WHITEPAPER

The Importance of LEDs in Switches

LEDS PROVIDE ADDITIONAL OPTIONS FOR DESIGNERS AND IMPROVE THE FUNCTIONALITY OF THE SWITCH

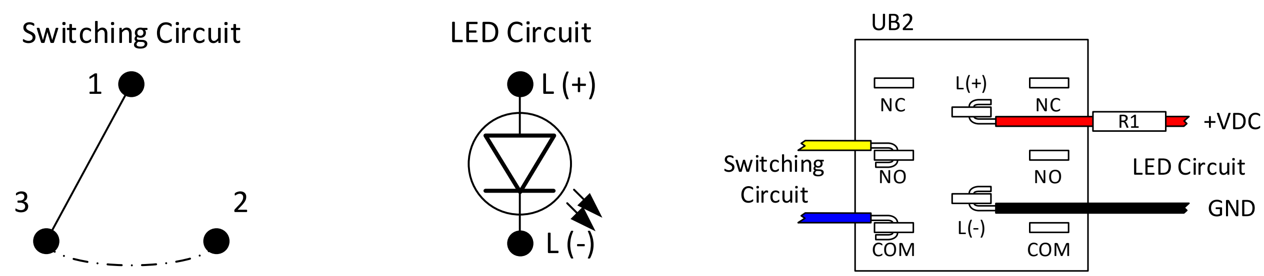
NKK SWITCHES

Why put an LED on a switch?

LEDs are a simple, compact way to indicate the status of a circuit. By having the LED in the switch, it reduces space and component count for an assembly.

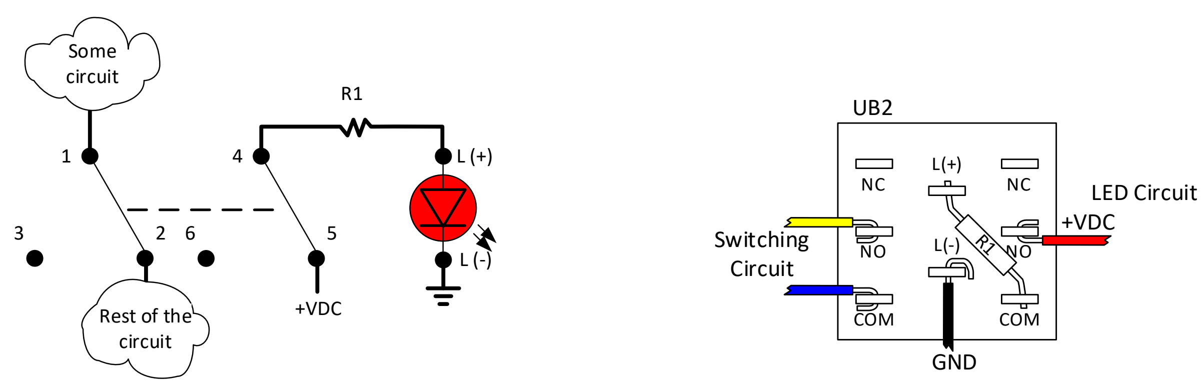
There are many ways to control LEDs. Some indicator circuits use the switch’s own circuity in an ON-OFF fashion. Others are bicolor or even RGB and are hooked up to a microprocessor to give additional visual feedback. Most of the illuminated switches available at NKK Switches have the LED circuit separate from that of the switching circuit. This is to provide maximum flexibility for design.

1. The two circuits found in an illuminated switch (single pole)



The simple indicator circuit shown above is one that uses a spare pole on the switch to turn OFF and ON the LED to show that a circuit is connected. This type of circuit just shows the state of the switch, either OFF or ON, with the reasonable assumption that if the LED is illuminated then the load circuit is active as well.

2. Simple single LED ON-OFF indicator using the second pole of a double pole switch to light the LED. The dotted line indicates that the two poles are mechanically connected to each other.

