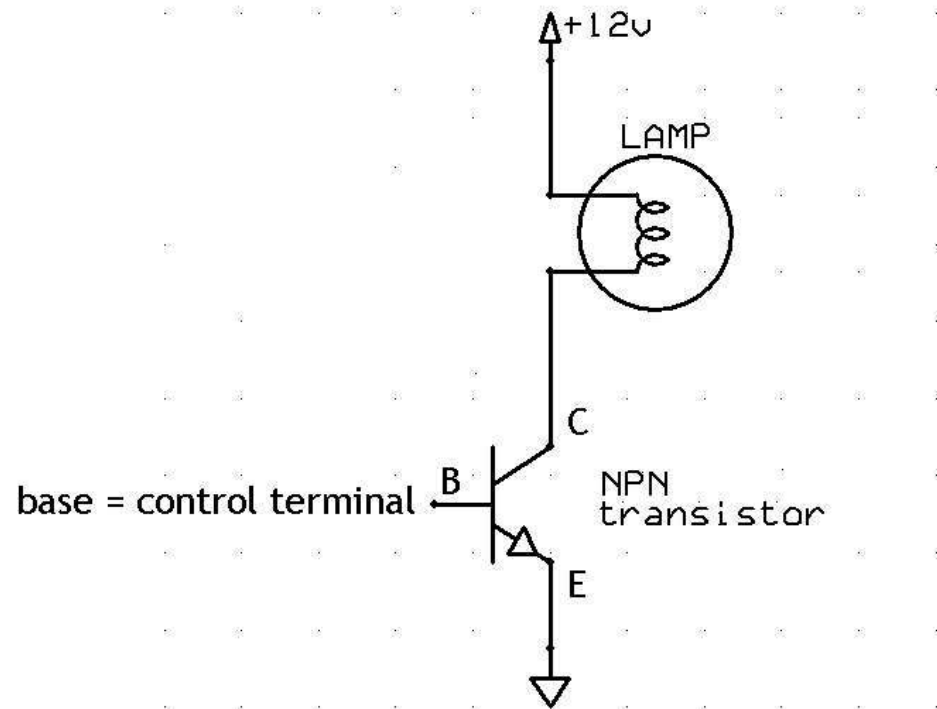
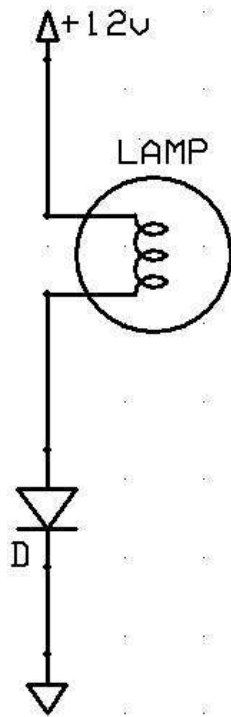
- Works like a “controllable diode”
- Three terminals
 - base ← the control terminal
 - collector
 - emitter
- C & E are connected in series with the controlled device



