



## Robot Room

<http://www.robotroom.com/Pumpkin.html>

# Replacing Halloween Pumpkin Candles with Color LEDs

As Halloween approaches, every electronics hobbyist wonders: Can I replace a pumpkin candle with LEDs? **Yes you can!**

This article will show you how to make several simple LED circuits powered by an ordinary 9V battery. No soldering is required. These circuits are also applicable and useful for robots and other electronic projects.



(If you aren't interested in the technical stuff, you can skip ahead a couple of pages to get to the pretty pictures and movies.)

Let's start by determining the benefits and issues of sticking with an ordinary candle. As a jack-o-lantern light source, the benefits of a candle/tea-light are:

- Inexpensive
- Disposable
- Readily available / easily replaced
- Flickers attractively
- Generates a festive pumpkin scent
- Indefinite shelf life
- Can be reused for other holidays (votive candles) and for power outages.

The disadvantages of a standard wax candle are:

- Source of ignition or fire (should be monitored, not kid-safe)
- Can be awkward to light
- Can be extinguished by wind
- Generated heat may reduce life of pumpkin
- Single color (yellowish-white)

LEDs (light emitting diodes) have none of the disadvantages of candles. And, a well-designed LED circuit can include some of the advantages of candles. (However, if your LED circuit is somehow generating a festive pumpkin scent -- you've got it wired wrong.)

To me, the advantages of being able to choose different colors and the reduction of the risks of burns cause me to select LEDs over candles for lighting my pumpkins this Halloween.

### Preparing an Artificial Pumpkin

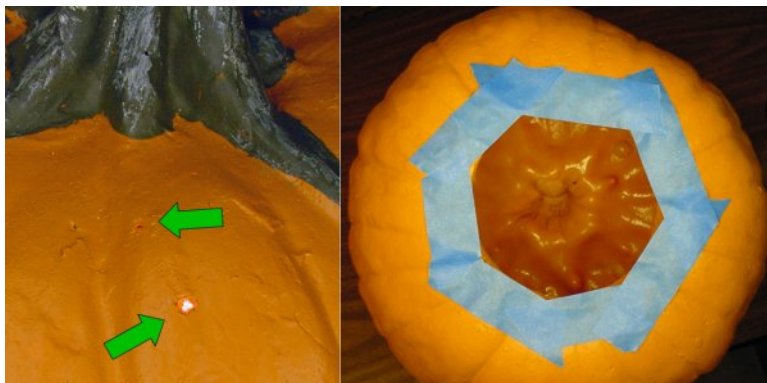
This article was written in September, before any decent natural pumpkins were available on the market. Furthermore, I'd like to be able to expand this article in future years and so I need a reusable pumpkin as a standard model. As such, I decided to use an artificial pumpkin for test purposes.

An artificial pumpkin??? Horrors!

Before you get too upset, recognize that this article is about producing an artificial light source. What better place to put an artificial light source than in an artificial pumpkin? And, this project ultimately will go into a real pumpkin.

My family visited two local craft stores, Michaels Arts & Crafts and Hobby Lobby Crafts. At Hobby Lobby we selected Funkins carvable pumpkins #009 for Halloween 2007.

Unfortunately, the pumpkin has an orange interior. That's not going to provide a strong reflection and the orange color is going to tint the lighting of any color LEDs. The inside of the fake pumpkin needs to be spray-painted white.



Left: Checking for holes in an artificial pumpkin.

Right: Taping holes and underside opening with blue masking tape.

Before painting, place a bright flashlight in the uncarved pumpkin and check the outside for any holes where paint might leak out. Cover those holes with blue painters masking tape (low adhesive -- such as Scotch blue masking tape or 3M blue masking tape). If you use ordinary white masking tape it may peel away some of the pumpkin skin when you try to remove the tape.

The underside of the Funkin is already cut open. So, we'll be spray painting from that direction. Coat the outside border of the underside opening with blue masking tape to protect it from overspray.



Left: Covering pumpkin with newspaper.

Right: Close-up photo showing masking tape not sticking.

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Cover the outside of the pumpkin with newspaper and stick it into a paper bag. Cut a hole in the bottom of the paper and tape it as best you can.

Because the interior of the artificial pumpkin is made from polyurethane foam, the cut portions are porous and tape won't adhere to it. Some spray paint is going to leak back there. That's why we covered the outside bottom of the pumpkin a few steps ago.



Left: Use rubber gloves when spray painting.

Right: Inside of the finished decorative pumpkin painted white.

I selected RustOleum spray paint (Plastic Primer) in white. Wearing plastic gloves, insert the tip of the spray paint can nozzle and apply a light coat of paint to the interior walls of the pumpkin.

Use short bursts as far away as you can be from the side you are painting. The ensuing paint cloud will partially coat the places you can't otherwise reach.

Don't try to get it all painted in the first pass. Instead, you'll have better results by letting it dry for a few minutes and then applying additional coats of paint.

After about an hour of drying, I applied a couple of light top coats in the interior using Krylon spray paint in flat white. I selected flat-white paint as opposed to satin paint or gloss paint, because I didn't want any glare or hot spots.

My wife carved the pumpkin using serrated pumpkin carving tools. She wanted to make a highly creative or ultra spooky pumpkin, but this article requires a "model" or "idealized" pumpkin for testing purposes. Sorry dear.

Let's see how to light up the jack-o-lantern...

## 2. Simple, Single LED Electronics

Although this article focuses on replacing a candle with LEDs for Halloween pumpkins, these LED circuits are applicable to any electronic project or device.

Before we look at the first LED schematic, let's determine the appropriate power source and maximum power usage for a pumpkin candle replacement.

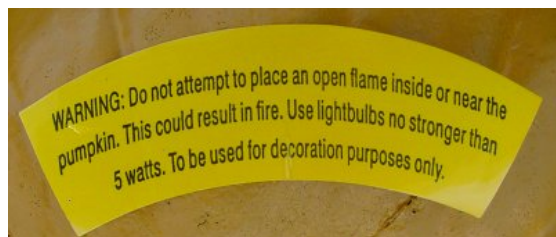
### Selecting the LED Light Power Source

It is possible to use a wall wart AC adapter to cheaply power the pumpkin LED lighting. However, the cords may present a trip hazard on a dark Halloween evening. It is also possible, although unlikely, that an exposed connection or wire might also pose an electrocution hazard in rainy or wet conditions. Therefore, for the purposes of this science project, we're going to stay away from electrical outlets.

