Preventing, Anticipating and Mitigating Off-Task Behavior in Special Needs Students

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***Abstract* — One of the difficulties presented to caregivers or teachers of young children with special needs – children with Autism Spectrum Disorder (ASD) or Emotional Behavior Disorder (EBD – is that they have trouble transitioning from on subject/activity to another. This leads to disruptions that are not related to the curriculum, and thus waste class time that is scheduled for curriculum. This paper describes a device that prepares the child for the transition using a circumferential LED timer. In addition, this timer rests on a circuit designed to anticipate disruption and another interactive device to mitigate the disruption leaving the teacher to continue with the scheduled curriculum.**

***Index Terms* — Operational amplifier, thin-film, LED, Bluetooth, asynchronous communication, master/slave, printed circuit board (PCB), microprocessor.**

I. Introduction

This project attempts to address this issue specifically while providing a means for identifying other possible behavioral interruptions through a low-cost, easy-to-use, unobtrusive system. This will be done by developing a wearable sensor worn by the child that will (1) visually indicate when transitions are approaching, and (2) notify the teacher BEFORE the onset of a behavioral issue that may interrupt the daily curriculum. In addition, a method will be provided to allow the student to calm down. This is a needed practice, especially for ASD students due to a greater need for predictability [1], challenges in understanding what activity will be coming next [2], or difficulty when a pattern or activity is disrupted [3]. Admittedly, it takes time to calm, or decompress, but autistic children need a cooldown to reset any sensory overloads.

The idea is to use a sensor tuned to autonomic response markers. All humans have evolved with a "fight or flight" response. Certain changes occur when this is activated, regardless of the person. The sensor will alert the teacher when it senses certain markers and the teacher may be able to intervene even before the child knows what is going on. Attached to the sensor, visible to the child, will be a timer to let them know when a transition is about to occur. This is also a practice in classes with special needs children, though not through this conveyance; usually the teacher announces time remaining, or there is an analog timer in the front of the class. Another practice that is attributable to today's technology is the use of electronic devices. The other part of the project will include such a device to allow the child to calm down. The sensor, timer and electronic device will be controlled with the Atmeg328P microcontroller using the Arduino IDE and programming language.

The entire system will be split into two devices: (1) the wearable sensor/timer, and (2) the interactive device. The wearable sensor monitors Electrodermal Activity (EDA), also known as Galvanic Skin Response (GSR). The timer is a simple LED ring. The interactive device is a touchscreen loaded with a simple paint program. As indicated, they will be programmed for use with the Atmega328P microcontroller. In addition, they will communicate to each other using a Bluetooth device.

II. Project Goals

The main goal of our project is to create a system that anticipates when a child with autism is about to have an attack and make the teacher aware before it gets out of hand. By doing this project we hope to learn and grow with this experience by;

- An all-around basis of teamwork
- Learning as EE's how to program
- Creating our own PCB's for the first time
- Better understanding of circuit design
- Knowing how to properly manage multiple tasks

We know that going in as a two-man group we will have to split the burden fifty/fifty. Which means we both need to understand how to implement such a project. Since each part of this project is split down the middle, we know that communication is going to be crucial if we are to succeed, and the challenges that come along with not having a programmer. Even though our group is small, we still want to prove that we are just as capable and just as reliable. Having a small group will test our patience, knowledge, and skillset as viable engineers and this project will help us prove just that.

Being a teacher is hard enough with generally over 30 students per class and if you throw in autism into the equation it makes it that much more challenging. A big issue for the teacher is not knowing when the student is about to have an attack or is already in a state of frustration. With our project we hope to detect the attack as it is about to happen and give the teacher an aide to let them know about it. As future engineers we hope to make the teachers life a little bit simpler by having this system in the class.

III. SYSTEM CONCEPT

The entire system is comprised of two separate systems that will communicate wirelessly: the wearable device on the child's wrist and the portable device that is near the teacher but can be given to the student. These two devices can operate separately and be synched up. The portable device has an LCD touchscreen which can be used for two purposes: starting a timer and/or starting a paint program to help mitigate the student from getting too over-worked.

The portable device will be involved with communicating with the device on the student's wrist. On the portable device we have an MCU, Bluetooth module, red LED, an LCD Touchscreen and portable battery. There are 3 layers on this portable device with the first being the custom PCB with the all the components, then the second layer on top of that is the battery shield with a 3.7 Li-Po battery, then the third and final layer on top of that will be the touchscreen.

