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5/10/19

Wearable Tech Device for the Administration of Light Emitting Diode Therapy: Final E90 Report

Abstract

A custom-made wearable electronics jacket prototype was assembled that incorporated an interconnected array of LEDs to administer therapeutic effects for individuals who could not have access to a traditional clinic to receive the benefits of therapy. The design of the jacket was based off the first law of photochemistry which states that light has to be absorbed by a chemical substance in order for a photochemical reaction to occur. Chromophores which are light-absorbing proteins enable this process by driving the synthesis of ATP which in turn helps the body create the necessary proteins that assist in cellular rejuvenation needed to heal the body. A 5x5 LED array was made using a PCB flex board and a 10 V battery. The project was successful but had some slight setbacks such as connectivity issues and battery weight that need to be addressed in future iterations of the project.

Objective

Create a custom-made wearable electronics jacket prototype that incorporated an interconnected array of LEDS to administer therapeutic effects for individuals on the go.

Theoretical Background

Phototherapy using lasers along with other light sources has been used in medicine for different treatments. Since the 1960s, low-level lasers (up to 500 mW) have provided a noninvasive, yet successful approach to accelerate tissue healing and manage inflammatory processes and pain.

This process known as photobiomodulation in the form of low-level light therapy and light-emitting diode therapy has been applied over human skeletal muscles before and after bouts of exercise in order to 1) protect against muscle damage induced by exercise, 2) improve athletic performance, like increasing fatigue resistance and muscle strength, and 3) accelerate muscle recovery.

These effects are valuable in rehabilitation processes that involve exercise programs to recover from muscle lesions and can mitigate the adverse effects of orthopedic surgical procedures, such as muscle weakness and atrophy, and accelerate the return to athletic sports or functional activity.

The biological principles that enable these phenomena to occur can be explained as follows: Light absorption by chromophores in the cells, with cytochrome c oxidase (Cox) as the main-light absorbing protein. The Cox enzyme, triggers a variety of secondary effects after light absorption among which are modulations in DNA/RNA synthesis rates and increases in the adenosine triphosphate (ATP) synthesis. These affect gene expression as it relates to several cellular pathways such as mitosis, inflammation, and mitochondrial energy metabolism as well as cell proliferation.

In particular, cytochrome c oxidase plays a key role in the electron transport chain which is primarily responsible for the creation of ATP. When ATP is formed, cells use the converted energy to build new proteins, such as collagen and elastin, which in turn assist with cellular regeneration. As a result, LED therapy has bed used to treat a variety of musculoskeletal disorders including carpal tunnel syndrome, fibromyalgia, osteoarthritis, and wound healing.

Constraints

The primary constraints that I was dealing with throughout the course of this project were: power source and safety.

The two primary sources for photobiomodulation would have come from either a laser or an LED. While using a laser certainly would have been more effective, due to the high intensity of light directed at a singular area, it would have been more dangerous to the user. This is because of a laser's collimated nature, so if it was fixated on an athlete's skin for an extended period of time there would have been the risk of burning the skin (not to mention the risk of possible eye injury), so I opted for the LED.

For the power source, I was deciding on whether to use an outlet or a battery. Since this project was designed for athletes in mind, I wanted my design to be portable so that they could wear the jacket before and after workouts. In terms of practicality, I needed to limit the power that was used by the LEDs, so I chose a 2200mAh battery that would be able to keep the LEDs on for an extended period of time.

Data

Current (in mA)	Output Power (in mW)	Voltage (in V)	Input Power (in mW)
10	69.9	1.74	17.4
20	146	1.79	34.7
30	217	1.84	55.2
40	283	1.87	75.0
50	343	1.90	95.0

This data shown above is a sample of the average of three trials I had for each type of LED that was available in the lab. Using a variable current source I started from 10 mA and increased it in increments of ten all the way up to 50 mA. From there I measured the corresponding voltage I got for that LED. Then I found respective input power levels by taking the product of the current and the voltage that I got from every measurement. Lastly, output power was determined using a power meter that I had set up in lab. Output power simply refers to the brightness of the LED. In the end, I decided to go with the P406-NO LED (transparent red) since I obtained the highest levels of output power using that type of LED. The data shown above is the averages of the P406-NO LED.

