Using an NPN transistor to drive multiple LEDs from a PIC microcontroller output

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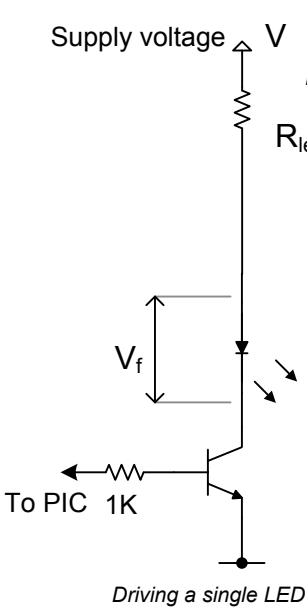
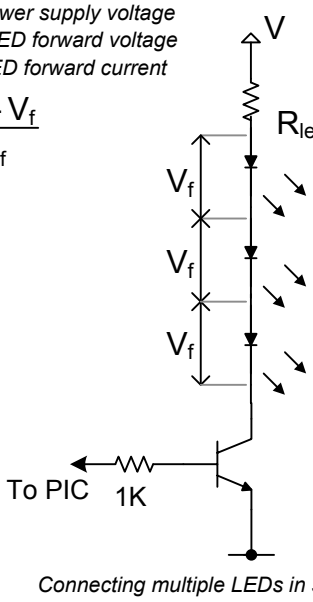


V is the power supply voltage
V_f is the LED forward voltage
I_f is the LED forward current

$$R_{led} = \frac{V - V_f}{I_f}$$

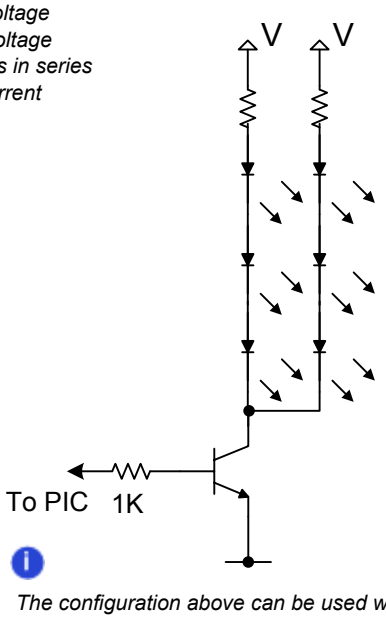
Driving a single LED



V is the power supply voltage
V_f is the LED forward voltage
n is the number of LEDs in series
I_f is the LED forward current

$$R_{led} = \frac{V - (n \times V_f)}{I_f}$$

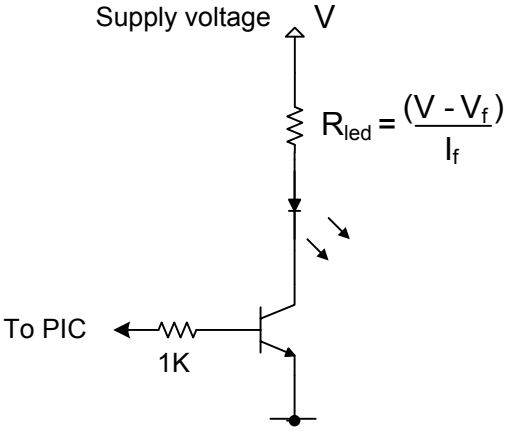
Connecting multiple LEDs in series



The configuration above can be used when the number of LEDs in series would be greater than the supply voltage. Try to work with a margin of 1 volt or greater between the supply and the total LED forward voltage.

- *The supply voltage should be a regulated DC source.*
- *When connecting multiple LEDs in series, the number of LEDs must be such that the sum of their forward voltages is less than the supply voltage otherwise they can't operate.*

How to calculate the value for the LED current limiting resistor



V is the power supply voltage

R_{led} is the current limit resistor value

V_f is the LED forward voltage

I_f is the LED forward current

These parameters should be taken from the datasheet for the specific LED being used. If this isn't available you will need to measure the forward voltage (see below)

You can't measure the forward current so if you don't know it you should work with a value of 15mA

Example $\frac{(10 \text{ volts} - 2 \text{ volts})}{0.015 \text{amps}} = 533 \text{ ohms}$

Resistors come in standard values, pick the nearest higher standard value to the one calculated – in this example it would be 560 ohms