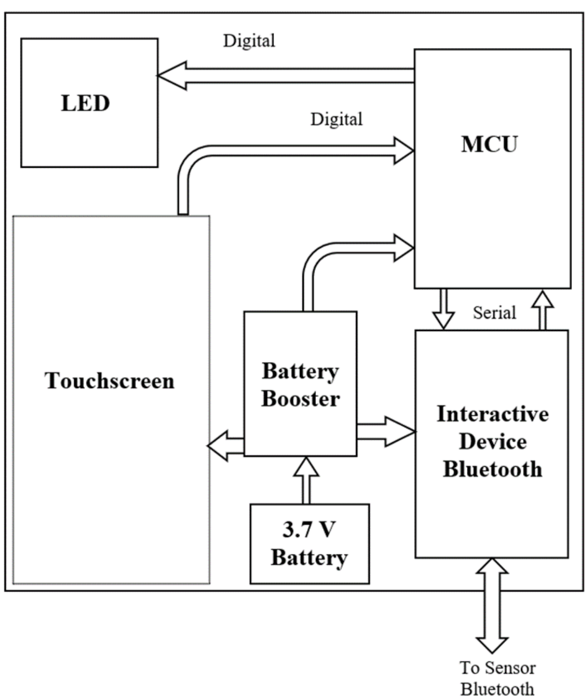

Fig. 1. Portable device system overview.

Figure 1 is a representation of the portable device. The touchscreen will have two purposes, the first functionality of the touchscreen acts as an indicator to inform the teacher that the student is about to have an episode and needs the device to calm down. The indicator will be a Red LED on the custom PCB that blinks, which then will notify the teacher discretely. The second functionality is for the teacher to be able to communicate with the students LED timer on their wrist to start a new subject. The timer will have all twelve LEDs illuminate at the onset of the timer, and will extinguish when the timer is over.

The second part of our project is a wearable device on the student's wrist. On this device we have an MCU, BT device, one sensor, a portable 3.7 Li-Po battery, and the LED timer. The idea is that when the sensor's rate of change goes above a certain threshold it tells the BT (master) device to communicate with the other BT (slave) device on the portable system to blink the red LED. The LED timer is mounted on the top as to indicate relative time (entire circumference indicates 5 minutes) until there is a transition. This will be activated through the touchscreen. Figure 2 is a representation of the sensor/timer system.

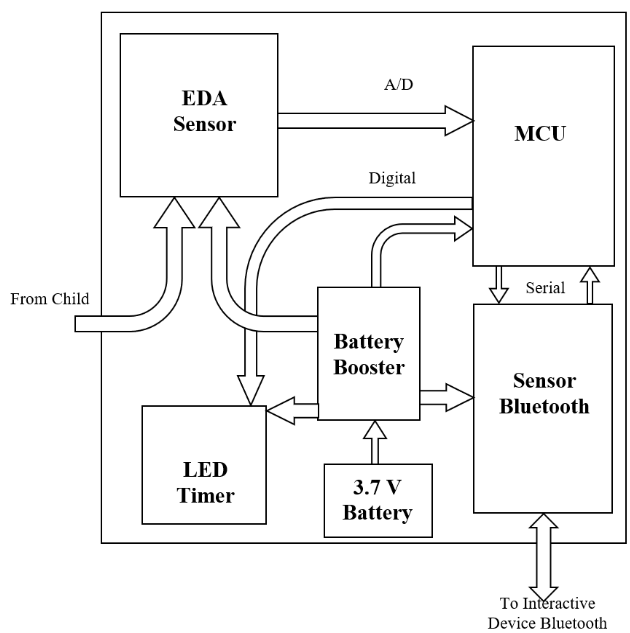

Fig 2. Wearable sensor/timer system overview.

The wearable device and the portable device are designed to be an indicator for both the student and the teacher. When the sensor flags an issue, the teacher will know via a blinking LED and when the teacher changes a subject the student will know via an LED timer. Both the wearable and portable devices will be lightweight, so it's not too distracting for the student and it must wirelessly communicate with the teacher to be discreet enough to not bother other students. A batter life of 8 hours is expected from a full-charge, so it will last all day at school.

IV. System Components

The PAM OTB for special needs students is a two-piece system that collectively comes together through wireless technology to become a product that helps both the student and the teacher without extra distraction. In this area we will introduce each component picked and talk about each one's function and how they will be involved in the whole project.