Standard 9 volt alkaline batteries are readily available, relatively affordable, and compact. Except under bizarre circumstances, they don't pose an electricution hazard. A 9V battery fits nicely in a pumpkin. Therefore, a 9V battery will be the power source for the LED pumpkin lights.

### Determining Maximum LED Circuit Power

The label on the Funkins artificial pumpkin states that candles can't be used, due to the risk of fire. Polyurethane releases nasty toxic gases when burned, so you really don't want to put a candle in there.



Warning label on Funkin artificial pumpkin.

The final sentence on the warning label is pretty funny. "To be used for decoration purposes only." I racked my brain trying to come up with the other possible uses for an artificial pumpkin. Floatation device? Soccer ball? Have people tried to make a pie out of it? (Mmmm, chewy.)

I tested the temperature of a single, unenclosed candle at 10 cm directly above the flame. The temperature was 180 Fahrenheit!

In past Halloweens, you may have noticed the browning of the top of a naturally moist pumpkin. You can imagine how dangerous it would be to put a candle in a dry, flammable, enclosed space like an artificial pumpkin. Don't do it!

Surprisingly, candles are inefficient light sources (0.3 lumens per watt). That is, candles produce far more heat than light.

The much maligned incandescent bulb (15 lm/w) is 50 times more efficient of a light-source than a candle. Depending on whom you believe, an average white LED is approximately 100 times as efficient (30 lm/w) than a candle.

The Funkins manufacturer states that a lightbulb up to 5W is acceptable. Unfortunately, we can't simply double that wattage for the efficiency gains of an LED over a lightbulb.

Here's why: LEDs release most of their waste energy as heat (80%), whereas incandescent bulbs release most waste energy as infrared (73%) and only some as heat (19%). I'm not going to bother to attempt to calculate how much of the infrared energy is absorbed by the pumpkin and turned into heat. To be on the safe side, I am going to assume the artificial pumpkin is safe from the heat of an LED light source of up to 1.19 watts of power ( $19\%/80\% * 5W$ ).

By choosing a relatively small amount of power usage, the temperature in the artificial and real pumpkins will be much lower than when using a candle. Furthermore, if we keep the circuit below 0.9 watts, the standard alkaline battery capacity (540 mAh) should last for at least 5 hours.

$$0.9W / 9V = 0.1 A = 100 mA$$
$$540 mAh / 100 mA = 5.4 \text{ hours}$$

### **Web Article vs. Book**

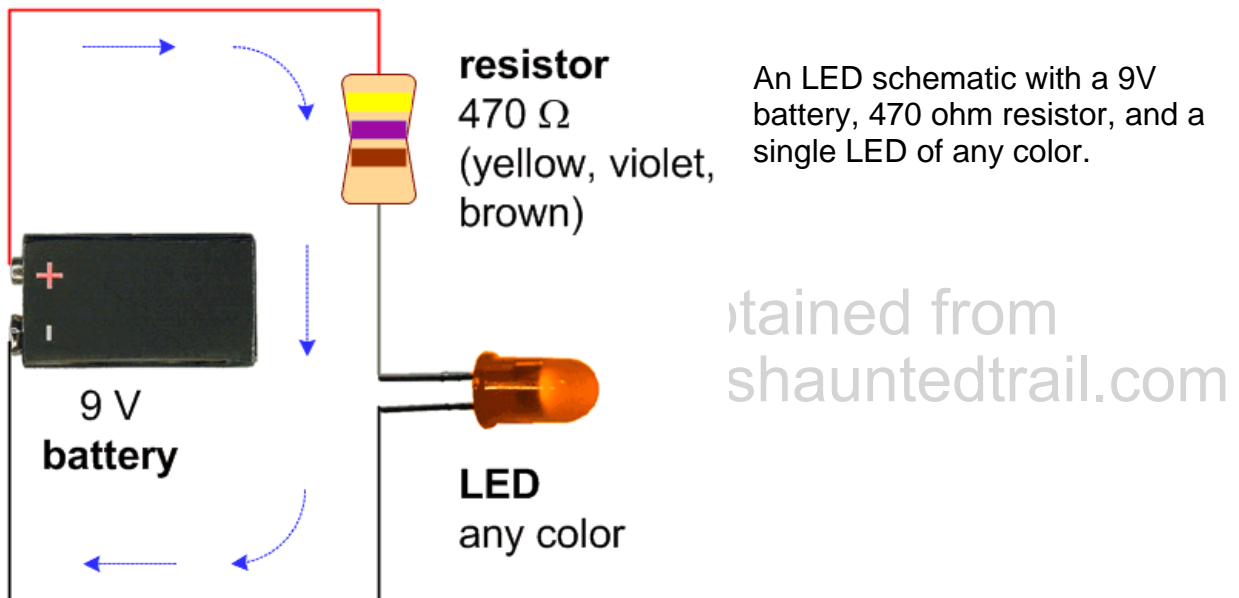
Depending on your background and tenacity, the remainder of this web article will provide enough content for most people to make the LED candles. However, for the sake of brevity, this web article doesn't provide deep dives on batteries, resistors, LEDs, multimeters, and solderless breadboards.

In my book, [Robot Building for Beginners](#), I assume you know nothing about electronics. Chapters 7 through 13 provide step-by-step instructions and explanations as to how to build an LED circuit, test it, and modify it.

After reading this article, if you're interested in building the circuits but need a bit more help coming up to speed on electronics, buy the book.

## The First LED Circuit

To begin, let's start with a single LED.



Conventional electricity flows from the positive terminal of the battery, through the resistor, through the LED, and then back into the other terminal of the battery. If you put the battery or LED in backwards, the circuit won't work. (Resistors can be installed in either direction.)

The amount of light produced by an LED is controlled by the resistor. The more light produced, the more energy consumed and the more heat is generated.

Although a few LEDs come with built-in resistors, most manufacturers leave off the resistor so that the circuit designer can select a brightness and energy consumption rate appropriate for their project. While you may grumble at having to select, purchase, and add a resistor to your circuit, you'd be unhappier if you had no control over the LED's luminance.

Some beginners in electronics try to attach an LED directly to a battery without using a resistor. In most cases, the LED will be instantly destroyed by too much energy. So, always use a resistor.

Electronics experts can pull a few tricks to use an LED without an obvious resistor by using a weak power source (like a lithium watch battery), by powering the LEDs from a semiconductor chip, or by matching the battery voltage exactly to the LED voltage usage. But, generally speaking, if you hook up an LED directly to a 9 volt alkaline battery, the LED will be permanently damaged.

