Selecting the Limiting Resistor for an LED using a Graphical Technique, Version 1.0

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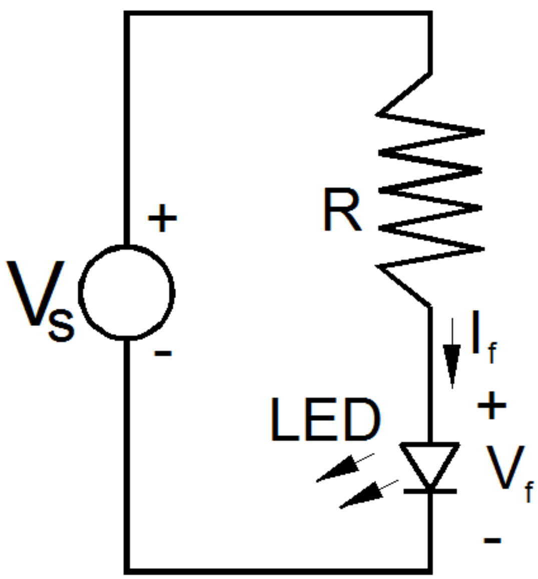


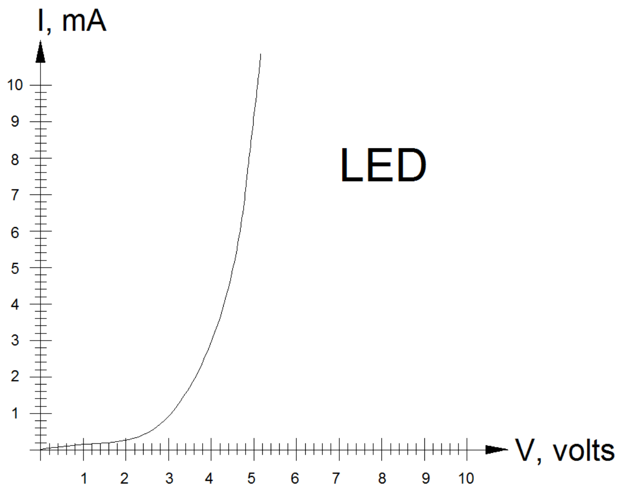
Finding the best limiting resistor to drive a Light Emitting Diode (LED) is a common circuit design task. In many cases, it is good enough to assume a fixed forward voltage, V_f, and pick a forward current, I_f. Then use the equation

$$R = \frac{V_S - V_f}{I_f} \qquad (1)$$

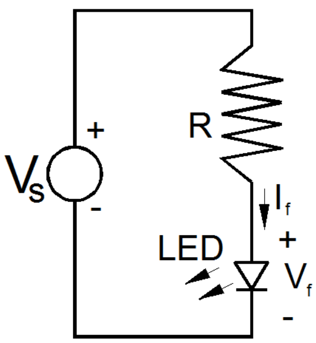
As long as V_s is much larger than V_f, this works well.

V_f is far from a constant and as its value has more influence on the equation, more information is needed. Dealing with the actual voltage/current behavior of an LED is complex but approaching it graphically tames it down.

Graphical, you say? What is that? Well, 45 years ago I was introduced to this approach at Union College in Schenectady, NY while pursuing a Bachelor of Science in Electrical Engineering. I hope I can do my gifted professors justice by explaining a tiny bit of it here. I will be focusing on the technique and not the theory behind it. A major benefit to using graphics is that you get a sense of how the circuit responds to changes in parameters.

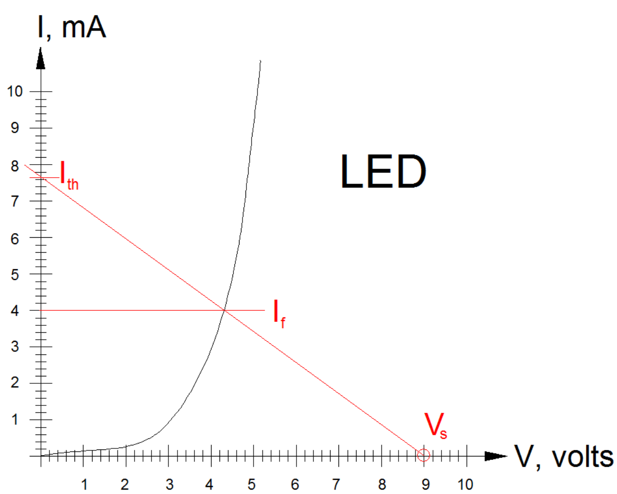


Here is a typical graph showing how the voltage and current vary for a given LED. The shape and values of the curve varies as a function of LED color, ambient temperature, and process used to make it. You can find this graph in your chosen LED's spec sheet.



You must choose V_s, the supply voltage, and I_f, the forward current in order to find the limiting resistor's value.

We are going to draw a "load line" on the LED graph. On the volts axis, mark the location of V_s. You may have to extend this line but take care to keep the tick marks accurately placed.



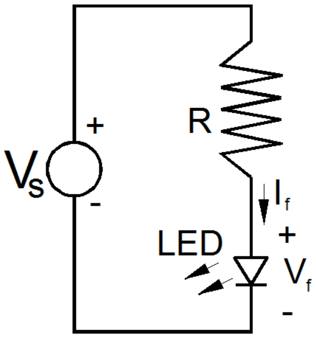
Then draw a line at the level of your desired I_f extending from the current axis and crossing the LED curve.

I have chosen a V_s of 9 volts and an I_f of 4 mA. Draw a line through the Vs point and where I_f crosses the LED curve. It should reach to the current axis. Call this intercept I_{th}. In this example, the load line crosses the current axis at about 7.62 mA.

