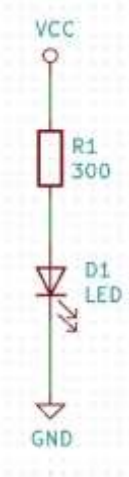
Evaluating hobbyist Surface-mount LEDs

Bruce E. Hall, W8BH

I have been learning how to create my own printed circuit boards. Several of my projects call for surface-mount LEDs. Which ones should I use? Are they all the same? And what current-limiting resistor is required? These all seem like such easy questions, but I searched and could not find good online answers for the beginner. Read on if you want to add a chip LED to your project and don't know how or where to start.



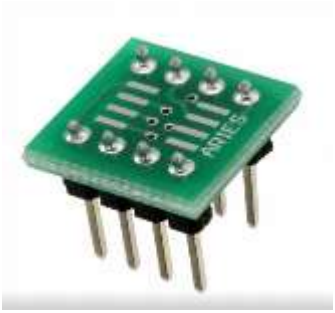
First, the basics: Wikipedia has a good discussion of a simple LED circuit here. You need a voltage source, an LED, and a resistor for limiting current through the LED. The value of the resistor R is determined by the voltage source (Vcc), the forward voltage drop (Vf) across the LED, and the desired current (I) through the LED: R = (Vcc-Vf)/I. LED specification sheets will give you Vf, usually in the 1.8-3.3V range, at a typical current of 20 mA.

In the circuit on the left, let's assume that Vcc = 5.0V and that Vf across the LED is 1.8V. That means that the voltage drop across resistor R1 will be 5.0-1.8 = 3.2 volts. If we use a 300-ohm resistor, the current through the circuit will be 3.2V/300 ohms = 10.7 mA. This value is sufficient since this current is less than the specified current of 20 mA. If we want maximum brightness at full current, we need a smaller resistor. From the formula above, R = (Vcc-Vf)/I = (5.0-1.8 V)/0.02 A = 160 ohms. Anything smaller will result in too much current and could damage the LED.

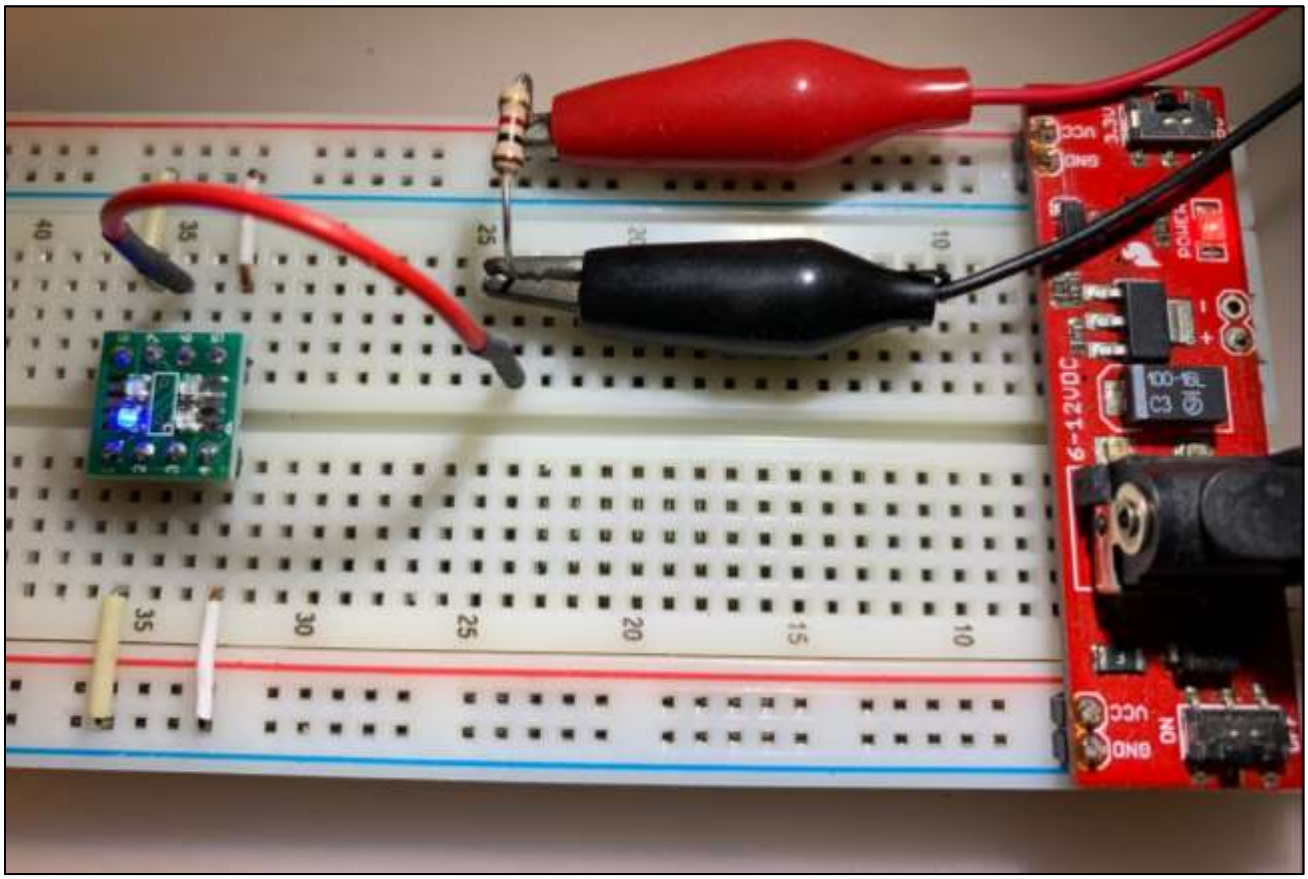
Are they all the same? No. Not all LEDs are created equal, even ones with the same size, color, and voltage drop. I purchased an assortment of 0805 smd components from 3pdt electronics on Amazon, which included a selection no-brand LEDs. I then purchased a few similar, branded LEDs through Digikey. They had surprisingly different current draw and brightness. I liked the no-brand LED better, which makes for difficult shopping!

