Costuming With RGB LEDs

Introduction

RGB LEDs that can show nearly any color of the rainbow are now widely available in many different form factors that are suitable for use in costumes and props. In addition, methods of powering and programming these LEDs have become far more accessible both technically and in price.

How RGB LEDs Work

An RGB LED actually contains three miniature light emitting diodes - one red, one green, and one blue. These are referred to as "channels". It's by varying the intensity of the channels that these devices can trick our eyes into seeing nearly any color.

One interesting thing about LEDs though, is that they can't actually be dimmed like older light bulbs. With incandescent bulbs, you could reduce the voltage (think of voltage as the speed of the electricity) and the lower the voltage, the less bright the light would be. Instead, LEDs have to fool us by blinking on and off faster that we can perceive. The amount of time an LED is on is referred to as its work cycle. If the work cycle is half on and half off, then the LED appears to be 50% as bright to us!

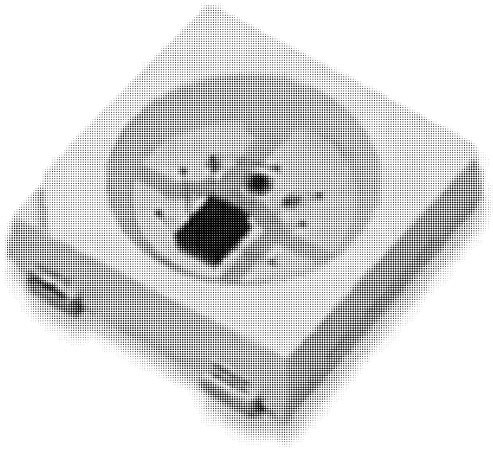
With current RGB LEDs we usually have 256 levels (0-255) of brightness for each channel.

How RGB LED Chips Work

Modern programmable LEDs pair the LEDs themselves with other integrated circuitry to allow the complete chip to show it's own color and communicate with other LED chips. Each channel of the LED has a circuit called a pulse width modulator (PWM). This is the circuit that handles rapidly turning the channel on and off to set the brightness of the color. In addition, there's circuitry to create something called a shift register. This is a circuit that allows the LED chip to receive channel data and pass it along to the next LED chip. This means the LED chips can be connected to each other sort of like electronic LEGO bricks!

Types of RGB LED Chips

While you can purchase discrete RGB LED chips, it's more common to buy them in strips or strands. One important thing to note is which brand of circuit is inside of it. Currently the most common types are WS2811/WS2812 (also known a Neopixel), which are 3-wire (positive, ground, and data) and APA102 (also known as Dotstar), which are 4-wire (positive, ground, data, and clock).



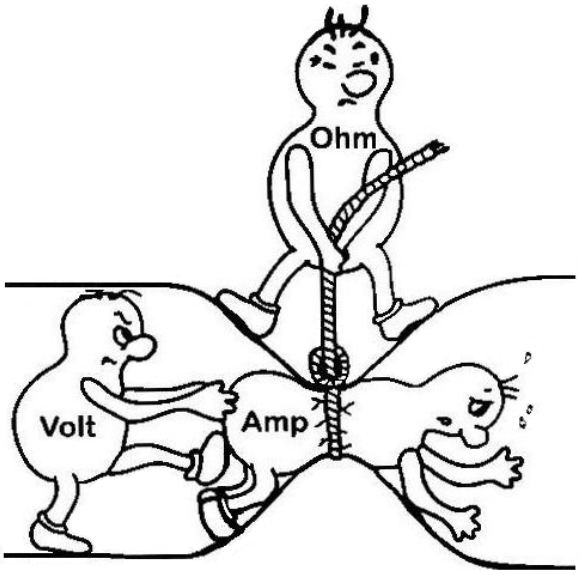
LED chips that do not have a clock wire operate at a fixed rate (usually 800Kbps). This means that the speed with which you can update a strand of these chips is limited by how many LED chips you have in it. In general this isn't much of a problem, except when you're making something that requires very high refresh rates, such as persistence of vision (when you spin LEDs around very quickly to make it seem like a solid screen). LED chips that have a clock wire can update at variable speeds, both much slower and much faster than the 3-wire LED chips.

The LED chips themselves are generally 5.0mm x 5.4mm x 1.57mm, however there are smaller ones available that are 2.0mm x 2.0mm x 0.84mm. These chips can then be packaged in many different ways ranging

from flexible strips and strands to grids or even discrete bulbs. The format and density of programmable RGB LEDs is constantly evolving. Just recently a new type became available that consists of diffused "pebbles" on a strand that are visible from all angles.

The method of packaging LEDs will both affect how the LEDs look and how rugged they are. LEDs meant for outdoor use may come with an "IP67" rating. The 6 means the LEDs are fully protected from dust and the 7 means they are protected against temporary immersion in water. Lower numbers indicate lower levels of environmental protection.

Powering RGB LEDs



Current Draw

Because RGB LEDs vary in color, they also vary in the amount of electrical current (milliamps) that they take. You can base the amount of power your piece will need on a few simple calculations.

Most RGB LED chips, when showing fully bright white (so red, green, and blue are all fully on) will use at most 50 milliamps (mA) of current (the amount of electrical flow). That said, particularly for costumes, it's rare that you'll want to use fully bright LEDs. It's common to max out at 50% or even just 25% brightness.

So, if you have a costume that has 40 RGB LEDs on it and you're going to limit it to 50% brightness, you can safely assume (based on 50mA max) that each LED would draw at most 25mA (50% of 50mA) and thus the whole piece could draw 1000mA (40 x 25mA) of current at most. To further limit that, animations will reduce that amount significantly. This is just a general rule of thumb, and nothing beats connecting your LEDs up to a multimeter and looking at the real world current draw.

