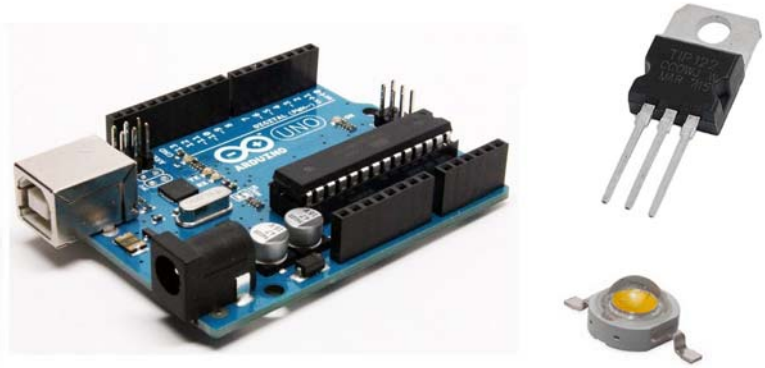
LAB 3 - HIGH POWER LOADS (Home)



ITEMS NEEDED

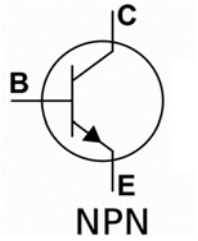
1. Arduino, cable, PC
2. Transistor (TIP 120, Darlington, Ic(peak) = 5 A, V_{CE} = 60V, Ic = 2500 I_B)
3. High power LED (3 – 3.4V, 600-700 mA, 3W)
4. Small breadboard
5. Resistor (for base) – 1.8 kΩ
6. Power supply (power plug adapter) (5V),
7. Solder & soldering iron
8. Various wires

INTRO

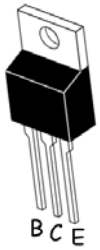
Micro-controllers can blink a standard LED directly from one of its digital pins. Standard LED's draw about **20 mA** at full brightness, and Arduino digital pins are rated to output as much as 40 mA max (actual limits are closer to ~20-25 mA). The limit for all of the Arduino pins put together is about 200 mA. But what if we want to use Arduino drive a large motor or an ultra-bright LED? These components draw MUCH more current than Arduino can provide. One way is to use a **transistor**. Transistors are essential devices that form the basis for all modern electronics and computers.

REFER to CT GUIDE on transistors.

Transistors in computers are used as **electronic switches**, just like a light switch. The switching in the circuitry is how the computer does its calculations. An Intel i7 CPU has around 1.75 billion transistors! A computer rated at 2 GHz has transistors that switch 2 billion times a second (try that with a light switch!). Transistors can also be thought of as **electrical spigots**, where a relatively small signal controls a relatively large current elsewhere. One type of transistor is the bipolar junction transistor (BJT). It has 3 legs: **base, emitter, and collector**. In essence, a small amount of current at the base controls a larger amount of current flowing through the emitter and collector.



Symbol for transistor



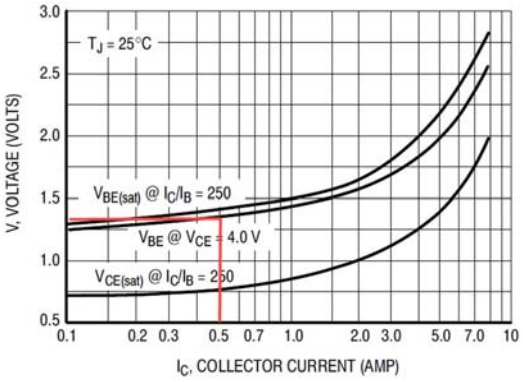
Picture of transistor
(with legs labeled)

We will use Arduino to control the lighting of a high power LED. The LED has a voltage rating of around 3V and, at full brightness, uses 600-700 mA of current – far more than Arduino can supply. Instead Arduino will send a small signal to the BASE of the transistor. The transistor will route a relatively large electrical signal from a 5 VDC regulated power supply (from the trainer or a DC power supply brick) through the high-power LED based on the small signal it receives at its BASE from Arduino.

Note, the LED can be VERY bright. For all exercises do not point the LED directly towards your eyes. For all exercises be sure to cover the LED with paper toweling (or similar) to reduce the brightness.

CALCULATIONS

Here we calculate the resistor value that is to be wired between the PWM pin of Arduino and the base of the transistor. The value of this resistor must be properly chosen so that about 500 mA will pass through the ultra-bright LED when 5 volts is applied from the Arduino digital pin.



Reference the data sheet for the transistor (in this case the TIP 121).
Ic is the current through the collector pin. This is the same as the current that will pass through the LED. I_B is the current into the transistor base. The TIP 121 has an Ic/I_B ratio of 250 (250x the current passes through the collector vs. the base).

$Ic = 250\ I_B$.

Thus, IB is computed per below, and we plug in Ic = 0.500A (or 500 mA).

$I_B = Ic/250 = 0.500A/250 = 0.002 = 2$ mA.

Thus we need 2 mA to pass into the base pin of the transistor. This will be controlled by a resistor that is wired between the Arduino and the transistor.

