Adjustable Focus, Intensity, and Gradient Light for Commercial Photography

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1 Introduction

1.1 Objective

Lighting is a crucial part of photography, and is one that despite the advances in technology has barely expanded past the dumb bulb phase of development. Photographers have to use custom-made filters for individual photoshoots, and change out the filters depending on the effect desired. Rick Kessinger studio would like a photography light that can be adjustable based on specific photoshoot requirements.

Our proposed solution is to create a programmable light array which can control three criteria, Intensity, how bright the overall light is, Focus, the location of the brightest spot of the light, and Gradient, the gradient of light from bright to dark. Each of these criteria will be controlled by an external knob which regulates the light settings independent of each other. These control inputs will then be routed to an array of LED lights which will adjust their values depending on user input. The entire design will be portable and include a battery system that is internally chargeable.

1.2 Background

Because of the niche use of a controllable LED bar light, a retail product does not exist. Despite that, this product would allow unprecedented freedom for a photographer. According to commercial photographer, a controllable light would allow “painting with light.” Unfortunately because the lack of an existing solution, Mr. Kessinger is forced to create a makeshift gradient out of diffusion paper and then tape it onto an LED light bar. This solution is clumsy and very restrictive as it forces the user to make a new filter every time a different gradient is needed. Additionally, because the LED bar is not purpose built for a photographer, it has the disadvantage of being powered by a wall plugin. This is difficult for a photographer as at times, the only light on in the photography studio is the LED light bar.

With our solution, the photographer will be mobile and in full control of the lighting for a photoshoot. This control would allow for fast adjustment and turnaround between different angles or different photoshoot and the ability to fully create the artist’s vision.

1.3 High-Level Requirements

- The brightness of all the LEDs must range from totally off to a brightness level suitable for photography depending on the focus and intensity setting.
- Must be able to adjust the gradient of light from bright to dark across the entire lightbar

- Must be man portable, and same intensity as non-adjustable lighting fixture that they currently use.

2. Design

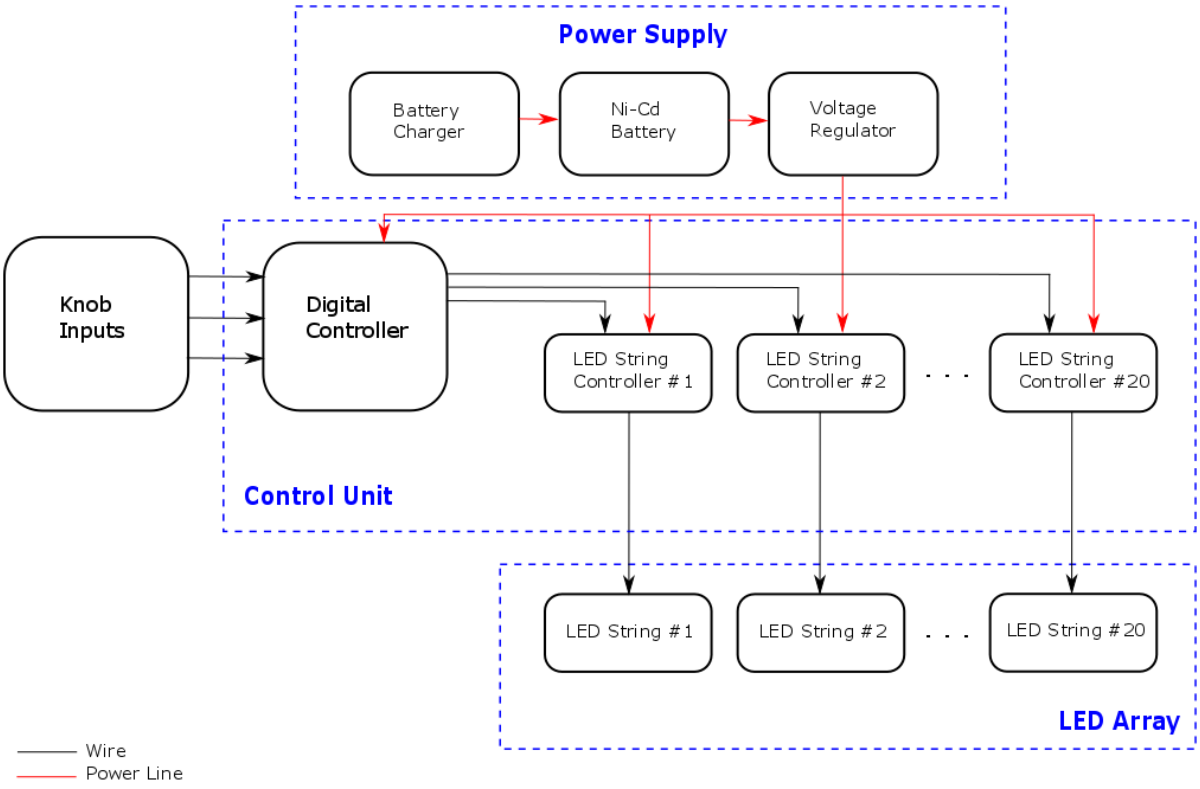

Figure 1: System Block Diagram

2.1 User Inputs

The user input will consist of three knobs. The first knob will control the focus of the light which is where the center of the light gradient is. The second will control the gradient of the light which describes how wide or thin the gradient is across the bar. The third knob controls the intensity of the light which describes the maximum brightness across the light bar. All three knobs will have 16 settings that the knobs will click into to set the user values for our controller.