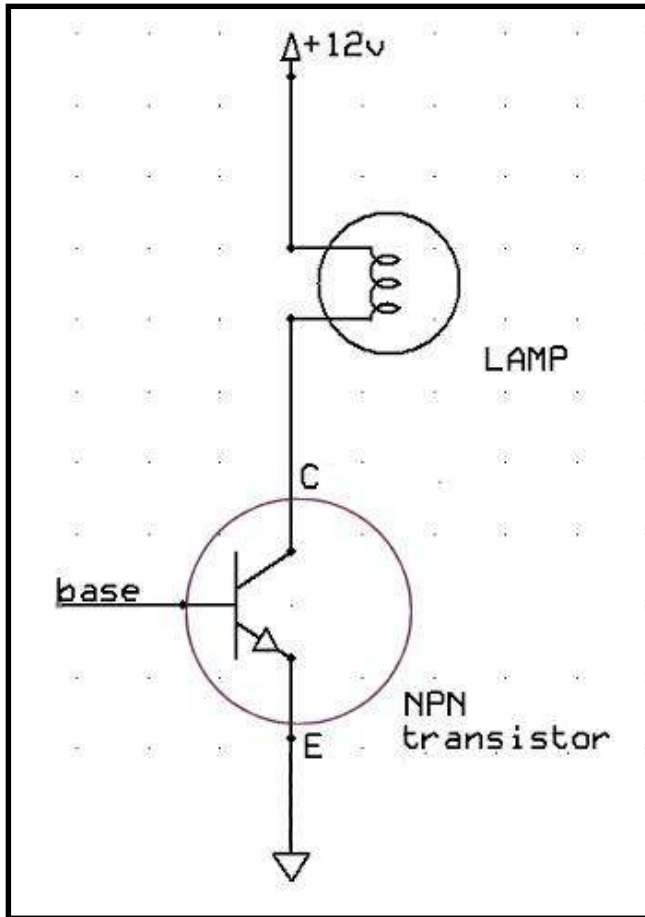
NPN transistor symbol



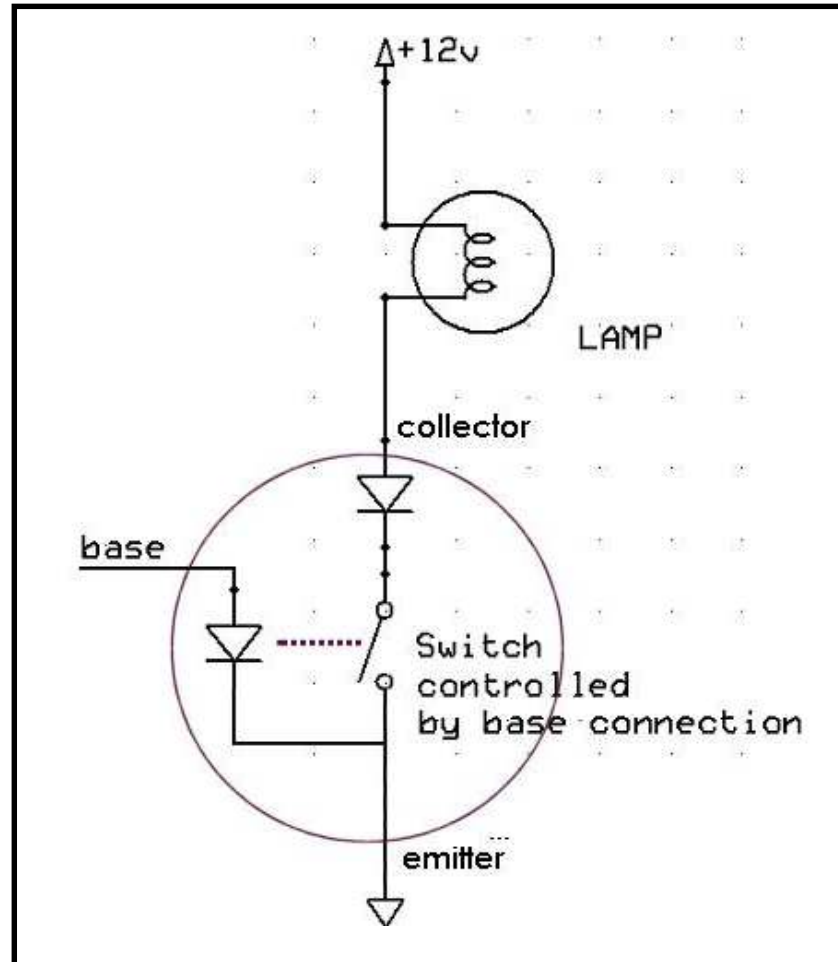
The transistor as a “controllable diode”