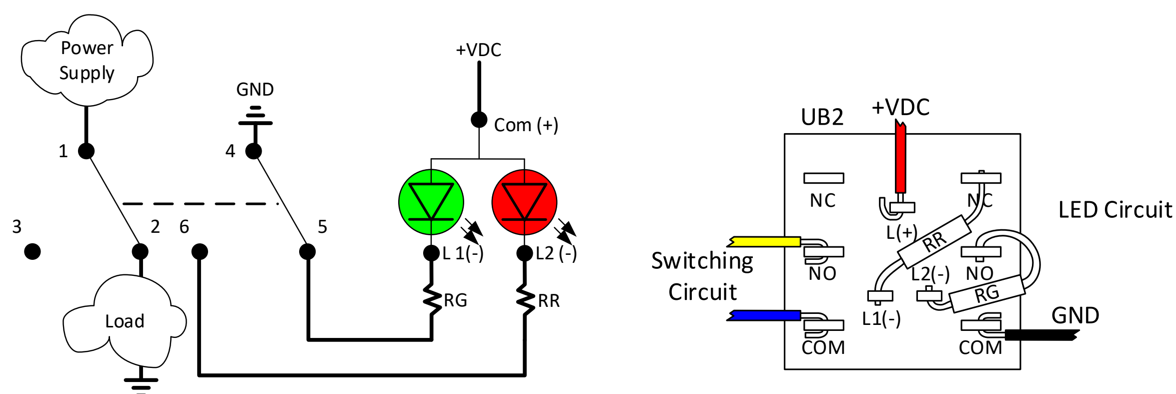


The indicator circuit shown above has the benefits of being simple and low cost but cannot differentiate between the OFF state and a no-power failure as the LED is off in both situations.

The switching circuit is represented as blobs as it could be anything that is allowed by the electrical requirements of the switch. Also, the switching circuit does not have an innate direction; the elections can enter and exit the switch in either direction. The external circuit will determine the current direction and what happens when the switch is actuated. This is not true for the LEDs; the current can only flow in one direction. LEDs are DC components so AC voltage will damage them.

A more complex version of this circuit is shown below, with the OFF condition having its own illumination and utilizing a bicolor LED.

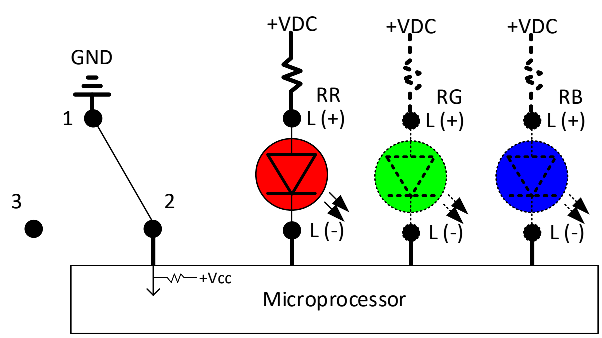
3. ON-OFF indicator using a bicolor LED



In this case, because both OFF and ON states have illumination, it is easy to identify what state the switch is in. Also, if the LED is not lit then there must be something wrong like the power is off or a wire is disconnected.

For more complex interfaces there is another way to illuminate the LED(s), through an external controller. This could be a microcontroller, driver, or some other control circuit.

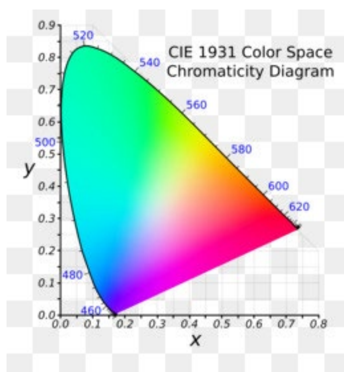
4. An example of a circuit using a microprocessor to read the switch and illuminate the LED(s)



This example may be more complicated but vastly more flexible in use. With control of the three LEDs, there are nearly unlimited colors possible. Even with two LEDs (red and green), amber is possible when both are lit. In this application the switch is both single pole and momentary, as all that is required of the switch is to tell the microprocessor to “do something”.