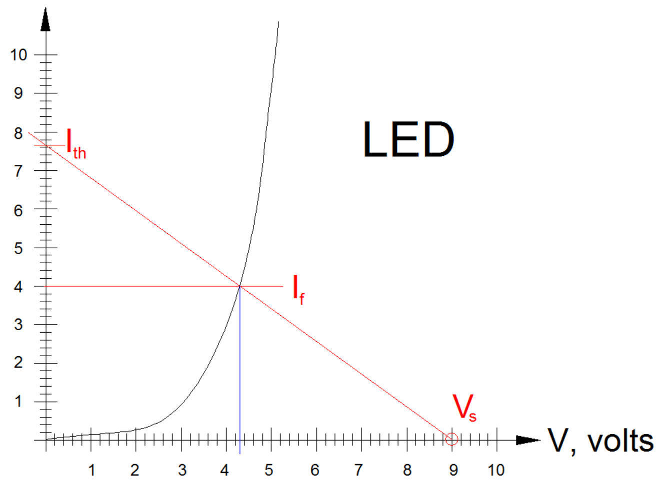
Calculate R by dividing V_s by I_{th}:

$$R = \frac{V_s}{I_{th}} \quad (2)$$

$$R = \frac{V_s}{I_{th}} = \frac{9\ volts}{7.62\ mA} = 1.18\ K\Omega$$

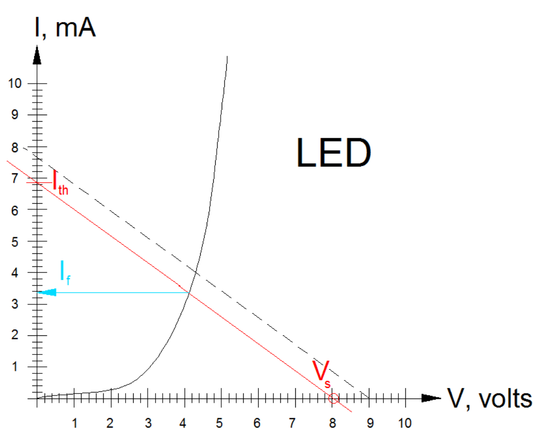


Let's see if this makes sense. We chose a V_s of 9 volts, an I_f of 4 mA and got an R of 1.18K. The voltage drop across the resistor will be $4\,mA \times 1.18K = 4.72\ volts$. This means that the voltage across the LED, V_f, should be 9 - 4.72 = 4.28 volts.



Going back to the graph, I drew a blue line down from the I_f equal to 4 mA intercept point. You can see that it hits about 4.3 volts on the volts axis.

But wait, there is more! We can use this graphical technique to see how our current varies as circuit parameters drift.

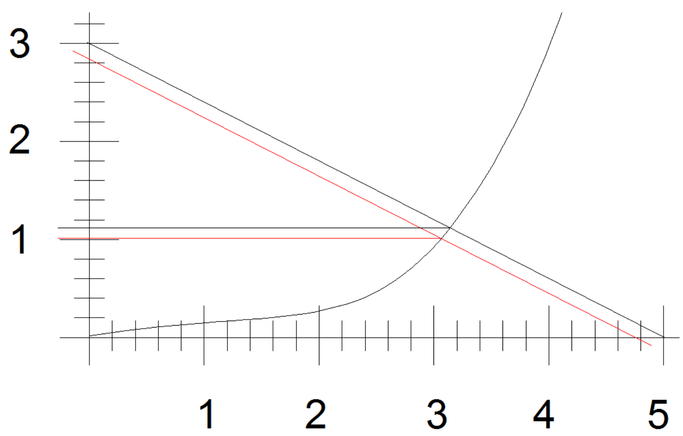


Say V_s drifted 10% lower. It would move from 9 volts 8.1 volts and the graph would look like this. My new load line (red) has the same slope but is shifted over. It was drawn to cross the volts axis at 8.1 volts and cross the current axis at $\frac{V_s}{R} = \frac{8.1\ volts}{1.18\ K} = 6.86\ mA$.

Our load line crosses the LED curve at about 3.4 mA so that is our new value for I_f.

A 10% reduction in power supply voltage caused our forward current to drop from 4 mA down to 3.4 mA, a change of -15%. So in this case, error in the power supply voltage is amplified by the circuit and causes a 50% increase in error in the forward current. Had we used a larger supply voltage, the change in forward current would have been less. Conversely, going to a smaller supply voltage will cause a larger change in forward current.

It is common to use a supply voltage of 5V. Assume it can vary by +/- 5%. Say I want a forward current of 1.15 mA (black line). My load line crosses the current axis at 3 mA which means my limiting resistor is $\frac{V_s}{I_{th}} = \frac{5\ volts}{3\ mA} = 167\ ohms.$



When the supply drifts down to 5V - 5% = 5 - 0.25 = 4.75 volts, our load line move in towards the origin. The new forward current is about 1 mA (red line), a change of 0.15 mA or 15%. So now the forward current error is 3 times that of the supply.

The smaller the limiting resistor, the higher the sensitivity of the forward current to changes in supply voltage.

The LED curve can also move as a function of temperature and manufacturing tolerances. As the supply voltage decreases, these changes can dominate. Furthermore, at high forward currents, the LED self heats and this will cause an additional change in forward voltage.

As you draw load lines, note where it crosses the LED curve. See what happens when you are near a change in slope.

Acknowledgments

Thanks to Homemade Tool's "led.linear1.org" for reminding me of this topic.

I welcome your comments and questions.

If you wish to be contacted each time I publish an article, email me with just "Article Alias" in the subject line.

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