I selected a resistor value of 470 ohms for this circuit so that any color LED could be used without risk of damage. However, in exchange for safety, the resistor value is not optimized for the brightest output for all LED colors.

## **Assembling the LED Circuit**

There are five ways you can put together this electronic circuit:

1. Bend and crimp the wires together using pliers. This is lame because the wires will wiggle loose and stop working. However, it's free and requires no soldering.
2. Attach the electronic components together using small alligator clips. This is nice as it allows you to experiment with rearranging the circuit. But, the clips cost money, the wires can come loose, the clips take up space, and the parts may touch each other and ruin the electronics.
3. You can insert the components onto a solderless breadboard. This is a great technique, as you can experiment with many different circuits in a compact space. Also, the breadboard is reusable for other projects. However, the solderless breadboard will cost a little bit of money and the parts can come loose (but not as easily as the previous methods).
4. You can free-form solder (solder end-to-end) the parts together after experimenting on the solderless breadboard. The parts won't come loose, and it is not difficult to do for small circuits. However, the parts may come in contact with each other if the circuit is crushed, rerouting the electricity in the circuit. Also, it is much more difficult to modify a circuit that is soldered together.
5. You can solder the parts onto a circuit board with holes (breadboard or specifically designed LED PCB) after experimenting on the solderless breadboard. This is the professional approach.

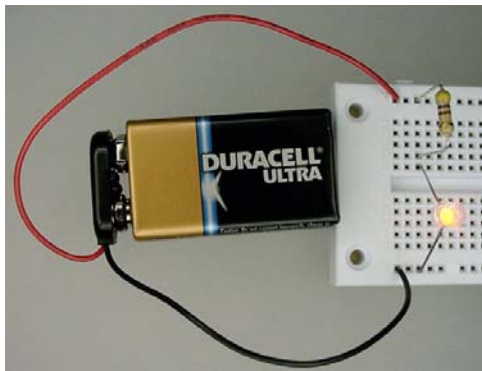
For this article, we'll be using method #3, because solderless breadboards are the easiest to use. Also, this allows you to quickly experiment with your own arrangements.

A small solderless prototyping board is available from Electronix Express (elexp.com), part #03MB101, for \$2.70. A RadioShack store may have a comparable board (part #276-175 for \$4.49), however, they seem to be getting out of the electronic parts business.

For all of the simple Pumpkin LED candle projects, you'll also need:

- A 9V battery connector (a plastic snap with wires that connect to the battery).
- An assortment of resistors, but at least 470 ohm, 220 ohm, and 180 ohm.
- An assortment of through-hole ultra bright LED colors (5 mm or T1 3/4 sizes are most popular).
- Some blinking LEDs / flashing LEDs.

If you're lucky, these items will be available at your local Radio Shack. But, if you want to save some money and have a better selection, check out online stores such as Electronix Express, DigiKey, Mouser Electronics, or Jameco Electronics.



A simple LED circuit implemented on a solderless breadboard.

Look at the holes on the prototyping breadboard in the photo here. Connect the wires and component leads to the same locations on your breadboard. If your LED doesn't light up:

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- Make sure the battery is fresh. Use a digital multimeter to measure the battery voltage if you're not sure.
- Check that the color bands on the resistor match yellow, purple, brown (can also have gold or silver on the end). Use a digital multimeter to measure the resistor's resistance if you're not sure. 450-500 ohms is fine.
- Try flipping the LED around. Maybe it is in backwards?
- Push the wires all the way down into the holes.

At this point, you have a nice test circuit for checking the color and orientation of any LED. (It's not quite as fancy as the [LED Tester](#), but it will do.)

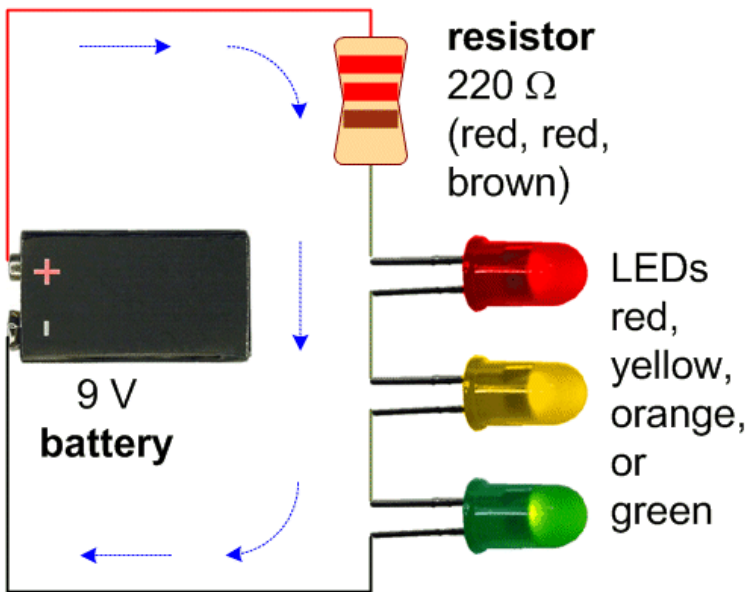
However, a single LED isn't bright enough to light up a whole pumpkin. Let's see how to add additional LEDs...

### 3. Brighter LED Lighting with Multiple LEDs

At this point, we've created a simple circuit with a single LED on a solderless breadboard. A single LED doesn't have enough luminance to light up a jack-o-lantern as well as a candle can.

Fortunately, adding additional LEDs is easy!



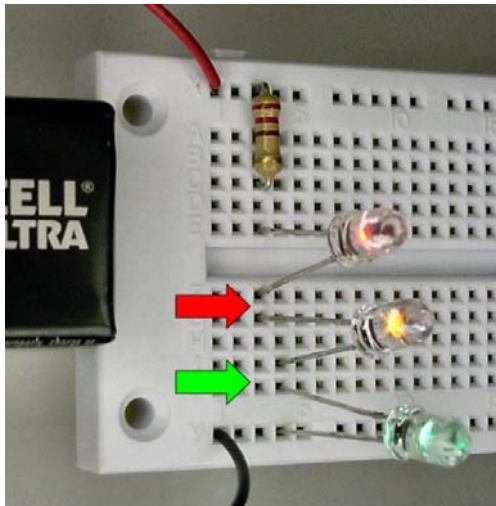


Schematic for an LED Pumpkin Candle with three LEDs.