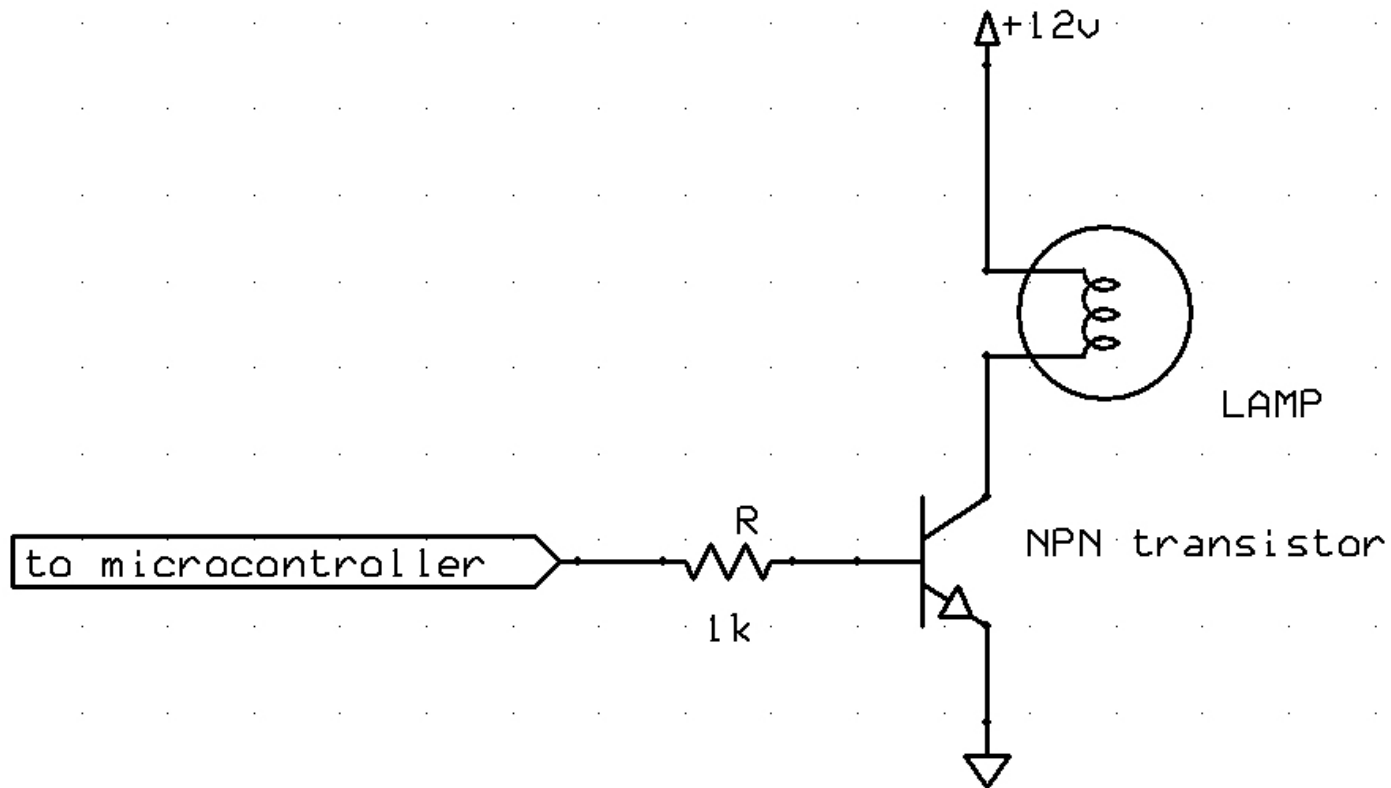
The transistor as a “diode controlled by a diode”



=



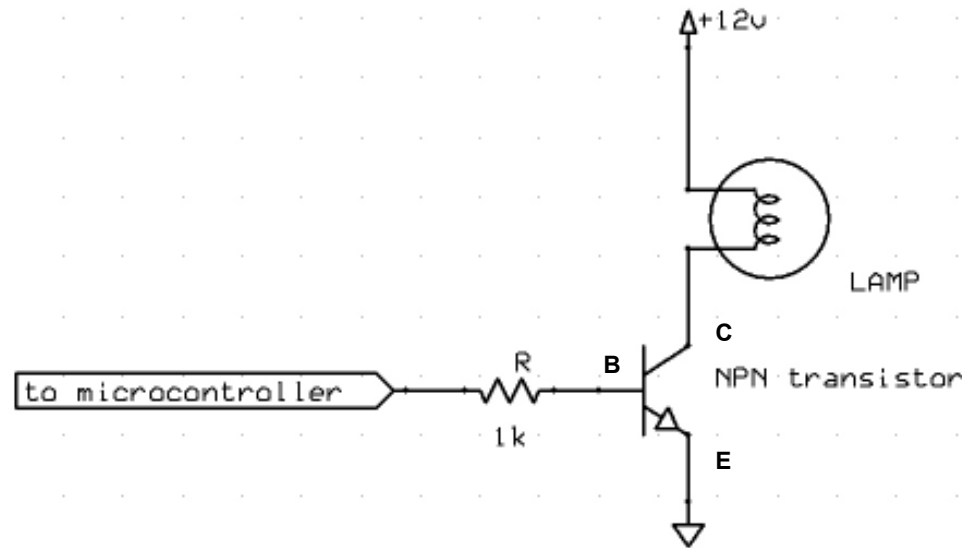
Using a transistor to control a light bulb



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



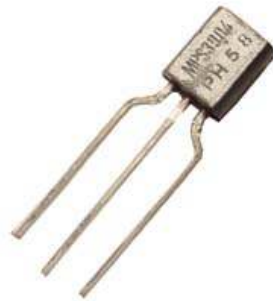
Transistor Advantages



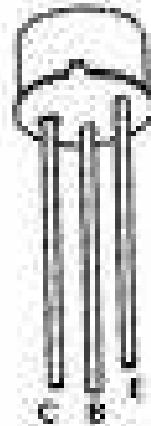
- Current into base is much smaller than current through lamp
 - base current \cong 1-10 mA
 - C-E current 1-10A or larger, depending on size of transistor
- Voltage on lamp can be higher than 5V
- Signal from microcontroller is able to control higher voltages
- Signal from microcontroller is able to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