Fortunately, I am a hobbyist and answer only to myself. My solution was to find something I like, characterize them, and buy a few hundred for my needs. I do not need branded items, so I turned to Amazon and purchased a small assortment of 0805 LEDs from Chanzon: 5 colors x 20 each, for less than $6. It's hard to go wrong with 100 @ 6 cents each. They also sell packs of 100 in each color.

It is easy to test a leaded-LED part: just drop it into your protoboard, add a leaded-resistor, and your off to the races. But those tiny surface-mount parts aren't so easy to use. For a while I thought about designing a simple PCB with a bunch of LEDs and resistors on it. Then I thought perhaps I'd just make a tiny adapter board for a single LED. But there is a better way: use a SOIC-to-DIP adapter. The pads on these 8 pin devices are just far enough apart that you can solder 0805 chips between them. Each adapter is about $3 at Digikey (A880AR-ND). Or you can buy an assortment of 30 adapters from MCIGICM on Amazon for $9.



The photograph below shows my setup. I soldered 4 LEDs onto the 8-pin SOIC adapter: red, green, yellow, and blue. The flat white wires are all of the cathode/ground leads. The red jumper wire is used to select one of the 4 on-board LEDs and apply power through a current limiting resistor. The voltage drop across the resistor is measured – note alligator clips going to my multimeter. The dual voltage 3.3V/5V power is supplied by a Sparkfun Breadboard Power Supply Stick (PRT-13157), an old design but very functional and handy.



Using this setup, it was easy to select the LED, supply voltage, resistance. I chose a range of resistance values from 200 to 3300 ohms, thus varying the current through the LED.

You might be thinking that this is a lot of effort for a simple LED. But there were several questions I wanted answers to:

- If the LED forward voltage is 3.3V, can it be used with a 3V supply?
- What happens when you supply less than 20mA? Will 5mA be enough? How about 1mA?
- Do all of the colors have equal brightness? What resistor do I need for a really bright LED?
- For battery-operated devices, how far can you reduce the current?
- How hard is it to burn out an LED?