A. Microcontroller

The PAM OTB design will use to Arduino ATMega 328p microcontrollers that will perform like a relay between the wearable and the portable modules. We chose this MCU because of the numerous analog and digital pins it offers which is perfect for a system with many peripherals. Also, we chose this MCU because of the vast libraries out there for people who are not familiar with programming. This specific chip is relatively inexpensive and is fast at 16 MHz which is great for those needing to receive and transmit data wirelessly.

B. Bluetooth Module

In both the wearable and the portable device we will be using a Bluetooth module to communicate between them and the MCU. The BT module we are using in the wearable is the HC-05 which can be set as master or slave. In our case we set the HC-05 as master on the wearable. On the portable device we are using the HC-06 which is slave only.

C. Battery Charger

This project requires two separate batteries to power each device. The portable device uses a power boost shield that can be stacked onto our custom PCB and we are using a 3.7V Li-Po battery with 2000mAh that sits nicely in the shield. For the wearable device we are also using a 3.7 Li-Po Battery with 150mAh that is also similar to the power boost 500 stackable but smaller, this power boost is not stackable like the one meant for the portable device, so it is small in size which is perfect for the wearable.

D. Sensor

The wearable device has one sensor. It monitors electrodermal activity (a.k.a. galvanic skin response. When the human body is stimulated, certain physiological signs are elicited. One is the common reaction of sweating. It is due to the autonomic activation of sweat glands in the skin due to some emotional arousal [4]. This galvanic skin response is measured in siemens (S), the inverse of resistance. Galvanic skin response has a characteristic response. This is shown in Figure 3.

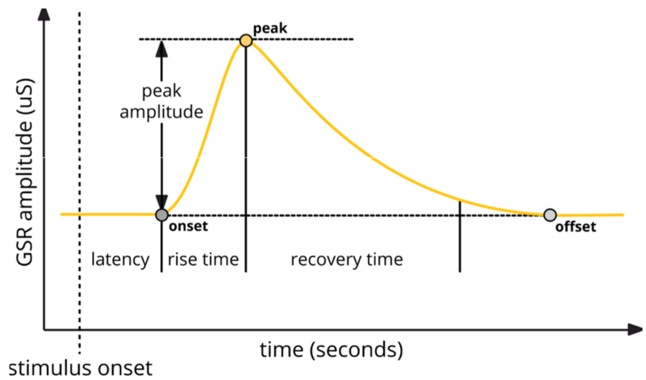

Fig. 3. Galvanic skin response with respect to time.

E. LED Timer

In our project we are using an LED ring that will act as a timer for the students to know what subject they are on and how much time is remaining for that subject. The ring we picked is called a neopixel ring with 12 RGB LED's from Adafruit. The teacher can initiate the timer at their discretion.

F. LCD Touchscreen

The portable device will use one 2.8" TFT LCD touchscreen which we got from Amazon. The idea behind using a touchscreen is to help the student calm down and transition easier from one subject to another. The touchscreen is resistive and comes with a stylus, so the student has a choice on which to use. Also, we chose this screen because of the ease of use with the Arduino libraries out there.

V. Hardware Detail

In this area we go into more detail of all the components we selected for our project in much more detail with technical specifications.

A. Microcontroller

The PAM OTB design will use two microcontrollers that will control our whole system. The microcontroller that we chose to go with was the ATMega328p which is made by Atmel industries. The MCU on the wearable reads the sensor values and communicates via BT to the other MCU on the portable device and tells the other BT module to blink a red LED. The specs on this microcontroller are [5]:

- 32Kb of Flash Memory
- 1kB of EEPROM
- 2kB Internal of SRAM
- 23 Programmable I/O pins
- Through Hole design

B. Bluetooth Module

As mentioned before we are using 2 BT modules in both the wearable and the portable device. Both the Bluetooth modules use a 2-pin connection to connect to the MCU. The HC-05 has 5 pins: State, Rx, TX, GND, VCC, and EN while the HC-06 has 4 pins: Rx, TX, GND, and VCC [6]. This helps to distinguish them. The BT module we are using in the wearable is the HC-05 which can be set as master or slave. In our case we set the HC-05 as master on the wearable. On the portable device we are using the HC-06 which is slave only. Both boards have a voltage regular on the VCC pin and accept a voltage in of 3.6v to 6V, however, the other pins are 3.3V only. This means you can power the boards from a 5V rail using the VCC In, but you should not connect the others pins directly to 5V.