Design Process

After I finished my systematic analysis of choosing the best LED which including measuring and observing current, voltage, input and output power levels I worked on customizing the battery that I would be implementing.

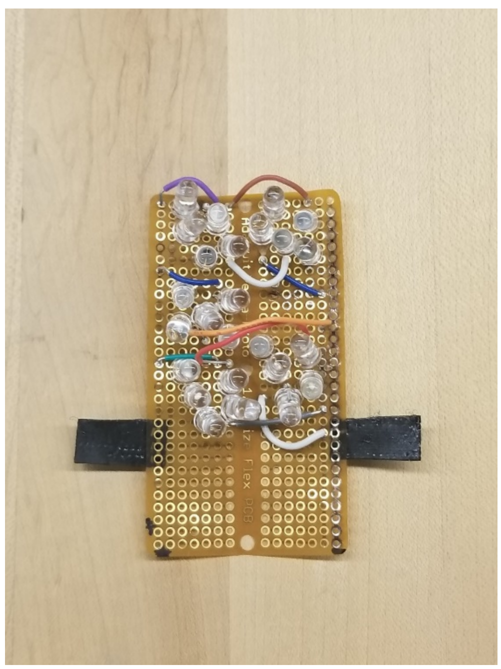
With the 10V battery I:

1) Modified it in order to integrate it with the jacket by cutting the ground and Vcc wires.

2) Added a removable port to extend the ground and Vcc wires.

3) Crimped the wires together so that they could fit through the flexboard.

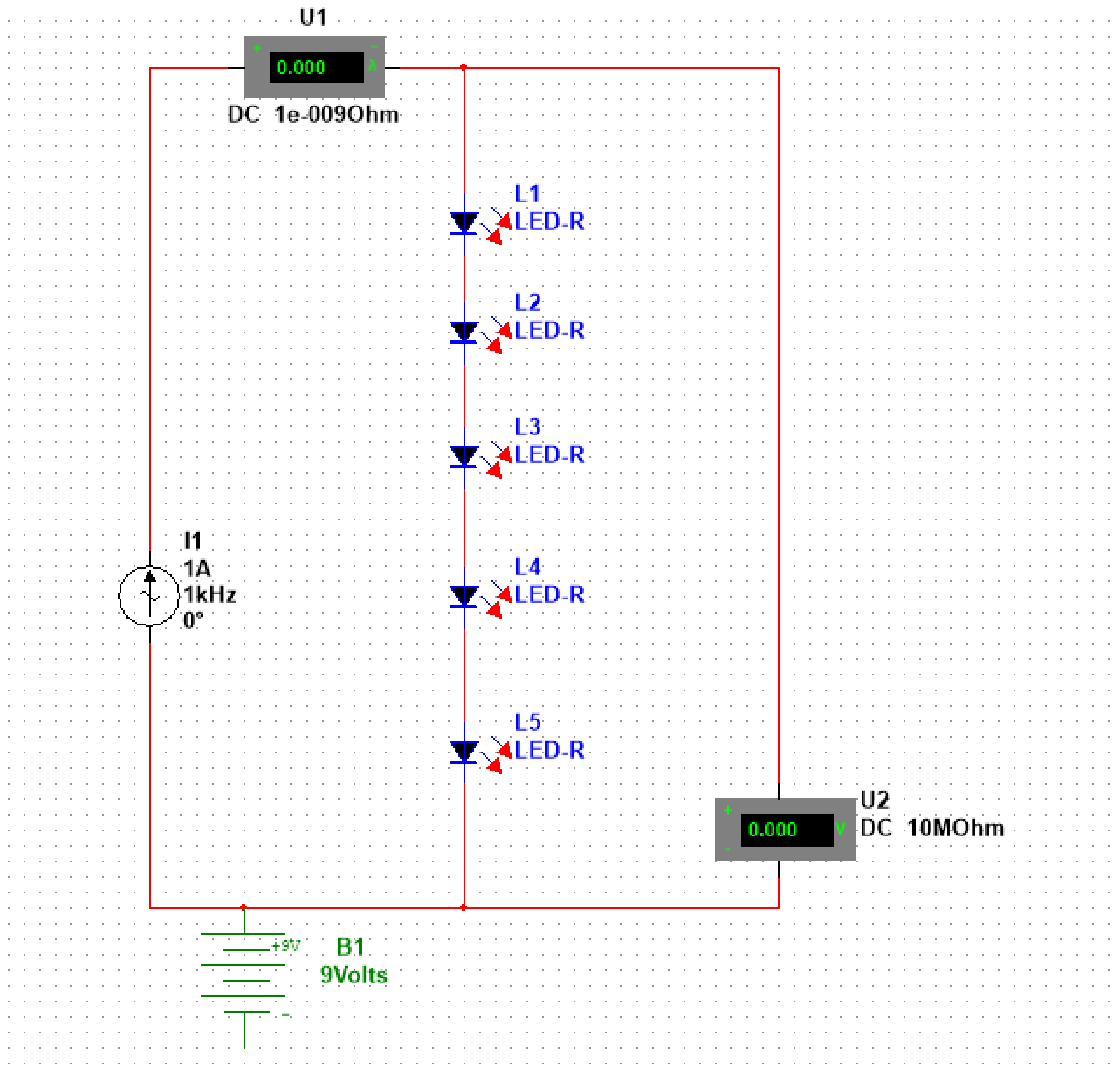
On the left is a picture of the 10V battery as I initially received it and on the right is the final modification of the battery that I actually used for my wearable tech device.