Requirement: Each input knob will constantly send a 4-bit digital signal to our controller describing its current setting.

2.2 Power Supply

A power supply is desired in order to keep the light bar portable. To make the light mobile, it will have a built in rechargeable battery pack. Ideally, the battery pack will be able to keep the light on for the length of a photoshoot but for longer shoots, the light will also be able be powered from a wall outlet. Output voltage will be regulated to 5V for the rest of the system.

2.2.1 Nickel-Cadmium Battery

The nickel-cadmium battery must be able to keep the lightbar continuously powered at maximum intensity for the length of an average photoshoot.

Requirement: The battery must store enough energy to provide 20 minutes of power to the light continuously at a voltage between 6V-9.9V. Protection circuitry will ensure that the individual Nickel-Cadmium cell voltage must not drop below 1V and the current must not exceed 1.4A

2.2.2 Nickel-Cadmium Battery Charger

The charger will be integrated into the light and will charge the battery through a charging IC while the light is plugged in. The battery charger will also include overcurrent and undervoltage protection to protect the batteries from damage.

Requirement: Charger must charge the battery fully in 16 hours from a standard US wall outlet and stay below 45°C and above -20°C[1].

2.2.3 Voltage regulator

This DC/DC converter module steps down the battery voltage (*6V-9.9V*) to the 5V suitable for the rest of the system.

Requirement 1: Must provide 5.0V ± 5% from a 6V-9.9V source
Requirement 2: Must remain below 45°C for a peak current draw of 2A

2.3 LED Array

The LED Array will consist of 20 LEDs with three different branches for color control. Each individual LED will be controlled externally by the LED string controller.

Requirement: Each LED must at maximum be outputting at maximum 100 lumens at 3.6V, and 15 lumens at 2.6V.

2.4 Control Circuitry

2.4.1 Digital Controller

The Digital Controller will take the 16-level inputs from the user knobs and translate these into 20 outputs for each LED. This controller will be entirely digital consisting of ICs routed onto a PCB.

Requirements: Operate at 3.3-5V and consume less than 10% of the LED Circuitry

2.4.2 LED String Controller

The LED String controller consists of MOSFET controlled resistor regulated circuit that will take the digital output from the controller and switch on certain resistors which will regulate the current that is traveling through the LED.

Requirement 1: Must control the LED Intensity to 16 levels. Each Intensity setting must be distinguishable from each other (±6.25% Intensity or less).

Requirement 2: Must consume less than 10% power of the LED strip.

2.5 Housing

The housing block will consist of a black external casing with a detachable battery slot. In addition to smooth the LED output, diffusion glass will be installed.

2.6 Risk Analysis

The largest risk to the completion of our project is in the LED string controllers. In order for our product to be functional, our light must put out a smooth, constant gradient. This means that lighting within a strip needs to be relatively consistent and intensity control across the gradient must be precise. Controlling brightness precisely entails controlling the current through each branch precisely.

If we don't have enough precision we will end up with a choppy unappealing gradient or a light with brightness hotspots. The biggest challenge to making a tightly controlled current is doing so without excessive power consumption or cost. With an unlimited budget and power supply we could easily create a controller that delivers multiple precise brightness levels. Our challenge is designing a low power, low cost circuit that can still deliver the necessary precision.

The string controller must be able to output 16 different levels of current so that the brightness of the LED strip cannot overlap with an adjacent LED strip. This implies that the precision of the controller must be at least 6.25% accurate otherwise the LED brightness levels will be indistinguishable from one another.

3. Safety and Ethics

There are several safety concerns with regards to a portable lighting fixture. nickel-cadmium batteries can fail catastrophically in three ways, either temperature failure, undercharge failure, or overcharge failure[1]. To compensate for temperature failure, the battery will have a thermistor which will isolate the battery from the charger and circuitry. Furthermore, a voltage and current regulating circuit will control the charging output to prevent overcharge which can lead to a thermal reaction. An undercharge protection circuit will also have to be implemented to prevent undercharge and the destruction of the battery.

In addition, as an electronic device that could operating in limited outside conditions, the outside casing must be built to IP 53 specifications to prevent accidental shorting of the internal circuit. Additionally, while LED lights do not produce a significant amount of heat, the fixture must be kept at under 40℃.

Citations

[1] M. Power Systems, "Nickel Cadmium Batteries Handling Precautions," in *Tayloredge*, 2003. [Online]. Available: http://www.tayloredge.com/reference/Batteries/Ni-Cd_Precautions.pdf. Accessed: Feb. 7, 2017.

[2] P. Horowitz and W. Hill, *The Art of Electronics*, 3rd ed. New York [New York]: Cambridge University Press, 2015.

[3] P. Krein, *Elements of power electronics*, 2nd ed. New York: Oxford University Press, 1998.