Even though this LED schematic includes three LEDs, it doesn't use more power than the single LED circuit!

The same electrical current that passes through the red LED is passing through the yellow LED and green LED on its way back to the battery. In fact, because some additional portion of the battery power is being converted into light by the extra LEDs, the three-LED circuit runs slightly cooler than the single-LED circuit.

To compensate for the extra LEDs, the resistor value has been reduced from 470 ohms to 220 ohms. If the resistance had not been changed, the LEDs would still have lit up, but the LEDs wouldn't have been as bright.



Three LEDs on a solderless breadboard.

When creating this circuit on a solderless breadboard, notice that the wires shift over one column between the red LED and the green LED. If your yellow LED doesn't light up, you've accidentally plugged all of the wires into the same column.

If none of the LEDs light up, then you have installed one or more LED(s) backwards. You can play around with guessing as to which LED is backwards, or you can keep a separate breadboard with the single-LED circuit to test the orientation of each LED.

The three-LED circuit has one important limitation worth noting: Unlike the single-LED circuit, the three LEDs can no longer be any color you want. The three-LED circuit can only use the red-to-green portion of the rainbow.

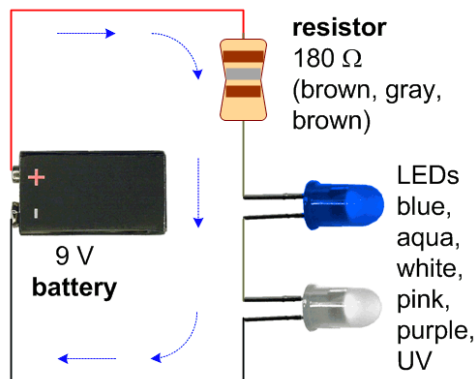
However, you can mix and match those colors. For example, you can have a red, yellow, and green LED. Or, you can use three red LEDs. Or, three orange LEDs. And so on.

But, you cannot reliably use aqua LEDs, blue LEDs, white LEDs, purple LEDs, or ultraviolet LEDs in the three-LED circuit. Each of those colored LEDs requires a high enough voltage (between 2.8V and 3.7V) that it is not possible to add three together and supply enough power from a partially-exhausted 9V alkaline battery or even a fresh rechargeable battery, such as a Ni-MH battery or rechargeable NiCad battery pack.

### Blue LEDs and White LEDs

A 9V battery can't fully power three white LEDs in series over the full life of the battery. A fresh 9V alkaline battery might power them for a short time, but they'd grow dim quickly.

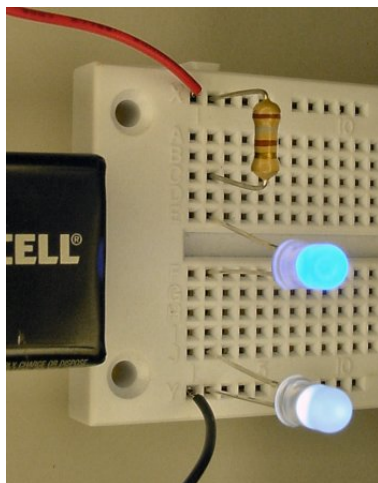
However, a 9V battery can power *two* LEDs:



Schematic for an LED Pumpkin Candle with two LEDs (white or ranging from blue to ultraviolet).

Notice the specified resistor has changed values yet again. This time, the resistance has been dropped to 180 ohms to compensate for the extra voltage that these colored LEDs require.

If the resistor had stayed at 220 ohms, the color LEDs would not have been as bright. If the resistor had stayed at 470 ohms, the color LEDs would have been even dimmer.



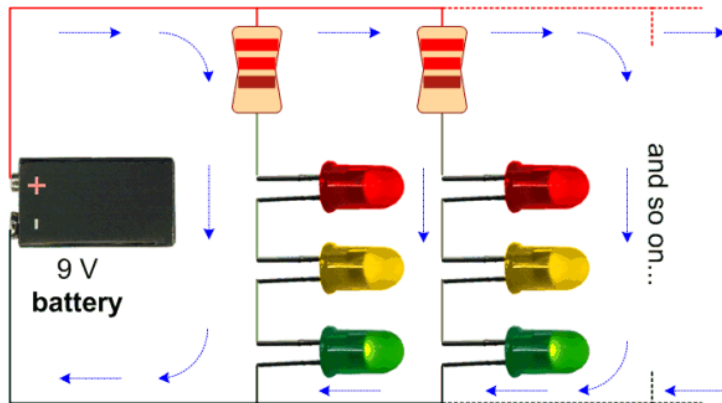
A blue LED and white LED on a solderless breadboard.

Two 5mm LEDs are easier to implement on a solderless breadboard than three 5mm LEDs. The resistor and LED wires are all in the same column.

## Even More LEDs

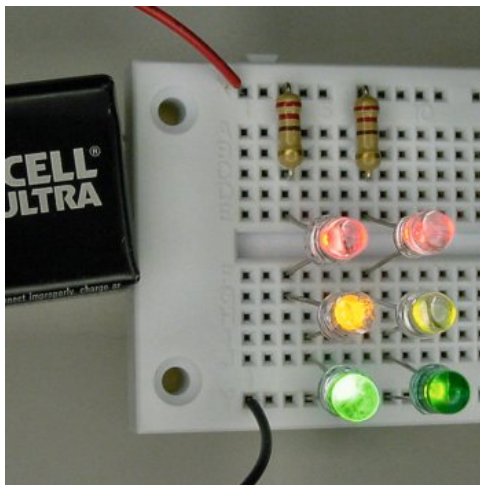
But, only two or three LEDs are still not going to be enough to light up a pumpkin!

To add additional LEDs, simply add additional strands of two or three LEDs parallel to the first series. You've finally made it to the LED schematic that will be used to create replacement pumpkin candles.



Schematic for a complete LED Pumpkin Candle with numerous parallel strands of LEDs.

You can add up to five parallel strands of three LEDs and still be within the project's temperature and power consumption limits. A fresh alkaline 9V battery will last over 5 hours with five strands.



LED Pumpkin Candle on a solderless breadboard with two parallel strands of LEDs.

