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Using UV LED Spotlights

Using UV LED Spotlights in the Haunt Industry by Michael and Steve Gemeny, Producers/Engineers, GoatMan Hollow

One lighting effect that has been missing from the spooky lighting guy's bag of tricks is a "dimmable" UV (ultra violet) or black light source. Standard black lights, for the most part, are fluorescent tubes which flicker uncontrollably when first turned on. The incandescent version of these, available at the local party stores, are little more than purple lamp bulbs, and don't produce enough ultra-violet for most applications. New technologies in UV reflective paints that can be invisible in white light and create full color artwork in black light have created a need for a black light that can fade from full brightness to completely off or vise versa. But this fixture has been almost as elusive as that 13 floor haunted house, (the one that you get your money back if you make it out). For years, Haunted Attractions including the Disney Haunted Mansion have achieved changing portraits by washing the painting with a white or colored incandescent light that over powers a UV light which is continuously illuminated. To transform the portrait, the white light is dimmed until only the UV shows. This same technique is also used for some Pepper's Ghost Transformations, but there is a new solution, which gives much more flexibility as an option.

In the summer of 2002 the crew of GoatMan Hollow™, in suburban Washington, D. C., decided to introduce a gallery of changing portraits for the coming season. The scene was to be the portrait gallery in Dr. Fletcher's mansion and the Art Department selected creepy second hand framed prints and over-painted them with invisible black light paints. As the set was being dressed out, the gallery was turned over to Lighting and Electric to finish, but attempt after attempt to pull off this age-old effect failed to live up to expectations. Once the season was over, the Engineering Department began pondering a better solution.

They discovered that LED technology (light emitting diode) was moving well past violet light and into the ultra violet wave lengths. After extensive research into this new technology a source in China was located and a hundred samples were ordered at just twenty-five cents each. Where did we find such an international contact? EBAY! (The EBAY curse; "May you find EVERYTHING you are looking for!")

Engineering knew from the outset that the effect would need numerous LED's in a safe package that would fit a fixture compatible with off-the-shelf dimmers. An initial design involving a stack of 14 LEDs served as a successful proof of the concept. Lighting and Electric had already standardized, on a 35 watt halogen "Clamp-light." These fixtures are UL listed "for use in damp locations," will accommodate theatrical jells, and best of all, over 50 of them were already in the GoatMan Hollow™ inventory. A rather aggressive goal of a dozen fixtures was set, so an additional 500 LEDs were ordered from China.

The first completed unit used two sets of 14 LEDs and made its debut in the GoatMan Hollow™ booth at the Horrorfind Weekend in August of 2003. The booth display used an off-the-shelf cross fader sometimes referred to as a "Rocker" and a matching fixture lamped with halogen bulb jelled in deep red. To the human eye a deep red and a deep violet appear close to one another, (as seen on a color wheel), but the reality of the spectrum is that violet is at one end of visible light and gives way to the invisible ultra-violet, while red is at the opposite end of visible light and gives way to the invisible infrared. By cross fading between these two extremes, the human eye sees little difference in the visible hue, while the visibility and invisibility of the black light paints are maximized.

With the concept proven, the design was adjusted. The remaining fixtures would be built with two stacks of 25 LEDs, and the zener diode was eliminated. With these changes the value of the current limiting resistors were also recalculated. In the haunt it was found that a single red halogen fixture could wash across a pair of portraits, while each portrait would require its own black light spot. The overall effect in the gallery was stunning. Cast members stationed in or near the gallery reported comment after comment from guests in the gallery such as "These paintings are off-the-hook!"

Since this first use, GoatMan Hollow™ has experimented with dimmable black lights for Pepper's Ghost Illusions and with UV makeup effects. The fixtures have been used with actor controlled wireless X10 dimmers, and rocking cross faders, indoors and outdoors with great success. One of them even found its way into a Science Fair project that was lit at full power for over three months. With over two years of experience not a single fixture has failed.

The design is presented here as a prototype with a successful track record in the hope that others will improve upon it. A successful product based on these prototypes should include potting for better insulation. The fixtures should be UL listed, always be grounded, and used on circuits which are protected by Ground Fault Interrupters (GFIs).

Theory of Operation

This article will present the construction of the Ultraviolet LED lamp that was used. The intent of this article is that others in the industry will advance this development and adapt it to their own particular needs.

Note: The authors assume no responsiblity for any damages resulting from the construction or use of this project. Different manufactures of LEDs will have different specifications, which will affect this design and the values of R1 & R2.