For full results at 3.3V and 5.0V see my table at this link. Results for 3.3V follow:

Vcc	R (ohms)	Vr	Vf	I(mA)	Vr	Vf	I(mA)	Vr	Vf	I(mA)	Vr	Vf	I(mA)
3.3	220	0.57	2.73	2.59	1.26	2.04	5.73	1.31	1.99	5.95	0.53	2.77	2.41
3.3	330	0.65	2.65	1.97	1.31	1.99	3.97	1.31	1.99	3.97	0.61	2.69	1.85
3.3	680	0.78	2.52	1.15	1.40	1.90	2.06	1.38	1.92	2.03	0.68	2.62	1.00
3.3	1000	0.85	2.45	0.85	1.43	1.87	1.43	1.39	1.91	1.39	0.70	2.60	0.70
3.3	1500	0.90	2.40	0.60	1.46	1.84	0.97	1.41	1.89	0.94	0.72	2.58	0.48
3.3	2000	0.93	2.37	0.47	1.48	1.82	0.74	1.43	1.87	0.72	0.74	2.56	0.37
3.3	2500	0.96	2.34	0.38	1.50	1.80	0.60	1.44	1.86	0.58	0.75	2.55	0.30
3.3	3300	0.98	2.32	0.30	1.52	1.78	0.46	1.45	1.85	0.44	0.76	2.54	0.23

First, notice that LEDs do not require 20mA to be useful. In fact, most LEDs are bright at 3mA. Look at the top line of the chart above, and notice that a 220-ohm resistor results in about 2.5mA for green and blue, and 6mA for red and yellow. The LEDs are very bright using a 220-ohm resistor. In fact, green is a little *too* bright.

On the bottom line of the chart, notice that a 3300-ohm resistor results in a current draw of 0.2-0.5mA depending on the color. At this current, the LEDs are dim but still visible. They are probably too dim for normal use, but, for low-power battery applications, a larger resistance like this would be appropriate.

These no-brand LEDs are one-quarter the cost of similar items available from Mouser and Digikey. So, what are you losing? For starters, no-brands do not come with spec sheets. You will not be able to check important parameters before you order them. There is no guarantee of quality. They will not come in humidity-controlled packaging like the branded parts. They may not survive high or prolonged soldering temperatures. And there is no “life-cycle” – no guarantee the part will be available next month, let alone next year. For a professional product these are all significant concerns. But not as much for a prototype or hobby project. For me, a penny saved is a penny earned.

This was a simple project that answered all of my questions. Here is a summary of what I learned:

- Yes, it is easy to burn out an LED. Apply VCC directly to the LED without a current limiting resistor and you will see a brief but very bright flash. The smoke follows, making it time to practice hot air rework. You can also partially destroy the LED, such that it still works but the light output is diminished. Don't forget the resistor.

- LEDs with 3.2V forward voltage work fine at 3.3 Vcc. With that supply they won't drop a full 3.2V. In the table above, the green LED has a 3V dropout. Using a 1K resistor the forward voltage drop is only 2.45V, the current is 0.85mA, and the LED is brightly shining.

- Only at full 20mA current will you see forward voltage drops approximating the specified values. At lower currents the voltage drop will also be less.

- At any given current, the green LEDs are brighter than all other colors: 1mA is bright, 0.5mA is moderately bright, and 0.2mA is dim.

- For the other colors, yellow is slightly brighter than blue, which is slightly brighter than red. For these colors, 5mA is bright, 1-2mA is moderately bright, and 0.5mA is dim.

- The simple design is a 1K resistor for all colors and at both voltages. Green will be very bright and the others not so much.

- A better design: For moderate brightness at 3.3V use a 1.5K resistor (0.6mA) for green LEDs and a 680-ohm resistor (1-2mA) for other colors. You can lower the resistance for more light output. Don't go smaller than 220 ohms.

- For very low power applications that require continuous light output, use a green LED with a 10K resistor. The current draw is 0.1mA. The LED will be very dim be still visible. Alternatively, power the LED normally at a very low duty cycle. A 50 millisecond flash every second is easily visible, yet only draws 5% of the fully-on LED.

Finally, what size should you use? Common sizes are 0402 (very small), 0603, 0805, and 1206 (larger). I chose 0805 since they are readily available and I feel comfortable using parts at that size. 1206 components are easier to handle, but harder to find for some components. Experiment and have fun!