C. Battery Charger

This project requires two separate batteries to power each device. The portable device uses a power boost shield that using a 3.7V Li-Po battery with 2000mAh. There is an onboard boost converter that can provide at least 500mA current and can peak at 1A [7]. For the wearable device we are using a smaller version of the stackable, a 3.7V Li-Po batter with 150 mAh, and it has the same booster as the shield, the power boost 500 has at the heart of it a TPS61090 boost converter from TI. This boost converter chip has some really nice extras such as low battery detection, 2A internal switch, synchronous conversion, excellent efficiency, and 700 KHz high-frequency operation.

D. Sensor

To achieve a cheap alternative to other such devices, the sensor was designed and built from various microelectronics rather than purchasing an EDA sensor. The electrodermal activity sensor is made from a non-inverting operational amplifier in which one of the resistors is replaced by skin between two electrodes. The input voltage is 0.5 volts achieved by a voltage divider. This voltage is ideal for EDA measurement while not affecting the person wearing it. The amplifier also boosts the output voltage, so it can be sensed by the microcontroller.

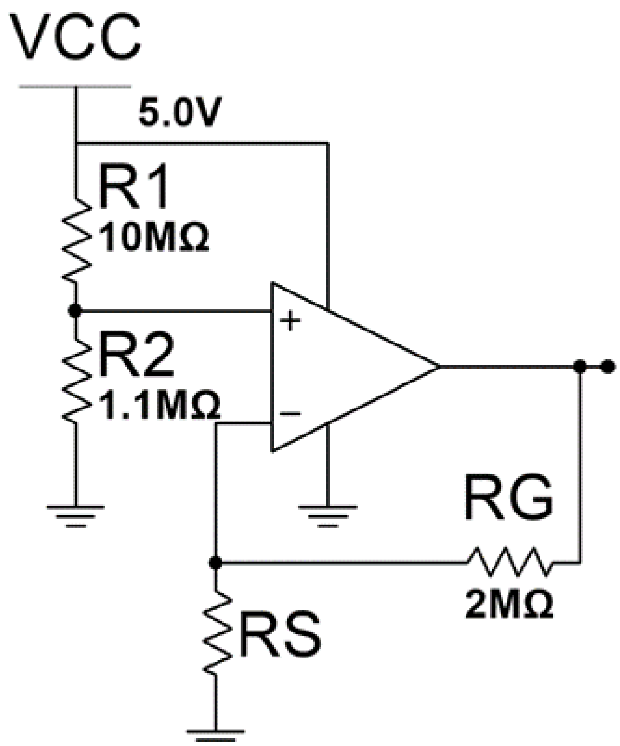

Fig. 4. Schematic of the EDA sensor.

Figure 4 shows the schematic for the EDA sensor. RG is the gain resistor, and RS represents skin resistance. Each end of the RS resistor is attached to an electrode. Both electrodes rest on the skin near each other. The end of one electrode is connected to the negative input of the op-amp. The end of the other electrode is connected to ground. In this manner, the output voltage is inversely proportional to the skin resistance, which is directly proportional to skin conductance, in which is what galvanic skin response is measured. This output is expressed in Equation (1).

$$V_{out} = 0.5\left(1 + \frac{RS}{RG}\right) \quad (1)$$

The operational amplifier is Microchip Technology's MCP6004 series quad op-amp. If is for low-power, general-purpose applications with a voltage range ideal for our project of 1.8 to 6.0 volts [9].

E. LED Timer

In our project we are using an LED ring that will act as a timer for the students to know how much time is remaining for that subject. The ring we picked is called a neopixel ring with 12 RGB LED's from Adafruit. There are 12 ultra-bright smart LED Neopixels arranged in a circle with 1.5" (37mm) outer diameter. An 8MHz or faster processor is required which is perfectly fine with our ATMega328p. Each LED on the ring has roughly 18mA constant current drive so the color will be very consistent even if the voltage varies, since no external choke resistors are required making the design slim which makes it perfect for the wearable device. The ring does require 5V of power which we will have as stated above in the battery section.

F. LCD Touchscreen

For the portable device will use one 2.8" TFT LCD touchscreen which we got from Amazon. The resolution is 320x240 which can be programmed fully using Arduino IDE libraries. This display is a 4-wire resistive touchscreen which is great because it comes with a stylus, so the student can use their finger or a stylus. The display requires 5V supply voltage to power on which it will receive from the Arduino MCU. The TFT is a stackable shield meant for the Arduino Uno and it has 20 possible pins that may be connected we are only connecting 14 of them [11].