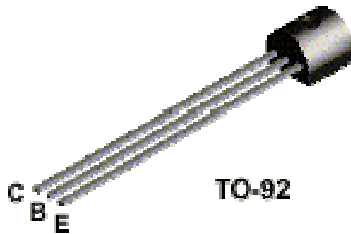
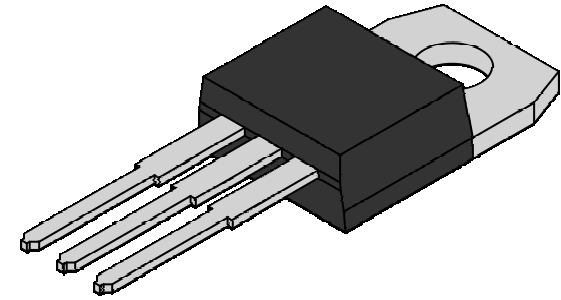
Transistor Packages & pinout



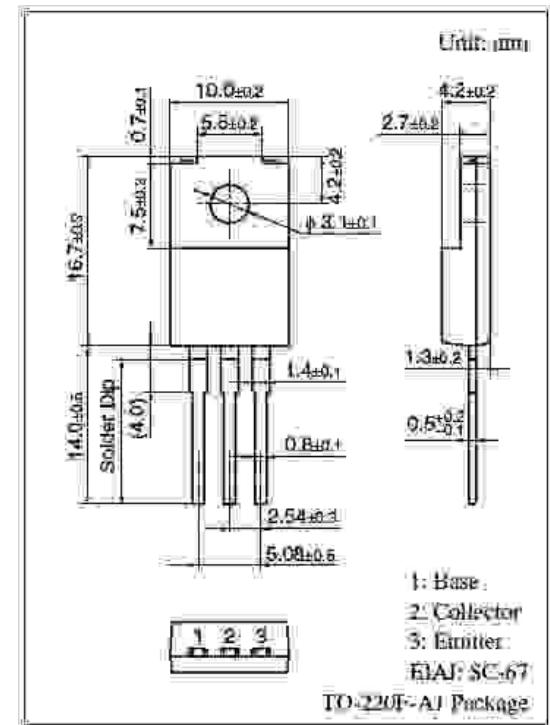
2N3904



**MPS2221A
(TO-18)**



TO-92



Check the datasheet!

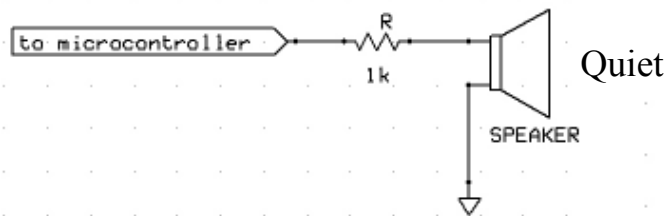


Transistor Ratings

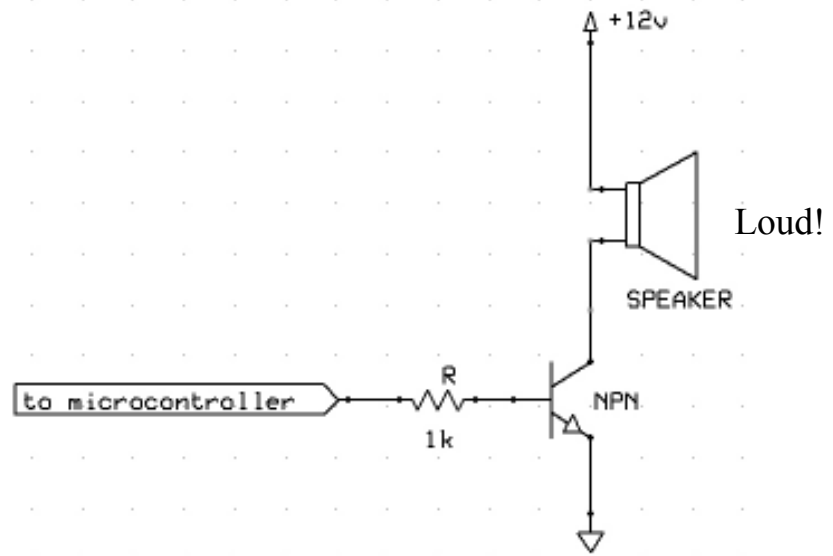
- V_{ce} maximum controllable voltage
- I_C maximum controllable current
- h_{fe} current gain