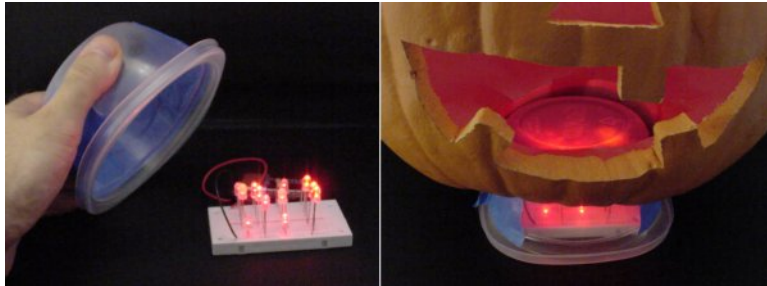
Electrically speaking, you can mix and match different colored LED strands. That is, you can have a strand of two blue LEDs, followed by three red LEDs, followed by an orange/green/red strand, followed by a strand of two purple LEDs.

Visually speaking, mixing colors tends to result in a homogenous mess, rather than a stained-glass window effect. But, that's why you have a nice solderless prototyping board: to experiment!

We're ready to light up a pumpkin...

#### 4. Lighting Up a Pumpkin with Various Color LEDs

The model pumpkin used in this article is an artificial Funkin. The bottom of the Funkin is open. That's where we'll put the LED light source.



Using a small plastic container to hold the LED light source under an artificial pumpkin.

A Glad Products container, 1 3/4 cup (14 oz, 414 ml) fits perfectly over the 9V battery and solderless breadboard. The pumpkin is placed over the small container.

To block the light from showing underneath the pumpkin, you can cover the sides of the plastic storage container with blue masking tape. Then, wrap a towel or pillowcase around the small container, as though the jack-o-lantern were wearing a scarf.

For a real pumpkin, you can either use this method, or you can throw the circuit board and alkaline battery into a Ziploc sandwich bag and place it on the bottom of the pumpkin. When you're happy with the look of the pumpkin, you should trim the leads of the LEDs and resistors to sit flush against the prototype board. Otherwise, the individual LEDs will be noticeable in the pumpkin's mouth.



Pumpkins lit with red LEDs and pink LEDs.

For red, I used four strands of three red LEDs.  
Total of 12 red LEDs.

For pink, I used four strands of two pink LEDs.  
Total of 8 pink LEDs.





These green LEDs are a little too yellow for my taste.  
The white LEDs look good.



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[Omarshauntedtrail.com](http://Omarshauntedtrail.com)



Two pumpkins lit with aqua LEDs and blue LEDs. The  
blue LED light is striking.





The purple LEDs look similar to the pink LEDs.



The ultra-violet LEDs appear dim because human eyes can't see very far beyond blue. I wonder whether a natural pumpkin will fluoresce.

Obtained from  
Omarshauntedtrail.com

There is a health concern about staring directly into an ultraviolet LED. The total UV exposure probably wouldn't be as great (and the wavelength isn't as energetic) as you would get from natural sunlight. However, your pupils may not contract and you may not blink or squint like you would if you were staring at a more visible light source. Temporary indirect exposure to a group of UV LEDs lighting up a pumpkin is unlikely to cause any more harm than would a blacklight. But, if you're concerned, or if you plan to leave the pumpkin unattended around children or incapacitated adults, avoid using a UV LED.

### **Don't Use Old or Junk LEDs**

All of the LEDs used for lighting up these pumpkins are modern, high-brightness LEDs in clear cases. These types of LEDs are also called ultra bright LEDs, high efficiency LEDs, or super bright LEDs.

Older LEDs tend to be much dimmer and are in tinted cases. Using lower resistor values would make them brighter, but they'll burn out.

I'm not sure what to do with my old LEDs. But, they're not appropriate for this project.

## Mixing LED Components of the Same Color

For color, size, and output consistency, I usually want my LEDs to be the same part number from the same batch. But when I clean up the robot room, I'm sometimes left with piles of unmarked LEDs. I can use the [LED Tester](#) to quickly determine the LED's color and brightness, but I can never be sure which exact part number the lone LED matches.

Fortunately, since the emitted light tends to blend inside of a pumpkin, this is a good chance to use leftovers or unknown part numbers (but not junky dim LEDs). Slight variations in color or output will go unnoticed.

## Mixing LED Colors

You can come up with other color variations by combining LEDs of totally different colors on the same board. For example, by using strands of red and blue LEDs, you can end up with a nice purple or pink color overall. White and blue LEDs combine to make a sky blue light source.

By mixing up popular or primary colors, you don't need to buy individual specialty LEDs like pink, purple, or aqua.

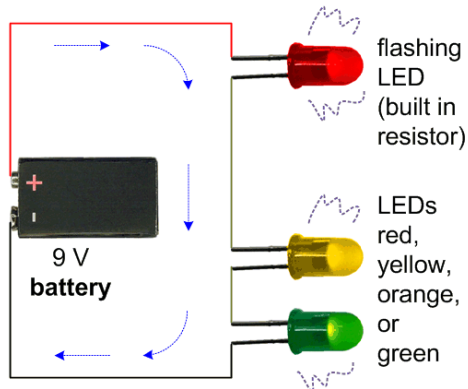
Now, that we've mastered lighting up a jack-o-lantern, can we make LED flickering candles by using blinking LEDs? A movie is coming up...

## 5. Making an LED Flickering Candle for a Halloween Pumpkin

Colorful pumpkin lights are very attractive, but constant luminance can be a little boring and artificial. By adding a blinking LED (also called a flashing LED) to the circuit, the pumpkin can appear as if it were lit by a flickering candle.

A blinking LED includes a tiny integrated circuit (IC) built into the LED itself. Most blinking LEDs operate from 3.5V to 9V, but you should ask the seller or manufacturer to be sure.

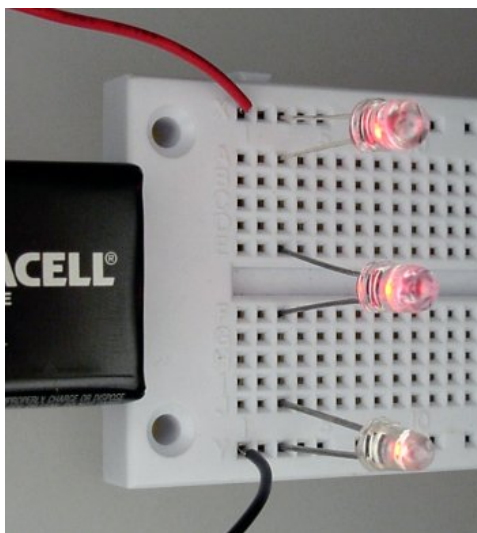
Blinking LEDs are available in various colors, although red is most common. Expect to pay around \$0.60 each per ultra bright flashing LED.