How to calculate the power rating for the LED current limiting resistor

The larger the difference between the power supply voltage and the LED forward voltage, the more power the LED current limiting resistor has to dissipate. The resistor used must have a power rating greater than the power it will have to dissipate. This is calculated as shown here

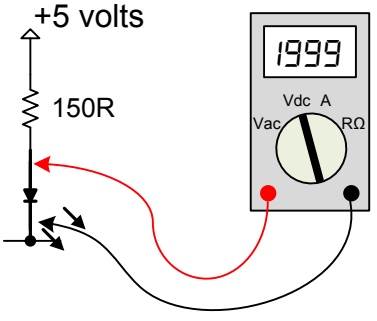
$$P_{watts} = I_f \times I_f \times R$$

Example (0.015 amps x 0.015 amps x 560 ohms = 0.126 watts

How to measure the LEDs Forward Voltage (V_f)

If you don't have the datasheet for the LEDs you plan to use, or just want to check the actual forward voltage you can measure it using the test circuit shown here. Make sure the LED is illuminated and then measure the voltage across the LED with a voltmeter.

The forward voltage for a standard red, yellow and green 5mm LEDs will be around 1.8 Volts to 2.2 Volts. For high brightness LEDs it will typically be 3 volts to 4 volts.



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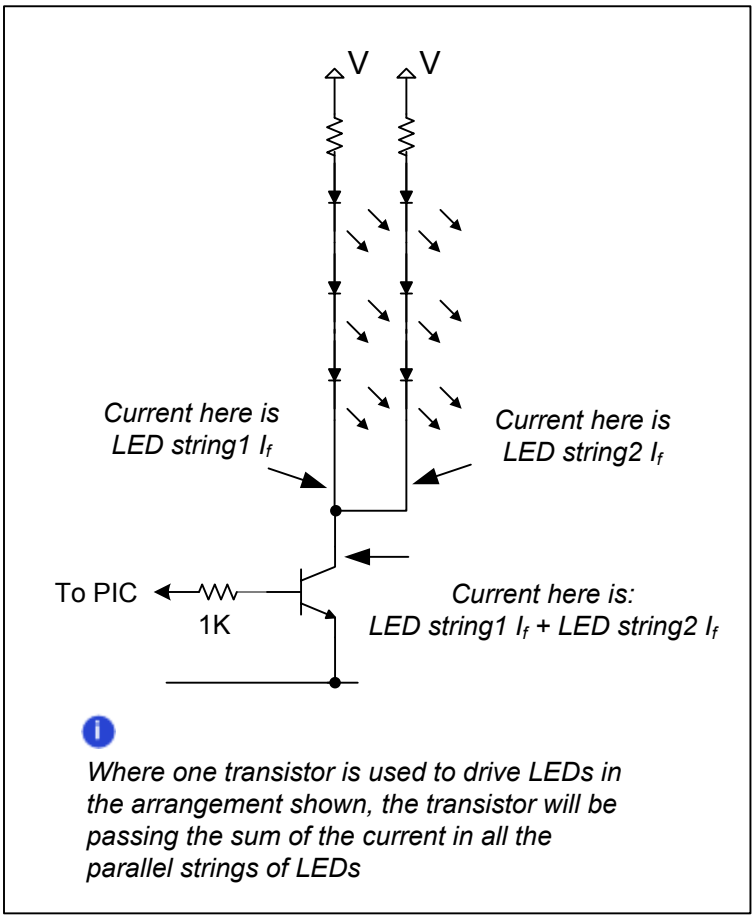
Transistors

Since standard 3mm, 5mm, 8mm and 10mm LEDs only require around 15mA to operate, we can use a small NPN transistor to drive them.

Some transistors that are suitable for use in LED driving applications are listed below. The Ic (collector current) max value is an absolute maximum and operation at or near to this value should be avoided. *For the full specification of each transistor consult the manufacturers datasheet for the specific device.*

Device	Ic max (mA)
2N2222A	800
2N3053	700
2N3704	600
2N3705	600
2N3904	200
2N4401	600
BC107	200
BC108	200
BC109	200
BC182	100
BC183L	100
BC184	100
BC237	100
BC238B	100
BC337	500
BC546	100
BC548	100
BC549	100
ZTX457	500



Where one transistor is used to drive LEDs in the arrangement shown, the transistor will be passing the sum of the current in all the parallel strings of LEDs

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High Power LEDS

This document has described how to drive multiple high brightness, low power LEDs.

