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.

How to calculate the value for the LED current limiting resistor

\[
R_{led} = \frac{V - V_f}{I_f}
\]

*V* is the power supply voltage
*R* is the current limit resistor value
*V* is the LED forward voltage
*I* 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** 
\[
(10 \text{ volts} - 2 \text{ volts}) = 533 \text{ ohms}
\]

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

\[
P_{\text{watts}} = I_f \times I_f \times R
\]

**Example** 
\[
0.015 \text{ amps} \times 0.015 \text{ amps} \times 560 \text{ ohms} = 0.126 \text{ watts}
\]

http://picprojects.org.uk
Using an NPN transistor to drive multiple LEDs from a PIC microcontroller output

http://picprojects.org.uk

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.

<table>
<thead>
<tr>
<th>Device</th>
<th>Ic max (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2N2222A</td>
<td>800</td>
</tr>
<tr>
<td>2N3053</td>
<td>700</td>
</tr>
<tr>
<td>2N3704</td>
<td>600</td>
</tr>
<tr>
<td>2N3705</td>
<td>600</td>
</tr>
<tr>
<td>2N3904</td>
<td>200</td>
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<tr>
<td>2N4401</td>
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<tr>
<td>BC107</td>
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<td>200</td>
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<tr>
<td>BC109</td>
<td>200</td>
</tr>
<tr>
<td>BC182</td>
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<tr>
<td>BC237</td>
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</tr>
<tr>
<td>BC337</td>
<td>500</td>
</tr>
<tr>
<td>BC546</td>
<td>100</td>
</tr>
<tr>
<td>BC548</td>
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</tr>
<tr>
<td>BC549</td>
<td>100</td>
</tr>
<tr>
<td>ZTX457</td>
<td>500</td>
</tr>
</tbody>
</table>

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.

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.
LED parameters

\[ V_f = 3.2 \text{ volts} \]
\[ I_f = 20 \text{ mA} \]

Calculate value for R

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

Calculate power rating for R

\[ 20 \text{ mA} \times 20 \text{ mA} \times 120 \text{ ohms} = 0.048 \text{ watts} \]

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

LED parameters

\[ V_f = 2.1 \text{ volts} \]
\[ I_f = 15 \text{ mA} \]

Calculate value for R

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

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

Calculate power rating for R

\[ 15 \text{ mA} \times 15 \text{ mA} \times 56 \text{ ohms} = 0.126 \text{ watts} \]

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

LED parameters

\[ V_f = 1.8 \text{ volts} \]
\[ I_f = 35 \text{ mA} \]

Calculate value for R

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

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

Calculate power rating for R

\[ 35 \text{ mA} \times 35 \text{ mA} \times 220 \text{ ohms} = 0.269 \text{ watts} \]

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