Schematic of a flashing LED in series with two steady LEDs.

Where did the resistor go in the schematic?  
The resistance is built into the blinking LED.

The schematic shows two red-to-green LEDs. But, you can use one white LED or one blue-to-ultraviolet LED in combination with one blinking LED if you prefer.



A single red blinking LED causes two steady red LEDs to blink at the same time on a solderless breadboard.

You only need to use one blinking LED to control one or two normal LEDs, so long as they are all in the same strand. In fact, it's a waste to put two blinking LEDs in the same strand. And, sometimes they'll mess each other up.

Combine a blinking strand of LED lights in parallel with 1 to 4 steady strands for an intermittent change in brightness. If all of the LEDs are the same color, the total light source will appear to flicker. If the flashing LED strand is a different color, then both the overall brightness and color will be altered.

The only problem with using a single blinking LED strand is that the blinks occur at a fairly constant rate (1-3 times a second). It's not a huge problem; it just looks a little more artificial than a true candle flicker.

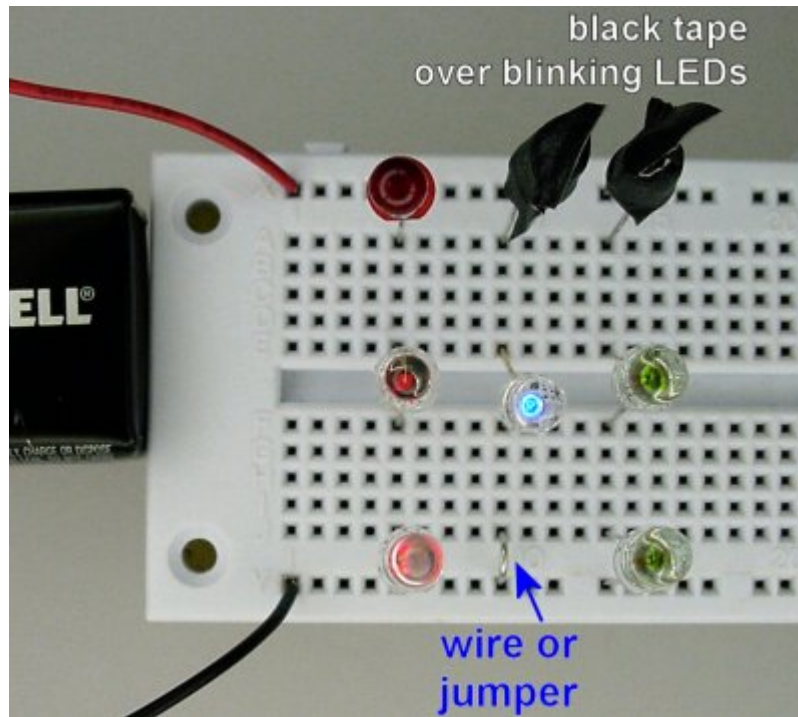
For a more spectacular display, make all five strands flash. The variances in the blinking LEDs cause them to become randomly synchronized and unsynchronized. The effect is fun and spooky, for just a couple of dollars.

As you can see, blinking LEDs add a lot to the decorative display with very little change in circuitry.



## Blinking Color LEDs

Blinking LEDs are available in colors other than red. Using the same techniques presented in earlier LED schematics, you can create an LED circuit that includes a blinking red strand, a blinking green strand, and a blinking blue strand.



Flashing red LEDs control different color strands of LEDs. Black tape covers the red flashing LED for the blue and green strands.

If you don't have blinking LEDs in a variety of colors, you can simply use a red blinking LED and cover it with black masking tape for the blue strands and green strands (see above). That way, the red doesn't interfere with the blue and green colors.

Because the brightness of the tape-covered blinking LEDs is unimportant, use the cheapest blinking red LEDs you can find, such as from BGMicro for only \$0.10 each (part #LED1064).

## 6. Pulsing an LED with an ATTiny45 Atmel Microcontroller

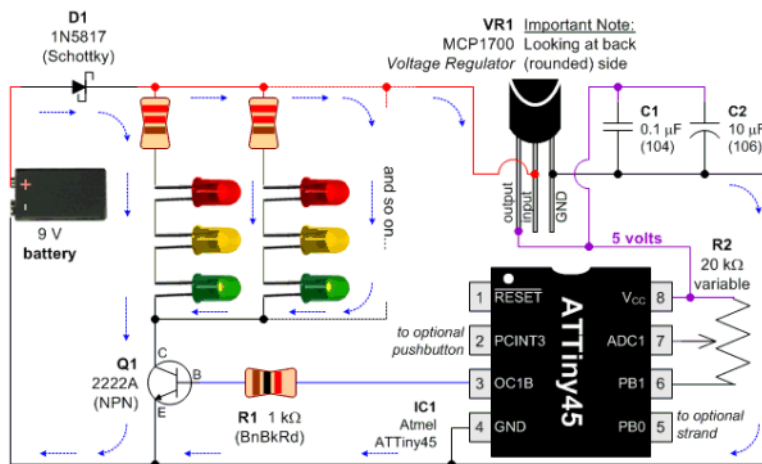
Discrete blinking LEDs are convenient, but the blink rate and blink duration are not configurable. I tried goofing around with using transistors, resistors, and capacitors to alter the blinking LED. In the end, I had so many extra electronic components that I figured it would be easier to simply program the lighting effect with software.

As soon as a circuit includes a microcontroller (MCU), it cuts down on the number of hobbyists that are capable of implementing it. Nevertheless, I decided to include this more complex circuit in this article to demonstrate the possibilities.

A number of fancy electronics (computers, MP3 players, etc) now include a pulsing LED that fades in and out. For example, a pulsing LED may indicate that the device is sleeping (in a low power mode).

I decided to recreate this pulsing effect for a pumpkin:

The color can be changed by installing different LEDs. The speed is adjustable through a potentiometer (small versions are called "trimpots").



Schematic to control LED lighting with an Atmel ATTiny45 microcontroller.

The heart of the original LED circuit still exists on the upper left side of the schematic. See the 9V battery and the parallel strands of LEDs?