Refer to the transistor's datasheet. It shows that at an Ic = 0.5A, the $V_{BE}(sat) = 1.375V$ (see figure).

$Ic = 0.5\ A \rightarrow plot \rightarrow V_{BE}\ (sat) = 1.375V$.

Calculate the resistor

R_B = Vdrop/I_B = (5 – 1.375)/.002 = 1812 ohms = 1.8 kΩ resistor

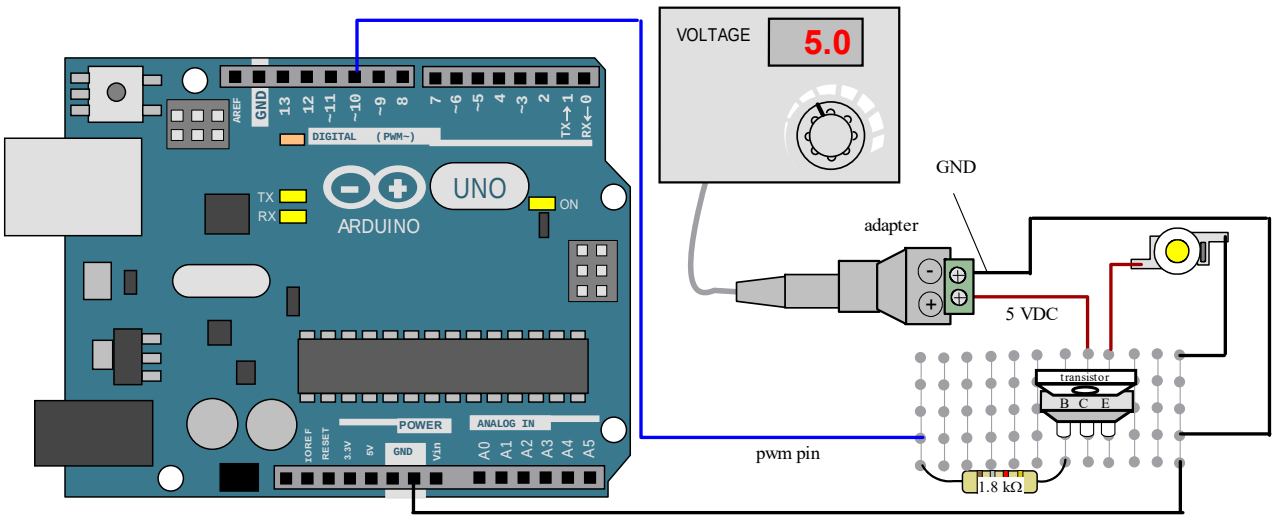
So use a 1.8 k ohm resistor. Do NOT use any other value resistor.

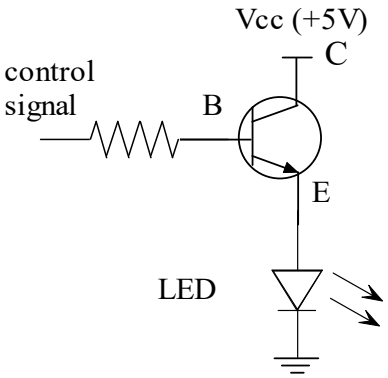
3.1 BLINK

EXERCISES

First solder solid "spool" wire leads to the high power LED. One wire should be red and the other black. The black wire should be soldered to the lead with the small slot on it. The instructor may issue a high-power LED with wires already soldered onto it.

Turn power OFF. Wire up the circuit as shown. Wire the LED to a PWM pin. Use a small solderless breadboard. The transistor will fit very snug in the breadboard. All GND's must be connected together on the breadboard (Arduino, power source, & LED).





Program the Arduino to blink the LED on and off (just like before, only it will be MUCH brighter). Use the digitalWrite (pinNumber, digitalState) command. Avoid looking directly at the LED to protect your eyes. Cover the bright LED with a cloth or towel to protect your eyes.

3.2 BLINK DIMMED

EXERCISE

Blink the LED at a dimmed value.
Replace the **`digitalWrite()`** with **`analogWrite(pin,level)`** command.
Select a level of about 30 (out of 255).
So the "level" should toggle between 0 and 30 (not 0 and 255).

3.3 DIM SINE

EXERCISE

Now try fading the LED from totally off to totally on using the sin ( ) command in Arduino. Try varying the brightness range and the frequency. Set the sine wave amplitude to about 20 (brighter than a standard LED but not too bright!). Declare floats for amplitude and frequency. Here is PARTIAL code.

```
// highPowerLED3_sin.ino --------------------------
// fade a hi power LED using PWM pin & analogWrite cmd & sine waves

// put the following into the loop fcn.  Also set pinMode in setup()

float amp = 10.0;   // need amp so map() works right
float freq = 0.5;   // freq in Hz
float tnow;

tnow = millis()/1000.0;

sig = amp * sin (2.0 * PI * freq * tnow) + amp;
//sig = map(sig, -amp, amp, 0, 15);

analogWrite(pin, ledlevel);
```

SUBMISSION

Either demo to instructor or video upload.
The instructor will let you know which to do.

For video uploads, the file names should be:
Filenames: (1) blink, (2) blinkDimmed, (3) dimSine