The Dimmable Blacklight is built up as an array of Ultraviolet LEDs powered by an unregulated power supply being driven by the 120 Volt AC wall current. Since the brightness of the LEDs are determined by the current flowing through them, dimming can then be accomplished using any of the standard industry dimming devices. The current flowing through the string of LEDs must never exceed the manufactures recommendation for a single LED. The number of LEDs in the string determines the voltage drop required across the resistor based on the voltage drop across each LED (also specified by the manufacturer) times the number of LEDs in the string. The total current through each string of LEDs is adjusted by R1 and R2 so as to not exceed this limit and is calculated using Ohm's Law and the total peak supply voltage. The value of R1 and R2 can be calculated using the following equation:

$$R = \frac{(Vp) - (N * VLED)}{ILED}$$

Where:
R = Resistance in Ohms (?)
Vp = 1.414*AC Voltage
N = Number of LEDs
VLED = Voltage per LED
ILED = Max LED current

For this project the LEDs were purchased in bulk off of E-Bay. The manufacturer's specifications called for a maximum forward current of 30 mA with a forward voltage per LED of 3.5 volts. After selecting a suitable fixture to house the circuitry we felt we could accommodate two strings of 25 LEDs. Thus the equation for our design becomes:

R = (1.414*120) - (25 * 3.5) / .03
R = (170 - 87) / .03
R = 83 / .03 = 2766

Another consideration in any electrical design is safety. Selecting a resistor of the proper wattage is essential in the design; otherwise the heat associated with limiting the current flow could cause the resistor to burn. The power being dissipated in the resistor can is determined by the voltage across it and the current through it and can be calculated as follows:

Power = Voltage * Current

In this case, preferring to add extra safety margin, it is assumed that the worst possible case would occur if the LEDs were all shorted thus placing the entire 120 Volts AC across the resistor. The necessary wattage for the resistor in this case is 3.6 Watts, which required using a 5-Watt, 2700-Ohm resistor (the next standard size).

Construction

First needed is to select a housing for the LED lamp. The flexibility, size and the UL rating of a small work light found at The Home Depot seems best for this purpose. It comes with a 35 Watt halogen bulb clamp light Model # L-855 made by Designers Edge (www.designersedge.com). This lamp is shown in Figure 1.

The size of the lamp dictates the shape of the circuit board that will house the LEDs. Based on the schematic shown in Figure 2, several hand wired prototypes were produced. This initial "pre-production" run would be used to test the concept.

Soldering any solid-state device into a printed circuit card can be a tedious process. Attention to detail is a must since soldering 50 LEDs is not something anyone wants to do over again, and if any one of them is installed backwards none of the LEDs will light. Each LED is made with a lip around the base of the plastic case. Along the edge of the lip, on one side there is a flat spot. All of the LEDs must be aligned with the flat spot facing the same "electrical" direction.

The first LED lamp assemblies were cut circles from perforated prototype material available at Radio Shack. Three circles of different diameters were needed to fit inside the enclosure at different depths. The largest board holds the LEDs, which were all hand wired according to the schematic in Figure 2. The second board was mounted 3/4 inch behind the front board. This board holds two resistors and a Bridge Rectifier as shown in Figure 3 along with one end of two 1/32 inch brass rods that align with the connector in the lamp housing. The third board is used only to provide support for the brass rods as they entered the connector in the lamp housing. Figure 4 provides a clearer, side view drawing of the assembly. Figure 5 shows the LED placement on the front board for producing more even illumination.

Results

With 50 LEDs each producing 1,000 milli-candles of UV light, the total light output of the lamp is about 50 candles. Experience has shown that this is about one third of the output a of a 35-watt incandescent bulb but in the Ultraviolet part of the spectrum.

In practical use, one lamp provides about enough UV to illuminate a "UV Active" scene about 8-feet square from 10 feet away. This may seem like a small area, but the real advantage is two fold. First, unlike a florescent tube light, they are more of a spot light with a fairly tight focused beam of UV. The second advantage to these lights is that they

can be dimmed while a florescent black light cannot. This enables many effects using programmable dimmers like X-10 and various "rockers" that simply are not possible with florescent black lights.

About the Authors:

Mike Gemeny is a Founding member and Producer of GoatMan Hollow™, a truly innovative walk through haunt, featuring stylized theatrical lighting and sound, layered over an actor driven, interactive story line, lending depth to terror. Mike is an Engineer by trade, and is a Lead Engineer at GoatMan Hollow™, and is ultimately responsible for the quality of the lighting and technical effects. You can contact him at MGemeny@pgcps.org, but be warned, he's a super nice guy, and may talk your ear off.

Steve Gemeny has been associated with GoatMan Hollow™ since before the first opening. Over the years he has designed and built numerous electrical and "magical" effects, produced scenes, acted and cleared hundreds of feet of trails. Steve is a key member of the Engineering, Lighting, Sound, and Grounds crews at GoatMan Hollow™. Professionally, Steve is an Electrical Engineer working for the Space Department of the Johns Hopkins Applied Physics Laboratory in Laurel, MD. He is a licensed Amateur Radio operator and can be reached via E-mail at: AA3NM@ARRL.NET.