A Simple Audio Amplifier



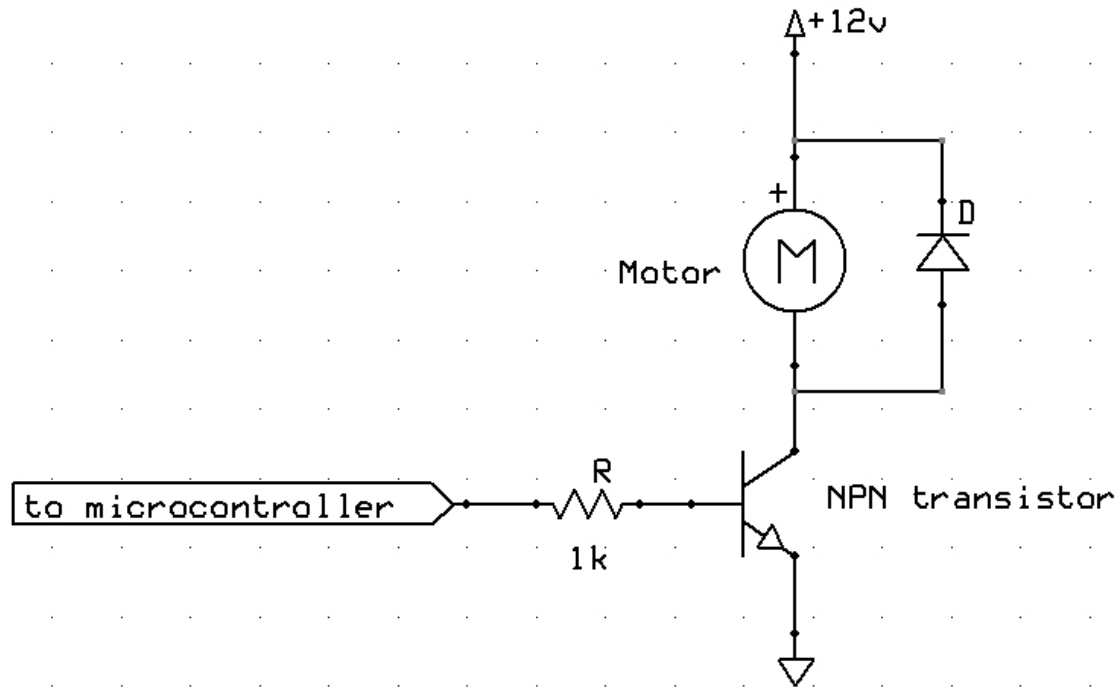
A typical speaker can be connected thru a resistor to limit the current