Only the brightness of each LED can be controlled. It is that blending of bright and dim LEDs that produce different colors beyond the original three.

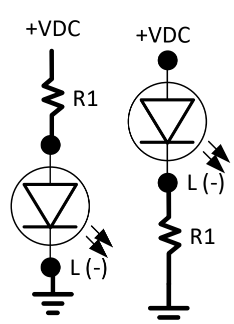
5. RGB Chromaticity Diagram



Why do I need a resistor?

All LEDs will need circuity to control current. The simplest are resistors. The resistor values must go in series (or in line) with the LEDs; meaning the current only travels one path. Without a resistor the LED will most likely burn up in a single flash and cease to function. Often, a switch user will break their LED by hooking it up directly to a 9-volt or 12-volt supply without a resistor only to discover they should have read the switch datasheet specifications first.

6. The resistor can go before or after the LED.



Some illuminated switches have LEDs with built-in resistors, but most don't. This allows for flexibility of design. If a switch does not have an LED with built-in resistor, then an external one needs to be added. This is sometimes called a ballast resistor.

Besides resistors there are other ways to regulate the current through an LED; for instance, constant current or PWM and devices like LED drivers such as MAX6957AAI+ or STP16CP05MTR. There are a variety of circuits available for this.

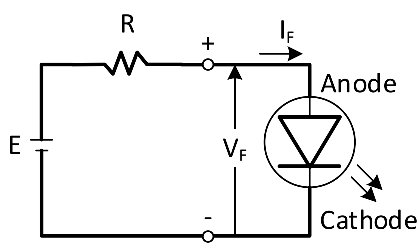
What value resistor is needed?

The resister value is dependent on three variables; LED forward voltage, LED forward current, and the source voltage. The LED forward voltage and LED forward current are listed in the switch datasheet in the LED section. Typically, they will be V_F = 2.1VDC and I_F = 20mA; or V_F = 3.5VDC and I_F = 10mA. This data should be checked first.

The source voltage is what is provided by the external circuity. The designer building the LED circuit should have access to this information.

Below is an equation available to find the resistor value.

7. LED circuit.



8. Resistor Value Equation

$$R = \frac{E - V_F}{I_F}$$

Where:

R	=	Resistor Value (Ohms)
E	=	Source Voltage (V)
V_F	=	Forward Voltage (V)
I_F	=	Forward Current (A)

Example: If the Source Voltage (E) is 9 volts DC and the Forward Voltage (V_F) is 2.1VDC and the Forward Current (I_F) is 20mA (which is the same as 0.020 Amps) then the Resistor value is:

$$R = \frac{E - V_F}{I_F} = \frac{9 - 2.1}{.020} = 345 ohm$$

Therefore, a 345ohm resistor is needed for maximum brightness. However, a 345ohm resistor may be hard to find. A 347 or 350ohm resistor could also be used, just so long as it is greater than 345ohm.

Another important attribute for a resistor is the Power Rating (P).

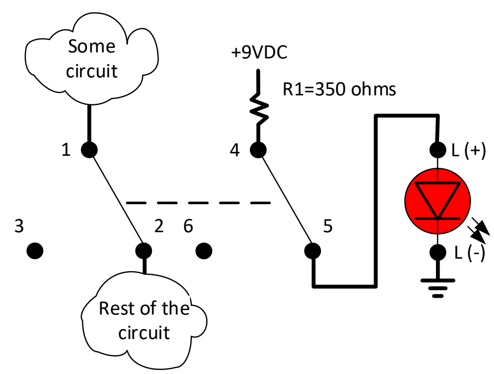
$$P = {I_F}^2 R$$

I_F is known (20mA) and now R is known (345ohms) then the power dissipated by the resistor is

$$P = {I_F}^2 R = (.020)(.020)(345) = 0.138 Watts$$

Adding a factor of safety makes it 0.25Watts. For this example, a 350ohm ¼Watt resistor would suffice.