High power LEDs, such as those manufactured by Cree, Luxeon etc work in the same way as small LEDs and the calculations for current limit resistor and forward voltages can still be used.

However, the power dissipated is much greater which in turn requires power transistors or better still N channel MOSFETs along with high wattage resistors. Managing the heat and the physical size of components can be an issue.

Ideally rather than using the passive current limiting described in this document some type of active current regulator should be employed. This is beyond the scope of this document.

Examples

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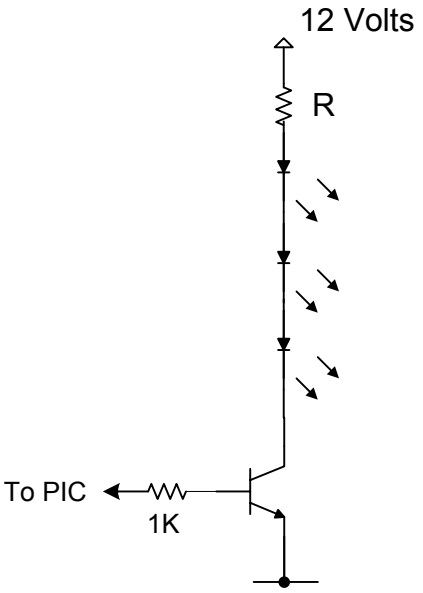


LED parameters

V_f = 3.2 volts

I_f = 20mA

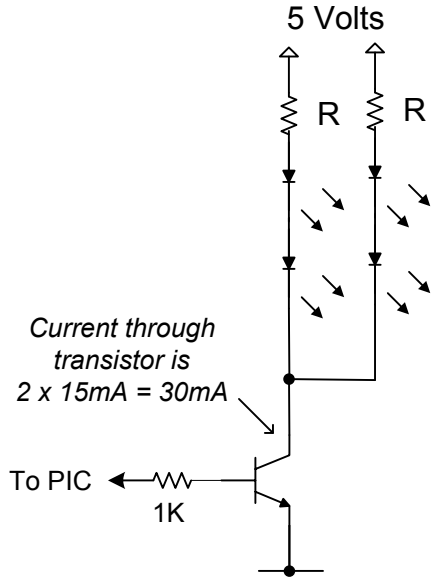
Calculate value for R

$$\frac{12 \text{ volts} - (3 \times 3.2 \text{ volts})}{20\text{mA}} = \frac{2.4}{0.02} = \textbf{120 ohms}$$

Calculate power rating for R

20mA x 20mA x 120 ohms = **0.048 watts**

In this case we can use a standard 120 ohm resistor with a power rating of at least 0.125 watt



LED parameters

V_f = 2.1 volts

I_f = 15mA

Calculate value for R

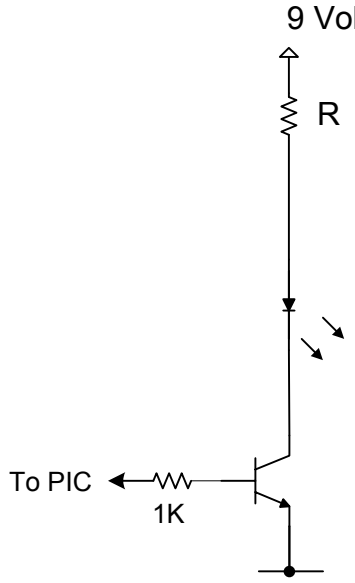
$$\frac{5 \text{ volts} - (2 \times 2.1 \text{ volts})}{15\text{mA}} = \frac{0.8}{0.015} = \textbf{53.3 ohms}$$

53.3 ohms isn't a standard value so we'll use 56 ohms

Calculate power rating for R

15mA x 15mA x 56 ohms = **0.126 watts**

Use a resistor with a power rating of at least 0.25 watt



LED parameters

V_f = 1.8 volts

I_f = 35mA

Calculate value for R

$$\frac{9 \text{ volts} - 1.8 \text{ volts}}{35\text{mA}} = \frac{7.2}{0.035} = \textbf{205 ohms}$$

205 ohms isn't a standard value so we'll use 220 ohms

Calculate power rating for R

35mA x 35mA x 220 ohms = **0.269 watts**

Use a resistor with a power rating of at least 0.5 watts