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

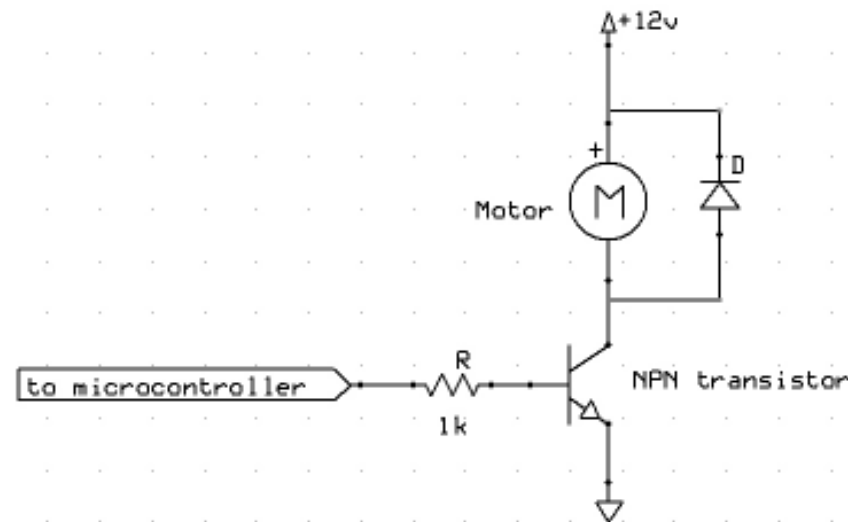


Controlling a Motor, Relay, or Solenoid

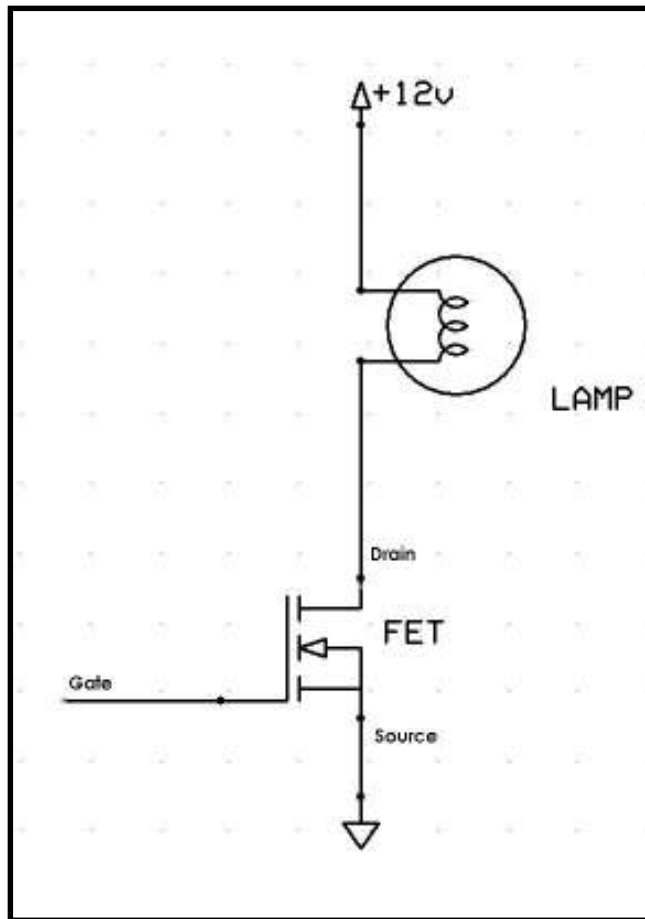


Always add a “snubber” diode across any inductive load!

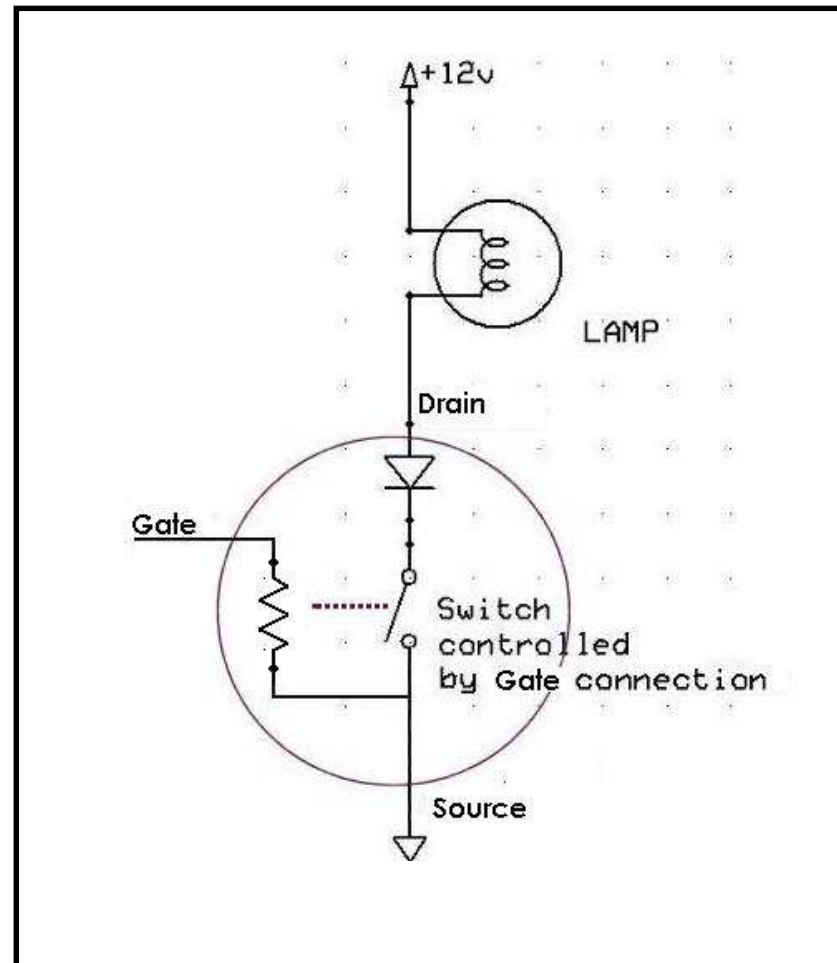
- Magnetic energy is stored in an activated motor, relay, or solenoid
- There is a momentum in the current passing through the device
- This energy will “fight” the transistor’s attempt to turn off the device
- The diode provides a path for the current to flow after turn-off



MOSFET Transistors



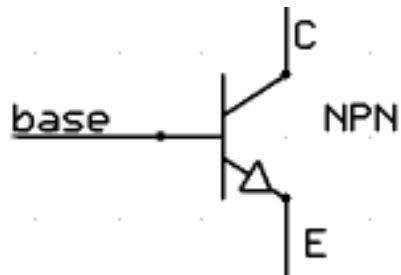
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Two types of Transistors