9. A LED circuit with 9VDC power supply and a 350ohm resistor.



This is for maximum brightness, but if a dimmer LED is preferred, then the current to the LED should be reduced. Pick 10mA for instance:

$$R = \frac{E - V_F}{I_F} = \frac{9 - 2.1}{.010} = 690\ ohm$$

The LED will be dimmer. Maximum brightness (based on the LED Forward Current) is just that: a maximum and not necessarily a target for designs. Most applications can tolerate or even require a dimmer LED.

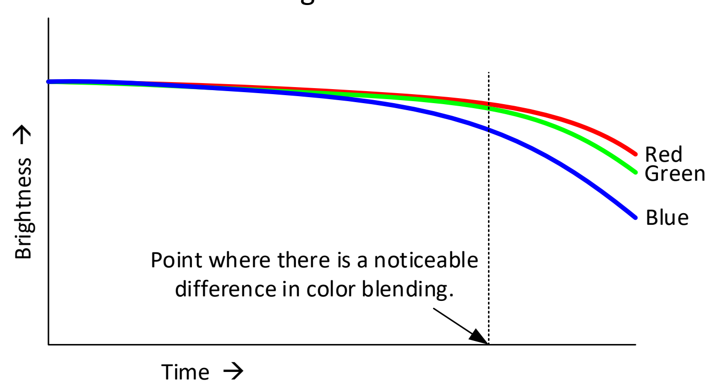
Life of an LED

The life of an LED is something most LED users don’t think about. It seems like LEDs live forever; especially when compared to incandescent bulbs.

Just like everything else in the world, everything has a lifetime. This is no different for LEDs. When an LED is illuminated it is slowly, imperceptibly, growing dimmer. If the LED is on maximum brightness all day long the point where it becomes noticeable can be down the road, years even, but not forever. When just using one LED at a time as an indicator, a dimming of the light is not as big a concern. It doesn't really matter if it's 10% dimmer then when it was first illuminated. As long as the LED is lit the user knows the status of whatever the light is for.

If three LEDs, such as red, green, blue (RGB), are used to create a rainbow color field, lifespan becomes much more important. Another consideration is that lifespan is dependent on the color of the LED; red having the longest, green not far behind, and blue is quite short. After a time, the blue LED will be dimmer than the green and red.

10. LEDs age at different rates.



When designing an application using the three colors, RGB, these constraints should be accounted for. When a set of switches are used together with some being illuminated more than others, patterns of colors or shades of brightness may occur as a result of some LEDs having more opportunity to age than others.

The best way to handle this within a switch application design is to lower the brightness of the LEDs just enough so that the LEDs are still bright enough to fulfill their operational purpose but not overly bright that it unnecessarily ages the LEDs.

When a considerable amount of the life of the blue LED has passed, it might be necessary to recalibrate the LEDs' brightness so the colors match (with the understanding that the LEDs will be dimmer). The good news is LED technology is improving and those lifespans are growing longer with each generation of new LED designs.

It's all about the legends

Switches have caps on them that allow for short legends identifying the purpose of the switch and indicator. For illuminated switches with clear caps the best legend technology is laser etch. A laser etched legend is dark and crisp, even more so when backlit by the LED.

11. The Legend

The added advantage of alternate legends

LEDs with complimentary colors like red and green, or blue and amber can be further enhanced by adding legends to the switch caps that change as the color changes. NKK has alternate legends that use filters to change a legend on a cap of a switch from one word to another such as "OFF" and "ON"; and "CLOSE" and "OPEN" depending on the color.

12. Alternating Legends

Conclusion

By having an LED on a switch, it provides the system designer options, and saves both space and component costs. The user knows the status at a glance through color or even just simple illumination.