- Pin Header Connection Type
- 4 Wire Interface
- 78.22mm by 52.7mm Dimension
- 2.8" Resistive Touchscreen
- 0.3 Ounces in weight
- 8-bit parallel interface

VI. SOFTWARE DETAIL

The software for the PAM OTB is made up of two separate codes; one for the wearable device and one for the portable device. The flowchart of the sensor software is shown in Figure 5.

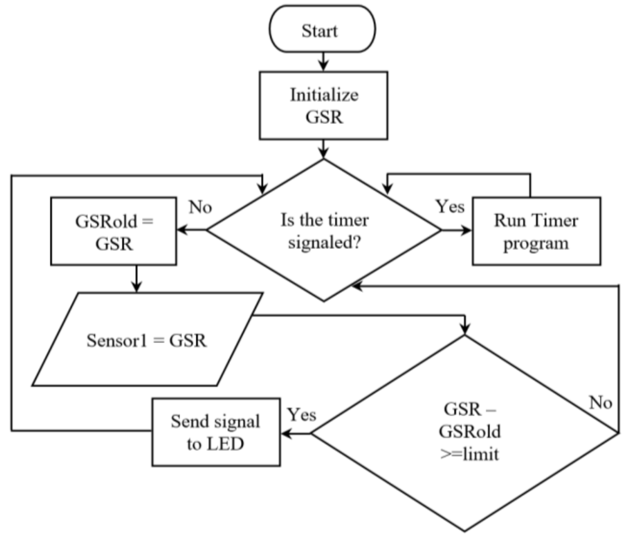

Fig. 5. Software flowchart of wearable sensor/timer.

If the wearable device receives a signal from the portable device, then it runs a timer program. This program illuminates the entire circumference of the 12-LED neo-pixel ring and extinguishes the LEDs at a rate of one LED per 25 seconds. This results in a total timer of 5 minutes. This is activated by the teacher as discussed later.

The wearable device also monitors the inputs from the sensor serially at a baud rate of 9600 using an analog-to-digital converter. These values are averaged over a thousand samples to smooth the input. This smoothing allowed for less hardware and thus space. This value is compared to the previous sample average. If the new GSR is greater than the old GSR by a few hundred millivolts, then this indicates an abrupt change in galvanic skin response, and it sends a signal to the portable device Bluetooth. This is to notify the teacher that there may be a problem.

The second code is for the portable device. Initially the device is idle. When the touchscreen is touched it displays the prompts to activate the timer or the paint program. If the area in the box designated for the timer is pressed, then it sends a signal via the Bluetooth to start the timer LEDs on the wearable device, and it goes back to idle. If the area in the box designated for the paint program is pressed, then the portable device starts a program in which different colors can be selected and shown when the touchscreen is touched. If the portable device is idle for 5 minutes, then it goes back to a black screen and awaits another touch. During idle, if it receives a signal from the wearable sensor, then it blinks an LED on the portable device that to get the attention of the teacher. The teach can cancel this blinking by pressing the touchscreen. From here, the teacher can either start the paint program and give it to the child, or allow the device go back to idle and take of the situation in another way. Figure 6 is a flowchart of the portable device software.