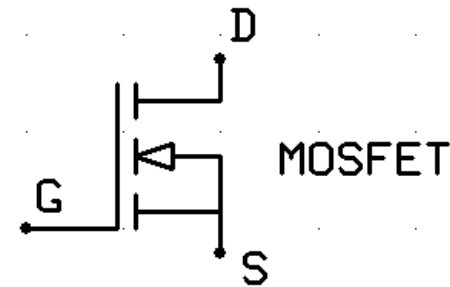
NPN Transistor

- Collector
- Base
- Emitter
- Input (base - emitter)
- Input behaves like a diode



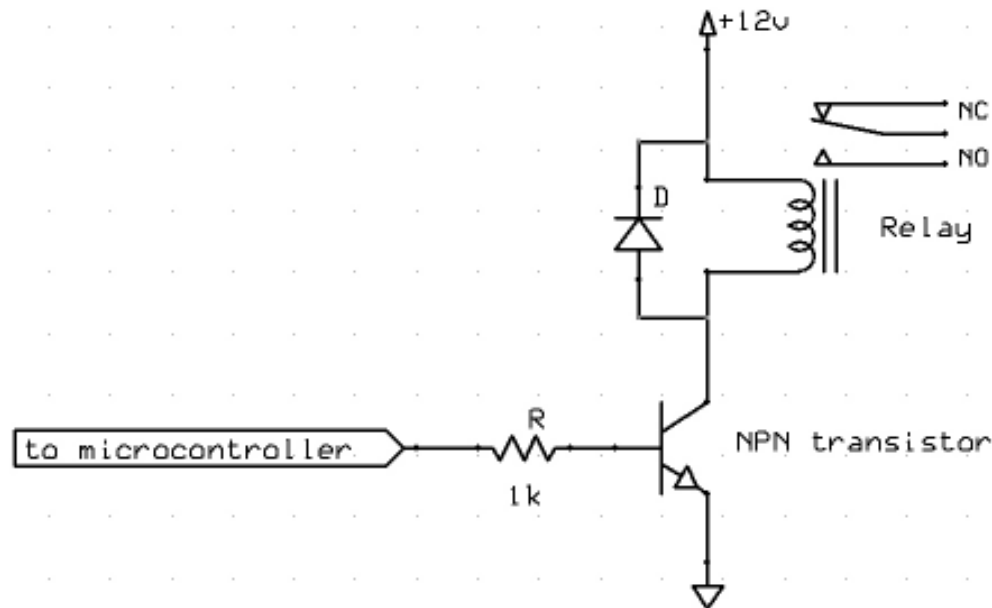
MOSFET transistor (N type)

- Drain
- Gate
- Source
- Input (gate - source)
- Input behaves like a large resistor