The circuit has become much more complicated because the microcontroller can't run on 9 volts. A Microchip MCP1700 LDO (low-dropout) voltage regulator (VR1) steps down the battery voltage to 5 volts for the microcontroller section. Several capacitors (C1 and C2) steady the voltage supply to avoid electrical glitches and noise.

A diode (D1) protects all of the electronics components against a reversed battery. This wasn't necessary in previous circuits because the strands of LEDs wouldn't be harmed by a reversed battery. But now, a microcontroller and other sophisticated semiconductor parts are installed, and they can be harmed by a flipped battery.

The Atmel ATTiny45 microcontroller has firmware (software inside a chip) that is written in C on a personal computer. The compiled software is then downloaded to the chip by an Atmel programmer. I use an Atmel STK500 board and the ImageCraft C compiler.

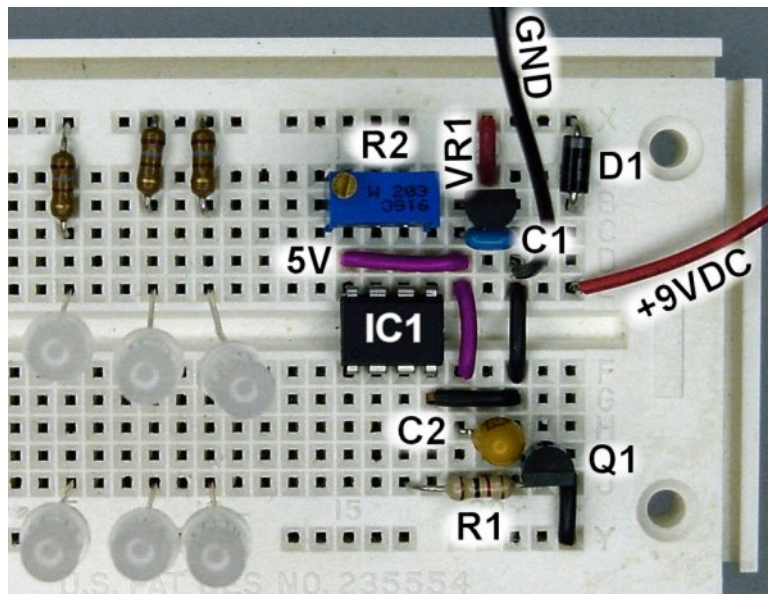
In the circuit, the Atmel microcontroller reads the trimpot (R2) using the built-in Atmel ADC (analog-to-digital converter). Depending on the voltage on the trimpot wiper, the microcontroller delays each increment or decrement of the LED brightness. Thus, by adjusting the trimpot, the rate of pulsing can be slowed down or sped up.

All of the power going to the LEDs is controlled through a single bipolar NPN transistor (Q1). A resistor prevents too much electricity from entering the transistor base pin, which the microcontroller controls.

The LEDs can be turned on completely by the microcontroller outputting 5V on the OC1B pin. That turns on the transistor (Q1) which completes the path back to the battery for the LEDs.

The LEDs can be turned off completely by the microcontroller outputting 0V on the OC1B pin. That turns off the transistor (Q1) which disconnects the path back to the battery for the LEDs. It's as though the battery wire were disconnected from LEDs.

To vary the brightness, the Atmel microcontroller switches the transistor on and off very rapidly. Because the microcontroller switches it so rapidly (four-thousand times a second), you don't notice the blinking. The longer it is turned on versus turned off, the brighter the LEDs. This is called pulse-width modulation (PWM).



Solderless breadboard layout with pulsing blue LED lighting controlled by an Atmel ATTiny45 microcontroller.

The left half of the breadboard looks similar to earlier layouts. The right half of the breadboard is now crammed with other circuitry. The power from the battery now connects the upper right half of the breadboard, because the microcontroller needs to control the power going to the LEDs.

"GND" stands for "ground". GND is the lowest voltage level for the IC chips in a circuit. In this case, GND is the negative terminal of the 9V battery.

### Candle Shutoff

As an added bonus feature, the Atmel AVR microcontroller timer automatically shuts off the LEDs after a certain period of time (presently 5 hours). So, you don't have to worry about draining the battery by accidentally leaving it on all night.

If the battery voltage drops too far (dead battery), the microcontroller shuts off the circuit. This is just like a candle going out.

At shutdown, the total circuit measures less than 22  $\mu\text{A}$  (or 0.022 mA) of current consumption. That means a fresh 9V volt alkaline battery would last:

$540 \text{ mAh} / 0.022 \text{ mA} = 24545 \text{ hours} = 1022 \text{ days}$ .

Of course, the battery won't be fresh when the LED candle turns off. But, the point is that the shutoff mode uses very little power. This may be particularly useful to avoid deeply draining a rechargeable battery.

Lastly, let's see what a nice LED PCB would look like...

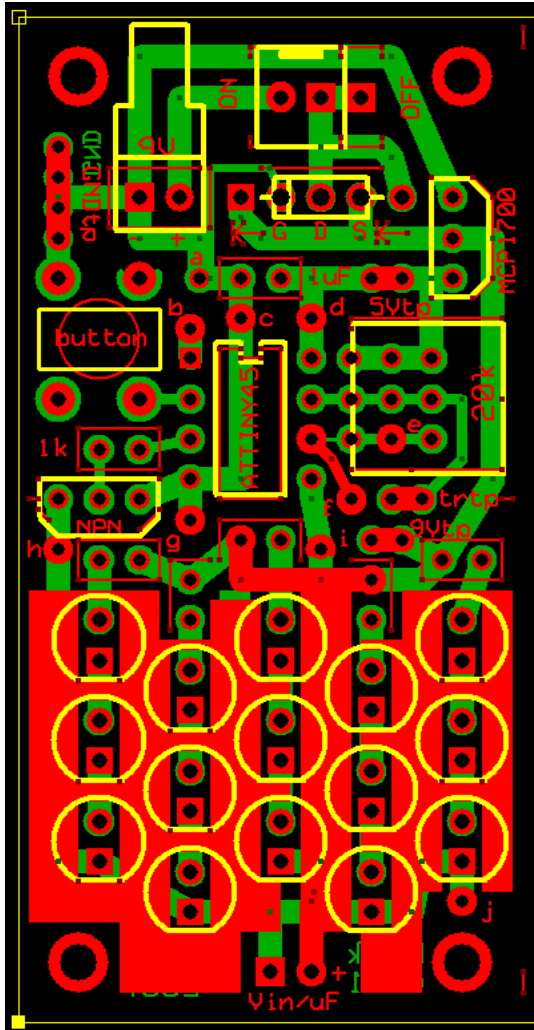
## 7. LED Printed Circuit Board



One of the advantages of LEDs over candles is that the LEDs can be mounted anywhere in the pumpkin. For example, the LED lighting can be mounted underneath the top of the pumpkin, facing down. Try that with a candle!