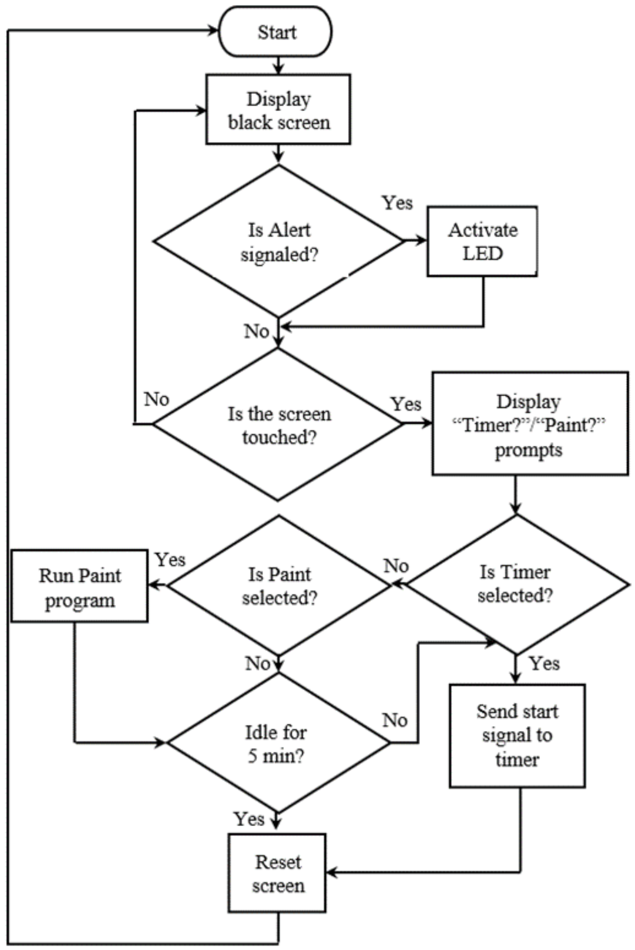

Fig. 6. Software flowchart of portable device.

VII. Board Design

The entirety of the PAM OTB design will be done using two separate PCB's. On these circuit boards there are two layers of copper and these contain the connections that are between each component. All the components are interfaced with one another via soldering then clean up the wires as needed.

To make our two PCB's we used a program called Eagle which is a free software for Students to design their own PCB. Before the PCB was created in Eagle we did all of our testing on breadboards to make sure there were no issues with shortages, or current limiting factors. Once we were confident on the breadboard we then created the schematic in Eagle and connected all the wires accordingly. Once we finished making sure our schematic in Eagle worked with no errors we chose to send if off to PCB Way, which is in China. The turn-around time was less than one week and cost less than $30 per board so a total of $60 for the two boards.

VIII. Administrative Content

To keep our project up to date we have concluded that we need to have a functioning prototype by late October, this should give us ample time to see if everything works as it should, and if it does not we will have time to send out for another prototype. Since we have the summer off we feel that we will be on-time or ahead of our set deadline to be able to have a functioning prototype within the allotted time.

Our goal is to create a product that will help both students with autism and the teachers that are there doing their best to help those students. We want this device to be low cost, low power, long battery life, and water proof. At this time there are other devices out there, but they are very expensive and are not as informative to both the teacher and the student. Our goal is to make a lost cost but effective product for all who may need it so that both parties feel comfortable in the classroom.

If we are to keep the cost low, then we need to look for reliable parts that are cost effective to make in other countries with high quality. The most expensive parts in our design were the TFT touchscreen, BT modules, and the Power booster with the batteries. The TFT touchscreen was $17, the BT modules were $10 per module, and the power booster with both batteries was over $60. The screen needed to be a resistive touchscreen to allow the student to be able to use either their finger or a stylus. We needed two BT modules to be able to communicate wirelessly between the two devices as that was a way to incorporate the teacher too. Using power booster allowed us to boost the power from the 3.7 Li-Po batteries to 5V which most of our system requires. The Li-Po batteries were necessary because they are rechargeable and last the duration of a school day.

The total cost of this project came to less than $200 which is less than some of the more expensive devices that are on the market, so we feel this is a successful device to mass market to the general public. We know we could reduce the cost even further by creating our own power booster and using different BT modules and a different

TFT and still be just as reliable. We hope our design helps those in need some day.

IX. Conclusion

This PAM OTB design has been both challenging and rewarding at the same time for our two-man group, especially the programming. When there are only two people in a group out of a possible four then things become increasingly difficult and when you throw in the fact that both are EE's but still have to program, then that creates a recipe for complications to arise. The problems we face were not just programming, but also not having the prior knowledge of Eagle or even the simple Arduino that we now understand. From the beginning of senior design, I we knew the daunting task ahead of us, but luckily, we had the help of other students in the lab and former professors who pointed us in the right direction. As the semester is coming to a close we feel that we did pretty good for a two-man group of Electrical Engineers and now we understand what we will be going into as future engineers.

X. ENGINEERS

Gary Shotts is a 32-year old graduating with a Bachelor's in Electrical Engineering. His career goal is work out at the Kennedy Space Center in Merritt Island, FL.

Jeffrey Thompson is a 36-year old graduating with a Bachelor's in Electrical Engineering. He works at the Kissimmee Utility Authority Cane Island Power Park in Intercession, FL as an Instrument Controls & Electrical Technician.

XI. Acknowledgements

This group really would like to thank all those students who stayed to help us when they too had a project to prepare for. Also, the professors who taught us over the years and took the time to point us in the right direction. The community who helped create the libraries on Adafruit and GitHub won't know but they too helped us in creating our project. Finally, the vast YouTube videos and PCB Way for getting us our two PCB's to make this all work.

XII. References

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