Battery Life

Knowing the max current draw of your piece will help you better estimate how long your battery will last. The capacity of batteries is given in milliamp hours (mAh) - a 5000mAh battery could power a project that draws at most 1000mA for at least 5 hours. Again, it's best to test this using your actual animations before you take your piece out into the world. Depending on how you're using your LEDs, it's not uncommon to double your worse-case lifespan.

Batteries

While it's technically possible to use disposable AA or AAA batteries, the current best option are rechargeable USB battery banks. They are cheap (You can get 5000mAH batteries for $10 or less) while also providing the 5 volts used by most RGB LED chips. You can even find cables that convert USB to standard power barrel plugs.

Wiring

Each element in an electrical circuit will slightly slow down the current. This is referred to as voltage drop. If you have too many RGB LED chips in a row the resulting voltage drop can result in distorted colors. The avoid this, a general rule is to inject power (connect directly from the battery to the LEDs) every 60 LEDs.

Controlling RGB LED Chips

WLED

An open-source project called WLED has become wildly popular recently and it's not

surprising why - this software runs on a very inexpensive ESP32 microcontroller and gives the end user a powerful ways of controlling RGB LED chips with IR remotes, smart phones, and home automation systems. A few companies are now making controllers based on packaging an ESP32 with WLED and adding connectors and additional features such as sound reactivity. These controllers range from $25-$50 and are very easy to use.

Microcontrollers (Arduinos, etc.)

If you want full control over your LEDs, you can always jump in and start programming them yourselves using microcontrollers. The most common library for controlling RGB LED chips with Arduino microcontrollers is called FastLED. It's easy to use, powerful, and provides support for all of the most common types of RGB LED chips.

If you use a microcontroller you have ultimate flexibility in how you use your LEDs. You can use sensors and buttons to make your piece interactive and you can even wirelessly network multiple pieces together to coordinate their animations and interactivity.

One thing to note is that you shouldn't pull power for the LEDs through the Arduino. Arduinos often provide 5v pins, but these are usually limited to a very small amount of current. Instead, LEDs should be directly connected to your battery.

Diffusing LEDs

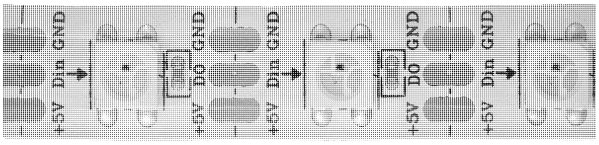
Some packaged LEDs come with built-in diffuser material. Such strips, sometimes referred to as "flexible neon", make it so that you don't really see each discrete LED - just a continuously strip of plastic with gradients of color. You can also diffuse LEDs yourself with fabrics, paper, plastic, or glass. There are diffusers and lenses available that can snap or glue directly on to LED chips.

Some diffusion materials may tint the color of the LEDs. PVC pipe, for example, diffuses LEDs well but tints the light yellow. Some LED controllers allow you to adjust the white balance of the LEDs to minimize this effect.

Attaching LEDs

While LED strips and strands are flexible, it's best to limit both the angle and amount of flexing in order to extend your LEDs lifespan. If you have to cross a major joint of the body such as the elbows or knees, it's best to do that with some stranded wire rather than with the LEDs themselves.

LED Strips



The components of an LED strip are surface-mount soldered to a flexible printed circuit board (PCB). If you bend the strip at too sharp of an angle it can break the solder joints and since each LED is fed from it's neighbor, a break like this will make ever LED after it stop working as well. This kind of break can also happen if you twist a strip, so be sure to keep them flat.

LED strips can generally be cut at fixed locations on the strip and these locations are usually noted on the PCB. Segments of strips can be soldered back together or connected to each other with stranded wire.

Because washing LEDs with water will usually break them, it's advised to attach LEDs to costumes in ways that allow them to be detached later when the costume needs to be cleaned. Snaps or velcro can be glued to LED strips to then attach them to clothing. Another technique is to sew fabric channels into costumes that LED strips can then be threaded through.

If the LED strip is for a prop or other item where washing isn't a concern, gel-type super glue, hot glue, and strong double-sided mounting tape all work well for attaching LED strips.

Segments should be connected to each other and to the power/control circuitry using removable connectors such as 3 or 4-pin inline JST connectors. This helps make your

piece more modular so if a strip goes bad you can have a backup ready to go and install it without any soldering.

LED Strands

LED strands usually consist of discrete LED bulbs with a built-in diffuser that are then connected with stranded wire. To make these strands last as long as possible it's best to avoid excessive strain on the connections between the LEDs and the wire. If possible, mount each LED bulb so that it's fixed in place. If this isn't possible, work to add other methods of strain relief including connectors so that even if your piece breaks, it's modular enough to allow for easy field repairs.

Strands can usually be cut at any point, which is useful for adjusting the amount of slack between bulbs.

Discrete LEDs

If you have individual LED chips by themselves or on breakout boards, these can be attached much like LED strips - glue, mounting tape, velcro, or snaps all work. The hard part about discrete LEDs are their fragility. If you decide to go this route it's advised that you make the piece as modular as possible to allow for easier repairs.

Conclusion

RGB LEDs provide a costume artist with a wide variety of ways for making their pieces glow and animate. RGB LEDs have become increasingly accessible both in price and in the amount of technical knowledge needed to utilize them.

Additional Resources

Adafruit NeoPixel Überguide
https://learn.adafruit.com/adafruit-neopixel-uberguide/the-magic-of-neopixels

WLED
https://kno.wled.ge/

Athom WLED Sound Reactive Controller
https://www.athom.tech/blank-1/wled-esp32-music-addressable-led-strip-controller

FastLED
https://fastled.io/