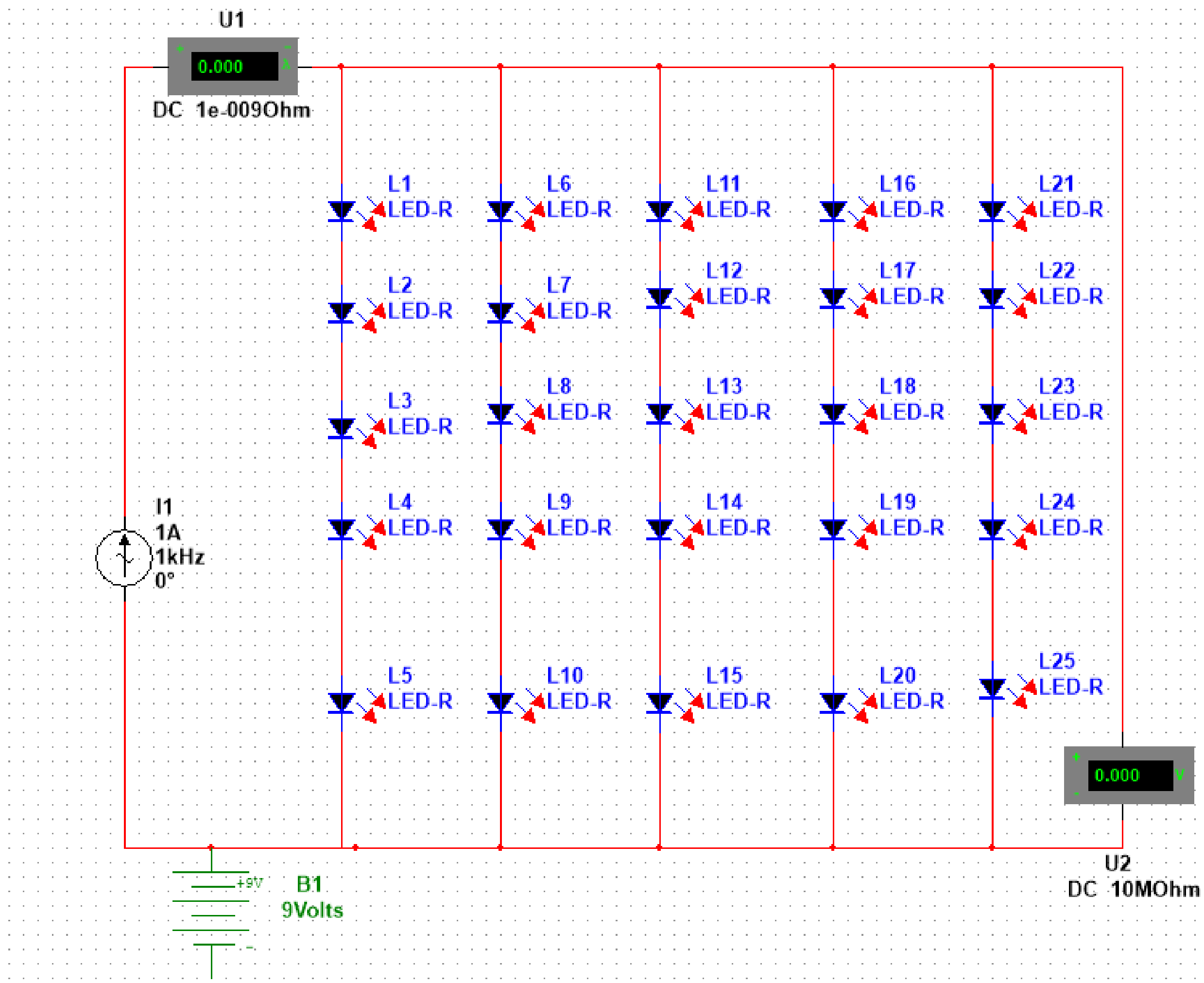
The last picture is the completed 5x5 LED array that I used for the wearable tech device. I had to hand solder each of the individual LEDs, ensuring that the voltage would go through the positive terminal then the negative terminal of the first LED then repeating the pattern of positive to negative for that subsequent array. I then used a series of wires to ensure that all five arrays would be connected to each other so that by making one column a positive bus and the opposite column a negative bus that I would be able to light all 25 LEDs concurrently.