Not only will overhead lighting provide a unique appearance for the pumpkin, but the individual LEDs will not be visible through the pumpkin's mouth. Furthermore, it will be easier to access the LED light and battery by simply removing the pumpkin's lid.

Although a solderless breadboard could be secured upside down in a pumpkin, the electronic components might fall out into the pumpkin goop. A better solution is to permanently assemble the LEDs onto a printed circuit board (PCB). Another advantage is that an LED PCB can be much more compact than a solderless breadboard.



The prototype PCB was designed in ExpressPCB's free PCB design software.

Each prototype circuit board is only 1.25 inches wide by 2.5 inches long by 0.5 inches thick (with mounted electronics). So, it should fit nicely even in a small pumpkin.

The printed circuit board prototype has a few optional extras that my circuit on the solderless breadboard does not have, such as a power switch and pushbutton.

There are extra holes on the board for test points and for minor rearrangements of the circuit. With a few additional wires, I can program the microcontroller to pulse or flash up to three columns of LEDs.

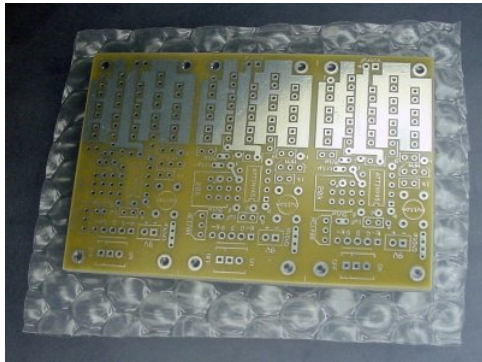
If the microcontroller portion is not needed, the PCB can be cut in half, making it only 1.25 inches square.

The LED PCB has room for 15 LEDs (five columns of three LEDs each). It isn't necessary to populate each LED hole. Columns can be left blank and individual LEDs can be replaced by a bare wire.

Thick copper traces (which appear as large red areas on the image) are placed on the two layers underneath the LEDs to reflect light away from the board and to act as a large heatsink. An LED heatsink helps draw heat away from the LEDs, which may extend the life and brightness of the LEDs.

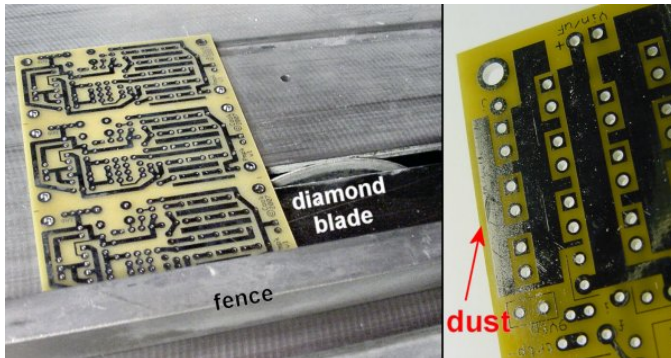
### Circuit Board Prototypes

I ordered the prototype printed circuit boards from ExpressPCB on Thursday morning. The miniboard service requires one day to manufacture and 2 business days of shipping. (The boards arrived one day early.)



Vacuum-sealed bubblewrap PCBs from ExpressPCB.

ExpressPCB seems to have recently changed their bagging. The three PCBs arrived in a nice new vacuum-sealed bubblewrap.



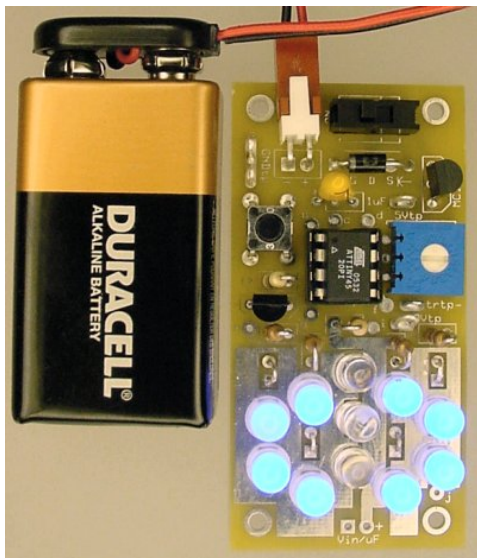
Left: Cutting PCB panels on a table saw with diamond blade, using the fence as a straight-edge guide. Right: PCB dust particles contaminate the board.

I panelized the circuit -- which means there are multiple copies or multiple different circuits per board. I did this because the miniboard service is limited to exactly 2.5 inches tall by 3.8 inches wide. So, I was able to fit three copies of the Pumpkin LED circuit per board.

To separate the PCBs, I used a MicroMark Table Saw (#80463) with a diamond blade (#81524). The saw and blade are pretty good, but they are expensive.

Unfortunately, this method of cutting a PCB leaves a lot of dust. I first vacuum it off with a shop vac. Then, I polish it with a microfiber dust-free lint-free pure cotton cloth. (Nah, actually, I wipe it on my shirt.)

A cleaner, less-expensive choice for separating PCB panels is to use a shear. MicroMark has a Miniature Shear / Brake (#83213) that perhaps I'll get for Christmas.



The completed LED pumpkin candle light with Atmel ATtiny45 microcontroller is slightly larger than a 9V battery.

The performance of the finished board is excellent. Due to voltage limits, only two blue LEDs can be installed per column, so a bare wire fills the spot of the missing third LED in four of the columns. The middle column contains three red LEDs (turned off in the photo) that the microcontroller can blink for a random spooky flash.

When a real pumpkin becomes available, I'll install it in the lid and take a picture. I think the board will be fine, but I may not have left enough room near the switch and battery connector for the screw heads.

## **Conclusion**

It is difficult to beat an ordinary candle on cost, disposability, and shelf-life. However, LED candles open up great decorative possibilities with their variety of colors.

This project should be fairly easy for most technical people to reproduce and experiment with. I encourage you to give it a try. It makes a great introduction to electronics.

Obtained from  
[Omarshauntedtrail.com](http://Omarshauntedtrail.com)