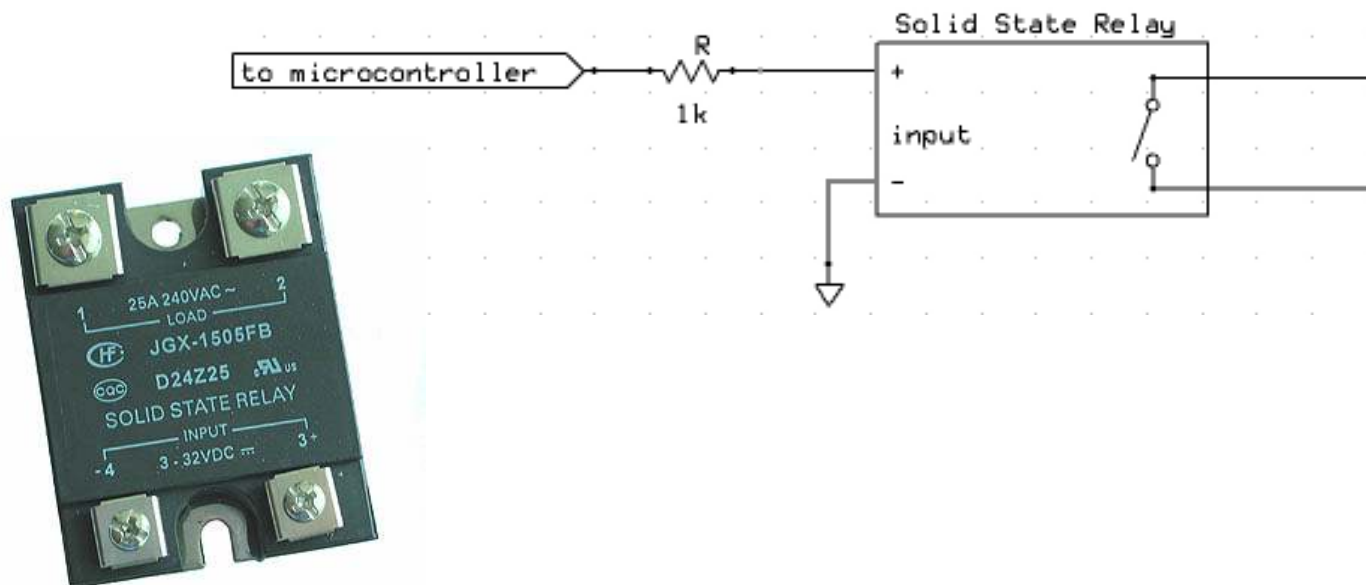
Mechanical Relays

- 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

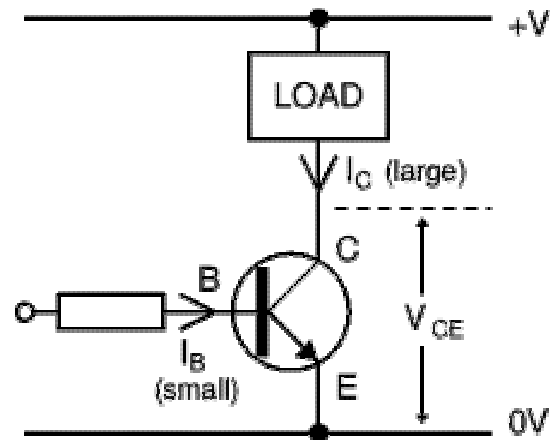


Summary

- 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

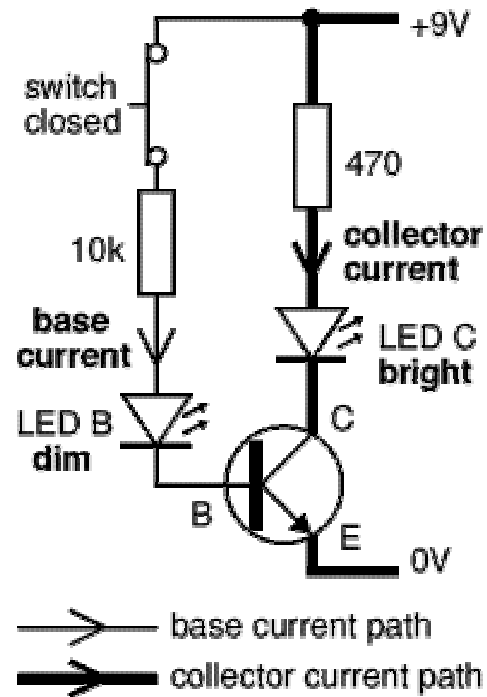


- Ratio of I_C to I_B is the transistor's "gain"
- Gain is sometimes abbreviated as h_{fe} or β
- β is typically around 100
- **Actual I_C may be limited by resistance of load**

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



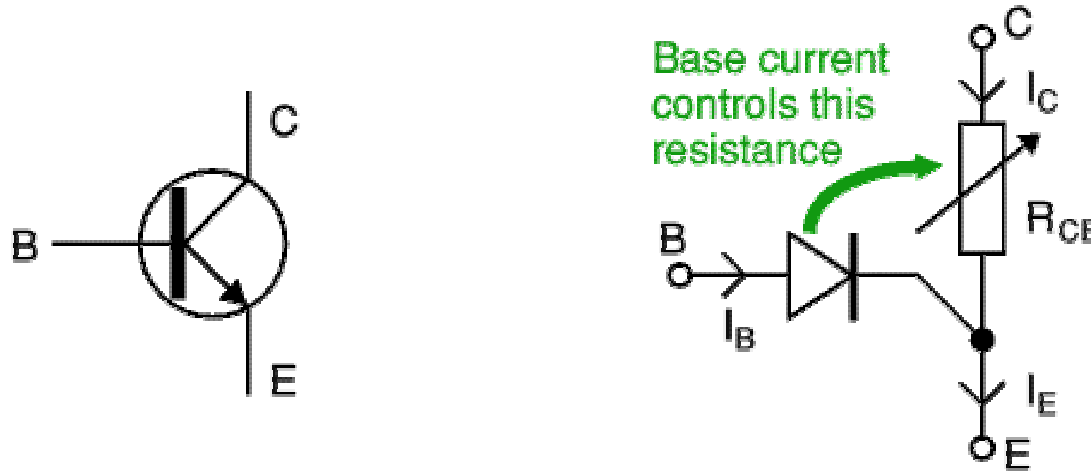
Transistors as Amplifiers



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



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})