LED Array Configuration

Before scaling up, to test the concept's feasibility I created a circuit with five LEDs in series in order to better analyze them.



After verifying that my concept would work, I proceeded to assemble more LEDS in series. Below is a schematic of what I'm planning on having by the end of the semester.



<u>Results</u>

In the first schematic shown, I adjusted the current to its highest capacity before all five LEDS shut off. As such, I found my maximum values to be:

Current: 44 mA
Voltage: 9.18 V

Total input power was found from the product of the current and the voltage which was:

(9.18 V) x (0.044 A) = 0.404 W

It is important to note that at 44 mA the LEDs shut off at that point because that was the maximum amount of power that the current source I was using in the lab could provide. At that point, I couldn't turn it up any further since there's an automatic safety switch built into the current source that turns it off once it reaches its maximum amount of power. I could have gotten a higher current reading if I used fewer LEDs or used a stronger current source. Regardless, my design was based off the data that I collected in the lab. In particular, this value that I calculated in obtaining the total input power was used in charactering the implementation of the battery. Since I measured 9.18V at 44mA, each LED had a voltage drop of about 1.836V. This approximates a 2V drop across each LED which was why I choose to use a 10 V battery in my design.

Future Work

While my prototype does indeed work, it is not at the point where I want it to be due to some re-emerging problems in the flex board.

One area that I need to address in future iterations of this design would be to reduce the weight of the battery. Initially I restricted the weight of the battery in order to make it less bulky for the individual. However, as I was testing my design throughout the semester the weight of the battery itself pulls the jacket down which in turn pulls the LED array down. If I want to see a viable product in the future I have to find a way to lower the weight while still ensuring that each LED receives enough voltage from the battery to properly light up.

Another area that I need to address in the future would be the type of PCB bread board used in the wearable tech device. I used a PCB flex proto board in order to keep up with the natural twists and turns that accompany human torso flexion. However, I kept running into repeated problems lighting up all the LEDs concurrently since the PCB flex board doesn't ensure full connectivity across the rows and columns. I found that the flex board has to be bent in a certain angle in order for the entire array to work properly, but this isn't ideal since it would force someone to unnaturally twist their body in order to receive the benefits of LED therapy. Next time, I'll try to use a rigid PCB circuit board as well as conducting tape to ensure that connectivity across all the rows and columns remains intact.

Acknowledgements

I want to thank Professor Lynne Molter and Edmond Jaoudi for their patience, guidance, and cooperation throughout the entire process. I also would like to thank Cassy Burnett for helping me obtain the necessary supplies that made my project possible in the first place.

References

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